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Original article

Comparison of quality characteristics between belacan from Brunei Darussalam and Korean shrimp paste

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ABSTRACT

Background: This study was conducted to compare the quality characteristics between shrimp pastes from Korea and Brunei. Belacan is a fermented shrimp paste from Brunei. Korea manufactures two products: one is fermented and dried Saewoojeot shrimp paste, and the other is a dried shrimp paste.
Methods: The quality characteristics studied were: chemical composition, amino acids, minerals, fatty acids, cholesterol, water activity, pH, and salinity.
Results: The moisture and salinity content were highest in Belacan ($p < 0.05$). The fat and ash content, Mg, Na, unsaturated fatty acids, and polyunsaturated fatty acids were highest in the Korean fermented Saewoojeot shrimp paste.
Conclusion: The protein content, pH, water activity Ca, Fe, K, P, Zn, total amino acids, essential amino acids, saturated fatty acids, and cholesterol content tended to be higher in the Korean dried shrimp paste than in Bruneian belacan and Korean fermented Saewoojeot shrimp paste.

1. Introduction

Shrimp paste is a strong-smelling, salty pink paste commonly used as a cooking ingredient in many Southeast-Asian dishes. Traditionally, shrimp paste is made from ground shrimp which is then fermented under the sun. Sometimes it is even formed into dried blocks before being sold. It is known as *nappi* in Bangladesh, *kapi* in Thailand and Cambodia, *belacan* in Malaysia and Brunei, *mamruoc* or mamtom in Vietnam, http://en.wikipedia.org/wiki/Shrimp_paste - cite_note-1Bagoong or *alamang* in the Philippines, *ngapi* in Myanmar, *shajiang* in China, and *terasi* in Indonesia [1,2].

Belacan is a type of fermented shrimp paste. This is one food ingredient unique to the local population in Malaysia. In Brunei, belacan is usually made on a cottage-industry scale. This product comes from the Water Village and coast area. Foreign matter is picked off the shrimps, which are then rinsed a few times in water to remove any sand and other materials. The shrimps are mixed with 15–20% coarse sea salt and kept in a *guni* (plastic sack). The mixture is allowed to ferment at a temperature of 30–32°C overnight. The mixture is spread on a bamboo *nyiru* and dried under the sun to remove most of the moisture. The mixture of shrimp and salt is pounded using a traditional wooden lesong. However, nowadays an electric blender is used instead of the *lesong* process [3].

Traditionally, products with fermented shrimp are most commonly consumed in East Asian countries including Korea [4]. The major processing of these products is salting, fermenting, and aging. Fermented shrimp products are divided into shrimp sauces, shrimp pastes, and lacto-fermented shrimp products, and are usually used as food additives for a salty and umami taste [5]. Fermented shrimp products generate essential amino acids (EAAs) through autolysis and fermented lysis during the manufacturing process [6]. For belacan, fresh shrimps caught in the Southeast Asian region are combined with salt and dried in the sun, and EAAs are produced through autolysis. EAAs are later divided into peptides and free amino acids by an enzyme, which gives flavor and

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umami taste [5]. Belacan has a 27% moisture content and 36% protein content [5]. Generally, in Southeast Asia, fermented shrimp paste has a moisture content of 56.1–70.9%, and a total nitrogen component of 1.51–2.41%. The free amino acids include aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, valine, cysteine, methionine, isoleucine, leucine, tyrosine, phenylalanine, tryptophan, lysine, histidine, and arginine [7]. To manufacture 1 kg of belacan, 3.7 kg of *Acetes* species shrimps is needed [1]. Research on belacan mostly focuses on nucleotide-related compounds regarding umami [1,4,5,7].

In Korea, there is a fermented shrimp product similar to belacan called Saewoojeot. Saewoojeot is a traditional Korean side dish; it involves fermenting and ripening shrimps by autolysis with addition of salt. The volume of added salt is 30–40% and the product is fermented for 4–5 months [8]. During the processing and aging, ATP, ADP, and IMP of Saewoojeot tend to decrease, while hypoxanthine tend to increase [9]. The content of free amino acids was in the order of proline, arginine, alanine, glycine, lysine, glutamic acid, leucine, valine, and threonine, and the total amino acid content is twice that of raw shrimps after 72 days of ripening [10]. Research on Korean Saewoojeot focuses on flavor components, amino acids by enzyme hydrolysis, and nucleic-acid-related materials [6,11–13]. Dried shrimps are also sometimes used when making food.

