Available online at www.sciencedirect.com
ScienceDirect
Food Chemistry 107 (2008) 1674–1680
Food Chemistry
www.elsevier.com/locate/foodchem

Analytical Methods

Nutritional composition of underutilized bayberry (*Myrica rubra* Sieb. et Zucc.) kernels

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Received 1 January 2007; received in revised form 29 August 2007; accepted 15 September 2007

Abstract

The kernels of five bayberry cultivars (Biqi, Zaodamei, Ding-ao, Dongkui and Wandao), grown in Zhejiang Province, China, were analyzed for their proximate composition, protein fractionation, amino acid profile, fatty acid composition and mineral contents. The antinutritive compounds, tannin and cyanide, were also quantified. These bayberry kernels possessed 25.0–27.64% DW protein. A majority of storage protein in bayberry kernels was of the globulin form. The kernel protein was rich in methionine, arginine, aspartic and glutamic acids while limiting amino acid was lysine. The most outstanding feature was the abundant fat content (62.5–68.1% DW) of kernels. Approximately 84.9–90.1% of the fatty acids were unsaturated with oleic acid (43.3–50.7%) and linoleic acid (34.1–46.8%). Bayberry kernels were good sources of magnesium, potassium and calcium. These results may offer a scientific basis for use of the underexploited bayberry seeds.

Keywords: *Myrica rubra*; Bayberry kernel; Nutritional composition; Nutritional quality

1. Introduction

Bayberry (*Myrica rubra* Sieb. et Zucc.) is native to eastern Asia, mainly in China, the family of Myricaceae (Chen, Xu, & Zhang, 2004). In China, it is cultivated mainly in south of the Yangtze river, where it is of considerable economic value. The fruit of the Chinese bayberry is red, purple, white, or pink in colour when ripen, depending on the cultivar. It is a small drupe and composed of a fleshy pericarp comprising individual segments and a hard endocarp protecting a single kernel (Miao & Wang, 1987).

Chinese bayberry fruit fleshes contain rich nutritional compositions such as carbohydrate, organic acid, vitamins and so on (Gong, Wang, Lin, & Liang, 2004; Miao & Wang, 1987; Wang, Zheng, Li, & Yu, 2001; Xia & Cheng, 2005), and are rich in anthocyanins as well as flavonols and exert strong antioxidant activity (Bao, Cai, Sun, Wang, & Corke, 2005; Ye, Chen, & Su, 1994). Besides being consumed fresh, the bayberry fruit can be made into various products such as juice, wine, jam and canned fruit. In some Chinese bayberry fruit processing industries, bayberry seeds are byproducts and discarded without further utilization.

Bayberry seed is a small stone in which a typical kernel is contained. A few works have been done on bayberry kernels. Zhang, Wang, Zhang, and Xu (1993) found there are some unknown compounds in Chinese bayberry kernels that can inhibit the growth of cancer cells or induce cell death. Zou (1995) isolated and identified bayberry kernels contain quercetin and myricetin. These compounds have antimicrobial and antioxidative activities according to previous studies (Burda & Oleszek, 2001; Cushnie & Lamb, 2005). Base on above reports, bayberry kernel possesses some bioactive substances and is worth to further investigation. Chen, Xu, and Xia (2004) determined the fatty acid composition of bayberry kernel with GC/MS (cultivar Biqi). Results exhibited this kernel could be used as potential oilseed source. However, other nutritional information

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doi:10.1016/j.foodchem.2007.09.042

of bayberry kernel such as protein, amino acid profile, mineral, etc., is still lacking.

Recently, more attention has been focused on the utilization of food processing by-products and wastes, as well as under-utilized agricultural products. Zhejiang is the top area in China producing bayberry fruit, with an annual production over 300,000 tons (data provided by Zhejiang Agricultural Office). The amount of bayberry stones, which comprise 10% or more by the weight of the bayberry fruits remaining after being processed, is quite large. At present there is not a systematic collection and utilization of this material. The bayberry kernel has remained underutilized because of limited information on the detailed chemical composition and nutritional value. The aim of this work was to analyze the nutritional composition of bayberry kernels of five cultivars grown in Zhejiang Province, China, and thereby determine the nutritive value of this byproduct in food or feedstuff.

2. Materials and methods

2.1. Sample collection

The mature bayberry fruits of five cultivars (Biqi, Zaodamei, Ding-ao, Dongkui and Wandao) were collected from different growers in Zhejiang Province, China, in June, 2006. These cultivars are the most widely planted in Zhejiang. In our laboratory, the fruits were separated into pulp and stones. The stones were shelled by cracking with a small hammer and manually remove the seed coat to obtain the kernels. The kernels were packed in black polyethylene bags and stored at −20 °C prior to chemical analysis. When needed, samples were powdered using a mortar and pestle for homogeneity.

2.2. Proximate composition

Moisture, ash, fat and protein contents were determined following the standard Association of Official Analytical Chemists (AOAC, 1990) methods. Moisture content was determined after attaining constant weight at 105 °C. Ash content was heated after obtaining constant weight at 550 °C, and then the residue was quantitated gravimetrically. Total fat content was obtained by the Soxhlet extraction method, using diethyl ether. Protein was determined by the micro-Kjeldahl procedure; the factor N × 6.25 was used to convert nitrogen into crude protein. Data were expressed as percent of dry weight (DW).

2.3. Total soluble sugars determination

Total soluble sugars were analyzed by Anthrone colorimetry (Han, 1996). Defatted kernel flour (~1 g) was extracted with 50 ml distilled water in a water bath at 80 °C for 30 min, centrifuged (12,000*g*, 10 min) and the supernatant collected. One milliliter of extract was added to 5 ml of the anthrone reagent (0.2% (m/v) anthrone in 80% (v/v) sulphuric acid) in stoppered test tubes. The tubes were incubated in a boiling water bath for 10 min. The samples were cooled and measured absorbance at 700 nm with a spectrophotometer (UV-2450; Shimadzu, Tokyo, Japan). Glucose standard curve was prepared simultaneously. Total soluble sugars were expressed as glucose equivalents.

2.4. Protein solubility fractionation

Protein classes of bayberry kernel were separated according to their solubility as described by Chavan, McKenzie, and Shahidi (2001). Defatted kernel flour (~1 g) was extracted with 25 ml distilled water at 25 °C for 15 min using a shaking water bath, centrifuged (4000*g*, 10 min) and the supernatant collected. The residues were re-extracted twice more with the same solvent. Obtained supernatant were combined and designated as the water-soluble fraction. The residue was then extracted successively with 5% (w/v) NaCl, 70% (v/v) ethanol at 65 °C in a shaking water bath, and 0.2% (w/v) NaOH in a similar procedure as for the water-soluble fraction; each soluble fraction was collected separately. Total nitrogen of the fractions collected and the residue left after sequential extractions were analyzed for the protein content using the micro-Kjeldahl method (AOAC, 1990). The content of each fraction was calculated as the percentage of the total nitrogen content of the kernel meal.

2.5. Fatty acids composition of kernel oils

The oils from powdered bayberry kernels were Soxhlet-extracted with *n*-hexane. The fatty acids were converted to methyl eaters according to the IUPAC method (IUPAC, 1990). Analyzes of fatty acid methyl esters were carried out with a Shimadzu-15A gas chromatograph (Kyoto, Japan), equipped with a flame hydrogen ionization detector and a capillary column (Agilent, DB-23, 60 m × 0.25 mm × 0.25 μm film). The injection temperature was 260 °C. The column temperature was kept at 130 °C for 1 min and programmed to 170 °C at a rate of 5 °C/min and kept at 170 °C for 3 min, then increased to 215 °C at a rate of 2.7 °C/min and kept at 215 °C for 8 min, at last increased to 230 °C at a rate of 40 °C/min and kept at 230 °C for 1 min. Identification and quantification of fatty acid methyl esters were achieved by comparing the retention times of the peaks with those standards.