The present study compared Bruneian fermented shrimp paste with two types of Korean dried shrimp pastes: one fermented and dried, and the other dried and unfermented. The aim was to provide a fundamental basis for simplification of the shrimp paste manufacturing process.

2. Materials and methods

2.1. Preparation and processing of shrimp paste

Belacan is a fermented dried shrimp paste made in Brunei from Acetes species. Traditionally, to make belacan, the fresh shrimps are e washed. The shrimps are placed in plastic sacks after 15~20% salt is added. The mixture is fermented at 30~32°C, and then sun-dried to remove most of the moisture, and ground afterwards. The method of manufacturing belacan differs depending on the country and region [5]. To make a parallel comparison with Bruneian belacan, a similar process was used as for the Korean fermented and dried Saewoojeot paste. The shrimps used for this were a similar species to those used to make belacan in Brunei, and the paste was manufactured after 15 hours of freeze-drying (FD 5512 freeze dryer; Ilshin, Chungnam, Korea), coarse-ground by an electric chopper, and fine ground in a colloid mill. To be used as a sample, unfermented dried shrimp paste that was bought in the market was coarse-ground in an electric chopper, or finely in a mortar, and made into a paste similar to belacan.

2.2. Proximate composition

Proximate compositions of the samples were determined using Association of Official Analytical Chemists(AOAC) [14]. The moisture content was determined by the weight loss after 12 hours of drying at 105°C in an oven (SW-90D; Sang Woo Scientific Co., KyunggiDo, Korea). The fat content was determined by the Soxhlet method with a solvent extraction system (Soxtec Avanti 2050 Auto System; Foss Tecator AB, Hoganas, Sweden), and the protein content was determined by the Kjeldahl method with an automatic nitrogen analyzer (Kjeltec 2300 Analyzer Unit; Foss Tecator AB). The ash content was determined according to the AOAC method 923.03.

2.3. Water activity

Water activity was measured by filling the ground sample without pores by using a water activity meter (LabMaster-aw CH 8853; Novasina, Lachen, Switzerland).

2.4. pH

pH of samples was measured using a pH meter (Accumet model 13-620-530A; Fisher, Waltham, MA, USA).

2.5. Salinity

Salinity of the samples was analyzed by the Mohr method [15]. The samples (5 g) were homogenized in 50 mL distilled water. And then were filtered through Whatman No. 1 filter paper (Whatman Ltd., Springfield, UK). A filtered solution of 10 mL was titrated with 0.02N silver nitrate.

2.6. Amino acids

Using the method of the Korean Food Standards Codex [16], 1 g of the sample was added to 15 mL 6N HCl, it was quickly sealed after being substituted into N2. It was hydrolyzed for 24 hours at 105°C oven , and then was allowed to cool. Deionized water (50 mL) was set and filtered through a 0.2 μm membrane filter. Taking 2 mL of sample was analyzed using an amino acid analyzer (pump PU-980, visible detector, wavelength; 570 nm, 440 nm (for proline); Jasco, Osaka, Japan). The column was analyzed using the gradient method with an ion exchange column (4.6 mm $\times$ 60 mm); dose of 10 μL; column temperature of 30°C; column flow 0.999 mL/min; moving phase buffer solution and ninhydrin solution.

2.7. Minerals

Mineral content was analyzed by the method of Zeiner et al [17]. The sample was incinerated, dissolved with diluted hydrochloric acid, and filtered to be analyzed using the inductively coupled plasma-atomic emission spectrophotometer (ICP-AES; JobinYvon JY138 Ultrace, France). A calibration curve was drawn with deionized water of more than 17 MΩ (NATO pure ultrasystem, Barnstead), and the standard solution concentration of each element was prepared at 0, 1 μg/g, 10 μg/g and 50 μg/g. The operating conditions for ICP-AES were set as power 1 kW for aqueous, nebulizer pressure 3, 5 bars for Meinhard type C, aerosol flow rate 0.3 L/min, sheath gas flow 0.3 L/min, and cooling gas 12 L/min.