2.6. Amino acids profile of kernel proteins

Accurately defatted sample (~100 mg) was hydrolyzed in 10 ml 6 M HCl at 110 °C for 24 h under nitrogen atmosphere. The cooled and filtered hydrolyzate was dried in a vacuum desiccator at 45 °C and redissolved in citrate buffer (pH 2.2). Aliquots of the solution were injected directly into a Sycom S-433 D automatic amino acid analyzer (Sykam, Eresing, Germany). Identification and quantification of

amino acids were achieved by comparing the retention times of the peaks with those standards. Tryptophan content was determined by the colorimetric method (Wang, 2000). Defatted flour (~40 mg) was hydrolyzed in 1 ml 10% (w/v) NaOH at 40 °C for 18 h and cooled; added 0.2 ml p-DMAB solution (5% (w/v) p-DMAB in 10% (v/v) HCl) and mixed; added 0.2 ml of 1% (w/v) sodium nitrate solution and mixed; added 5 ml HCl and mixed. The mixture was heated at 40 °C for 45 min. After centrifugation (12,000*g*, 10 min), the absorbance of the supernatant was determined at 590 nm. Tryptophan standard curve was prepared simultaneously. Amino acid composition was reported as gram of amino acid per 100 g of protein. Chemical score of amino acids was calculated according to the FAO/WHO (1991) reference pattern.

2.7. Mineral analysis

The mineral content of each sample was determined by using Agilent 7500A ICP-MS (California, USA). Kernels were weighed (~0.5 g), then digested with concentrated HNO_3 (~5 ml). After digestion, the samples were diluted to 40 g with de-ionized water. Total phosphorus was determined colorimetrically according to the phosphovanadomolybdate method (AOAC, 1990).

2.8. Tannin content determination

Tannins were determined as described by Sze-Tao, Schrimpf, Teuber, Roux, and Sathe (2001) with a few modifications. Defatted flour (~1 g) was extracted using acidified methanol (1% HCl, v/v) for 20 min at ambient temperature in a sonic water bath and centrifuged (10, 000*g*, 10 min). One milliliter extract was reacted with 3 ml of 4% (w/v) vanillin-methanol and 1.5 ml HCl in the dark at ambient temperature for 5 min, and the absorbance was read at 500 nm. Methanol used as blank and a catechin standard curve was run simultaneously. Tannin content was expressed as catechin equivalents.

2.9. Cyanide content determination

Cyanide content was measured by determining the amount of hydrogen cyanide (HCN) released on hydrolysis (Bradbury, Egan, & Lynch, 1991). Samples (~10 g) were dissolved in 60 ml 0.1 M H_3PO_4 and blended for 2–3 min and filtered. To 2 ml of the solution was added 2 ml 4 M H_2SO_4 hydrolysis at 100 °C for 50 min and cooled. To the cooled solution was added 5 ml 3.6 M NaOH with mixing, and stood for 10 min. One milliliter of the mixture was added to a test tube containing 7 ml 0.2 M phosphate buffer (pH 6.0), and 0.4 ml 0.5% (w/v) chloramines-T solution was added. After it was cooled in ice, 1.6 ml pyridine/barbituric acid was added, which was prepared by adding 40 ml pyridine to 1 g barbituric acid dissolved in 200 ml distilled water. The purple colour was allowed to develop for 60 min and the absorbance was measured at 583 nm. The phosphate buffer was used as blank. A stock solution of potassium cyanide (KCN) was used to calibrate the standard curve. Results were expressed as mg HCN/kg DW.

2.10. Statistical analysis

One way analysis of variance (ANOVA), with multiple range significant different (LSD) test ($P < 0.05$) was carried out using SPSS13.0.

3. Results and discussion

3.1. Bayberry kernel morphology and proximate composition

The stone of bayberry is similar to that of peach and plum, which is only single kernel covered by the hard shell. The bayberry kernels were triangular in shape. In descending order, kernel size of five bayberry cultivars was Dongkui, Ding-ao, Zaodamei, Biqi and Wandao. Table 1 shows some characteristics of these kernels. Bayberry kernels from five different cultivars were covered by a thin

Table 1
Physical and chemical characteristics of bayberry kernels[a]

	Cultivar				
	Biqi	Zaodamei	Ding-ao	Dongkui	Wandao
Physical characteristics					
Kernel coat colour	Brown	Dark brown	Brown	Light brown	Brown
100 kernel weight (g)	4.24 ± 0.24x	6.33 ± 0.08y	5.62 ± 0.24z	7.60 ± 0.07u	3.98 ± 0.12x
Chemical characteristics (w/w, %)					
Moisture[b]	6.80 ± 0.05x	7.31 ± 0.07y	7.08 ± 0.05z	8.58 ± 0.04u	5.59 ± 0.04v
Ash[c]	3.64 ± 0.11x	3.38 ± 0.10y	4.02 ± 0.12z	3.86 ± 0.16u	3.99 ± 0.08z, u
Fat[c]	65.52 ± 1.03x	68.02 ± 1.90x	62.55 ± 1.84y	66.59 ± 0.77x	68.18 ± 2.10x
Protein[c]	27.64 ± 0.06x	26.91 ± 0.10y	25.04 ± 0.32z	26.63 ± 0.12y	25.25 ± 0.24z
Total soluble sugars[c]	1.58 ± 0.04x	1.75 ± 0.12x	1.92 ± 0.14y	1.99 ± 0.06y	2.01 ± 0.07y

[a] Values are means ± standard deviations of triplicate determinations. Values in the same row followed by different letters are significantly different ($P < 0.05$).
[b] Expressed on fresh weight.
[c] Expressed on dry weight.

coat having light to dark brown colour. The 100 kernel weight range was 3.9–7.8 g. The kernel mass of Dongkui was significantly higher than other cultivars in the same amount of kernel ($P < 0.05$).

The proximate compositions of the bayberry kernels analyzed are also presented in Table 1. Bayberry kernels from five different cultivars contained 5.59–8.58% moisture; 3.38–4.02% ash; 25.04–27.64% protein; 62.55–68.18% fat; and 1.58–1.99% soluble sugars. There was a significant difference for moisture content within these kernels ($P < 0.05$). The moisture content was highest in Dongkui kernel, followed by Zaodamei kernel and was lowest in Wandao kernel. All these kernels had low moisture levels, implying they have good shelf life characteristics. Ash content in Ding-ao and Wandao kernels did not differ significantly ($P > 0.05$), and Biqi kernel was lowest. The most abundant component found within bayberry kernels is fat (oil). Their values indicate that all these kernels are good oil seeds. The oil contents of these kernels were approximated to the values reported by Chen et al. (2004). Values for Biqi, Zaodamei, Dongkui and Wandao kernels were not different ($P > 0.05$), and were significantly higher than of Ding-ao kernel. These kernel oils are light yellow in colour. According to Chen et al. (2004), the acid value of bayberry kernel oil (cultivar Biqi) was 0.416 mg KOH/g and peroxide value was 0.023%. Their finding indicated that processing of bayberry kernel oils for industrial or edible purposes would be economical. Protein is the second abundant component within these kernels. Protein contents for Zaodamei and Dongkui kernels were not significantly different ($P > 0.05$); nor were those for Ding-ao and Wandao kernels, but each was significantly lower than that of Biqi kernel ($P < 0.05$). These kernels possessed high protein content and could be recommended as protein supplements. There were not significantly differences between Biqi and Zaodamei kernels in total soluble sugars, the same as within Ding-ao, Dongkui and Wandao kernels ($P > 0.05$).

3.2. Protein fractionation

To further determine the type of bayberry kernel protein, the separation of different protein fractions was carried out using a number of solvents, namely water, salt, alcohol and alkali. The fractions extracted with water, salt, alcohol and alkali are defined as albumin, globulin, prolamin and glutelin, respectively (Osborne, 1924). The relative proportions of protein fractions of bayberry kernel are presented in Table 2. Mean of 13.51%, 78.00%, 1.48% and 6.15% of the total protein of these bayberry kernels were soluble in water, salt, alcohol and alkaline solutions, respectively. Albumins and globulins were the major proteins. Large portions of protein in bayberry kernel are of the globulin form. The insoluble fraction (residue) is likely due to the presence of other proteins which might be complexed with phenolic compounds, including tannins, and could remain in the residue (Chavan et al., 2001).

3.3. Amino acid profile of kernel proteins

Human and animal cannot synthesize all the amino acids, so some amino acids must be supplied through food consumption. Therefore foods and fodder rich in exogenous amino acids are desirable. The nutritive value of dietary proteins is determined by the pattern and quantity of essential amino acids (EAA). Table 3 shows the amino acid profiles of bayberry kernel proteins. Their EAA were comparable to the FAO/WHO recommended pattern (1991). The amino acid profiles of five bayberry cultivars kernels were similar and their proteins were rich in essential amino acid (28.38–29.21%). The chemical scores of methionine + cystine, isoleucine, leucine, histidine, threonine, tryptophan and tyrosine + phenylalanine were higher or almost equivalent to the FAO/WHO requirement pattern. Bayberry kernel proteins were rich in glutamic and aspartic acids with 21.35–22.75% and 7.89–8.50%, respectively. Besides these two amino acids, leucine and methionine acids were also present in fairly high concentrations 6.75–7.65% and 4.41–4.85%, respectively. Lysine was the limiting amino acid in bayberry kernel (1.55%–2.05%). The low lysine content can be complemented when these kernel proteins are consumed in conjunction with other foods containing high amounts of lysine.

3.4. Fatty acid composition

Results of proximate analysis revealed that bayberry kernel had substantially high fat content. Fatty acid composition of these kernel oils is presented in Table 4. Seven to eight fatty acids were identified in bayberry kernel oils. There were no uncommon fatty acids. Bayberry kernel oils

Table 2
Distribution (%) of protein fractions of bayberry kernels [a]

Protein fraction	Cultivar					Mean ± SD
	Biqi	Zaodamei	Ding-ao	Dongkui	Wandao	
Water-soluble (albumin)	12.35 ± 0.44	13.33 ± 1.01	13.64 ± 0.07	14.14 ± 0.32	14.07 ± 0.95	13.51 ± 0.73
Salt-soluble (globulin)	79.8 ± 1.63	79.02 ± 2.03	76.80 ± 0.53	77.74 ± 0.45	76.66 ± 0.31	78.00 ± 1.38
Alcohol-soluble (prolamine)	1.12 ± 0.04	1.40 ± 0.12	2.08 ± 0.22	1.45 ± 0.34	1.34 ± 0.11	1.48 ± 0.36
Alkaline-soluble (glutelin)	6.21 ± 1.12	5.53 ± 1.22	6.26 ± 0.60	5.72 ± 1.16	7.01 ± 0.65	6.15 ± 0.58
Residue	0.52 ± 0.00	0.72 ± 0.02	1.22 ± 0.20	0.95 ± 0.01	0.92 ± 0.01	0.87 ± 0.26

[a] Results are means of tree determinations and are expressed as percentage of total protein (%N × 6.25).

Table 3
Amino acid composition (g/100 g protein) of bayberry kernel proteins[a]

Amino acid	Cultivar					FAO/WHO (1991) requirement pattern
	Biqi	Zaodamei	Ding-ao	Dongkui	Wandao	
Threonine	3.10 (0.91)	3.21 (0.94)	3.15 (0.93)	3.22 (0.95)	3.22 (0.95)	3.4
Valine	3.30 (0.94)	3.41 (0.97)	3.22 (0.92)	3.49 (1.00)	3.27 (0.93)	3.5
Methionine	4.74 (2.81)[b]	4.41 (2.69)[b]	4.43 (2.58)[b]	4.85 (2.94)[b]	4.70 (2.70)[b]	2.5[b]
Isoleucine	3.92 (1.40)	3.01 (1.08)	2.88 (1.03)	3.16 (1.13)	3.10 (1.11)	2.8
Leucine	7.34 (1.11)	7.65 (1.16)	7.57 (1.15)	7.02 (1.06)	6.75 (1.02)	6.6
Phenylalanine	3.69 (1.02)[c]	3.65 (1.011)[c]	3.52 (0.991)[c]	3.86 (1.07)[c]	3.48 (0.97)[c]	6.3[c]
Lysine	1.63 (0.28)	1.68 (0.29)	1.85 (0.32)	2.05 (0.35)	1.55 (0.27)	5.8
Tryptophan	0.82 (0.75)	1.36 (1.24)	1.63 (1.48)	1.56 (1.42)	1.76 (1.60)	1.1
Total EAA	28.54	28.38	28.25	29.21	27.83	
Non-essential						
Aspartic acid	8.04	7.98	7.91	8.5	7.89	
Serine	3.69	3.49	3.57	3.74	3.44	
Glutamic acid	21.35	22.2	22.6	22.75	21.9	
Proline	3.73	2.44	3.65	3.78	3.57	
Glycine	5.12	5.17	5.16	5.5	4.99	
Alanine	3.53	3.37	3.39	3.61	3.52	
Cystine	2.29	2.32	2.02	2.51	2.06	
Tyrosine	2.72	2.73	2.71	2.87	2.6	
Histidine	2.87 (1.51)	3.13 (1.65)	3.09 (1.63)	3.04 (1.60)	3.02 (1.59)	1.9
Arginine	14.48	14.59	14.27	15.2	14.51	

Data in parentheses show the essential amino acid (EAA) score, which is the result of dividing grammes of EEA in 100 g test protein by grammes of EEA in 100 g FAO/WHO (1991) reference pattern.
[a] All values are mean of duplicate determinations.
[b] Value includes Met and Cys.
[c] Value includes Tyr and Phe.

Table 4
Components of fatty acids in bayberry kernel oils and their relative content (%)[a]

Fatty acid	Cultivar				
	Biqi	Zaodamei	Ding-ao	Dongkui	Wandao
Palmitic acid (C16:0)	10.41	11.08	9.81	10.19	11.68
Palmitoteic acid (C16:1)	0.82	0.81	0.60	0.79	0.90
Stearic acid (C18:0)	3.20	3.92	ND	2.15	ND
Oleic acid (C18:1)	43.23	49.58	42.28	47.55	43.12
Linoleic acid (C18:2)	41.67	34.04	46.63	38.61	43.68
Linolenic acid (C18:3)	0.14	0.09	0.14	0.09	0.10
Arachidic acid (C20:0)	0.11	0.12	0.10	0.14	0.11
11-Eicosenoic acid (C20:1)	0.41	0.36	0.42	0.41	0.40
Total saturates	13.72	15.12	9.91	12.38	11.79
Total unsaturates	86.27	84.88	90.07	87.45	88.20
Monounsaturates	44.46	50.75	43.30	48.75	44.42
Polyunsaturates	41.81	34.13	46.77	38.70	43.78

ND: not detected.
[a] All values are mean of duplicate determinations.

were found to be highly unsaturated varying from 84.88% to 90.07%. Mono-unsaturated and poly-unsaturated fatty acids contributed 43.30–50.75% and 34.13–46.77%, respectively. Therefore, bayberry kernel may be a good source of unsaturated fatty acids. Unsaturated fatty acids in human diet lower the risk of cardiovascular diseases (Ezeagu, Petzke, Lange, & Metgea, 1998). Previous study has shown that the oils of bayberry kernel (Biqi cultivar) contained oleic and linoleic acids at relatively high levels (Chen et al., 2004). Our results were similar to the reported values. Oleic and linoleic acids were dominant in these samples accounting for 43.12%–49.58% and 34.04%–46.63%, respectively. All the oil samples examined are rich in both oleic and linoleic acids, and may be used as edible cooking and salad oils or for margarine manufacture (El-Adawy & Taha, 2001). Saturated fatty acids constituted 11.79%–15.12% of total fatty acids; among there plamitic acid was the dominant fatty acid with content of 9.81%–11.68%. Steatic acid was not detected in Ding-ao and Wandao kernels and found in Biqi, Zaodamei and Dongkui kernels with 3.20%, 3.92% and 2.15%, respectively. Other fatty acids (palmitoteic acid, linolenic acid, arachidic acid and 11-eicosenoic acid) were detected in small quantities in all

Table 5
Mineral concentrations of the bayberry kernels (mg/kg dry matter basis)[a]

Element	Cultivar				
	Biqi	Zaodamei	Ding-ao	Dongkui	Wandao
Sodium	0.02	2.07	12.70	2.91	1.01
Magnesium	3462.60	3658.56	3087.75	3710.05	2842.89
Potassium	5897.54	6278.35	7808.92	7380.43	4624.33
Calcium	2451.70	959.39	998.13	1386.99	1108.01
Phosphorus	32.85	43.57	35.08	52.62	47.41
Manganese	54.82	42.39	32.76	70.51	61.22
Iron	82.29	87.47	125.61	101.56	90.82
Copper	24.28	22.10	17.90	15.94	23.86
Zinc	82.19	63.57	104.88	100.92	69.50
Selenium	0.32	ND	0.22	0.14	0.13
Chromium	ND	0.53	0.26	ND	0.14

ND: not detected.
[a] All values are mean of duplicate determinations.

Table 6
Antinutritional factors of the bayberry kernels[a]

	Cultivar				
	Biqi	Zaodamei	Ding-ao	Dongkui	Wandao
Tannins (g/100 g)	0.19 ± 0.06x	0.24 ± 0.08x	0.22 ± 0.02x	0.16 ± 0.02x	0.21 ± 0.02x
Cyanide (mg HCN/kg)	1.84 ± 0.11x	1.95 ± 0.03x,y	1.14 ± 0.09z	2.03 ± 0.10y	1.93 ± 0.05x,y

[a] Values are means ± standard deviations of triplicate determinations, expressed on dry weight basis. Values in the same row followed by different letters are significantly different ($P < 0.05$).

kernels. The difference of fatty acids composition in bayberry kernels may depend on the climatic conditions and cultivar of the fruit.

3.5. Mineral content

Table 5 shows some of the mineral contents in the kernels. The kernels were very rich in potassium, magnesium and calcium with 4624.33–7808.92, 2842.89–3710.05 and 959.39–2451.70 mg/kg, respectively. Potassium was the most abundant element in bayberry kernels, followed by magnesium and calcium. The other elements, in descending order by quantity, were iron, zinc, manganese, phosphorus, copper, sodium, selenium and chromium. Arsenic was not detected in bayberry kernel. Results showed that a wide variation was observed in the quantitative composition of mineral in kernels from different bayberry cultivars. This may have some relations with their growing environment and varieties. In sum, bayberry kernels are good sources of magnesium, potassium and calcium.

3.6. Antinutritional factors

The nutritional effects of tannins are mainly related to their interaction with proteins, and tannin-protein complexes are insoluble, so that protein digestibility is decrease (Shi & Di, 2000). As shown in Table 6, the tannin content in these bayberry kernels ranged between 0.11% and 0.24%. Although the kernel coat colour and the kernel size can affect the total tannin content (Chang, Collins, Bailey, & Coffey, 1994; Marconi, Ruggeri, & Carnovale, 1997), our results found the tannin contents were not significantly different ($P > 0.05$) in these kernels.

Table 6 also shows that these kernels contained 1.14–2.03 mg HCN/kg. Value for Ding-ao kernel was significantly lower than other kernels ($P < 0.05$). Because of the potential release of HCN, Cyanogenic glycosides may cause toxicity (Vetter, 2000). The potential toxicity in kernels may be decreased by grinding, soaking and cooking (heat treatment) causing the degradation of the Cyanogenic glycosides (Silem, Günter, Einfeldt, & Boualia, 2006; Umoren, Essien, Ukorebi, & Essien, 2005).

4. Conclusion

Comprehensive reports on the chemical composition of the Chinese bayberry kernel have not been previously reported. This study revealed that bayberry kernels have high protein, fat, essential amino acids, potassium, magnesium. Because of their high contents of unsaturated fatty acids, bayberry kernels might be acceptable substitutes for highly unsaturated oils. The multipurpose utilization of bayberry stones could provide extra profit and at the same time minimize waste disposals during processing bayberry fruits. Further studies will focus on the physical and chemical characteristics and functional properties of its major components i.e., oil and protein.

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