2.8. Fatty acid and cholesterol

To analyze the fatty acid composition, fat was extracted according to the method of Folch et al [18], and 2 mL 0.5N NaOH/methanol was added to 20 mg of fat, which was later saponified for 10 minutes at 105°C. It was examined after applying 2 mL boron trifluoride/methanol, and methylated. Then, 2–3 mL hexane (HPLC grade) and 2 mL saturated NaCl solution were added. The supernatant of the mixture used the separated funnel was analyzed by gas chromatography (Hewlett Packard 6890 series; Palo Alto, CA, USA). The column was set up with an HP-FFAP capillary column (25 m $\times$ 0.32 mm internal diameter, 0.5 μm film thickness); initial oven temperature of 130°C (1 minute), increased at 2.5°C/min to a final temperature of 230°C (10 minutes); injector temperature 230°C, detector temperature 250°C; helium carrier gas with a spilt ratio of 20 : 1, and flow rate of 1 mL/min.

Cholesterol content was determined according to the method of Piironen et al [19], with some modification. Extracted fat from sample was followed with the mixture (60% KOH 8 mL and alcohol 40 mL) by 1 hour of at 100°C, followed by 60 mL of mixed solution for cooling. The application of 50 mL of benzene and 1N KOH 100 mL separates the supernatant, which was added by 0.5N KOH 20 mL and anhydride sodium sulfate. Sample solution was then analyzed by GC (Hewlett Packard 6890 series) after decompressed enrichment and application of 5α cholestane solution as an internal standard solution. The column was HP-1 capillary column (30 m × 0.32 mm internal diameter, 0.25 mm film thickness), detector (initial temp. 200°C (1 min)), oven temp. (increase rate 20°C/min, final temp. 300°C (6 min)), injector temp. 250°C, detector temp. 300°C, helium carrier gas, and flow rate of 1 mL/min.

2.9. *Statistical analysis*

All samples were analyzed in triplicate. Data were analyzed using SAS software, ver. 9.0 ([20], SAS, Cary, NC, USA). Duncan's multiple range test was used to compare the differences among means. Significance was defined at $p < 0.05$.

3. Results and Discussion

3.1. *Proximate composition*

The proximate compositions of the Korean and Bruneian shrimp pastes are shown in Table 1. The shrimp paste from Brunei showed the highest and most significant moisture content ($p < 0.05$). The protein content was shown to be significantly higher in the Korean dried shrimp paste ($p < 0.05$). The fat and the ash content of the Korean fermented Saewoojeot shrimp paste tended to be higher than in the other pastes. Montano et al [21] reported that the Filipino shrimp paste, *Alamang*, had a moisture content of 33.2%, fat content of 0.91%, and ash content of 43.9%. Deshmukh [5] reported that a shrimp paste from Singapore, which is also called belacan, contained 27% moisture and 36% protein. In the Bruneian belacan used in the present study, the composition differed depending on the regional differences in manufacturing procedures. Fermented fish and shrimp paste products from Asia have a moisture content of 56.1–70.9% [7].

3.2. *pH, water activity, and salinity*

The pH, water activity, and salinity of the Korean and Bruneian shrimp pastes are shown in Table 2. The pH of the Korean dried shrimp paste was significantly higher than in the other pastes. The pH of the Saewoojeot paste was 6.83–7.23, and the pH decreased during fermentation [12,22]. Mizutani et al [23] showed that Korean shrimp paste had pH 7.50, and Yoshiko [7] reported that Korean Saewoojeot paste had pH 7.10, and Fillipino fermented shrimp paste had pH 7.50, which were similar to the results of the present study. The pH changes depending on the type of shrimp paste tested, and on the manufacturing method [24].

The water activity of the Korean fermented and dried Saewoojeot shrimp paste was 0.682, which was significantly lower than that of the Bruneian fermented paste (0.728) and Korean dried shrimp paste (0.771) ($p < 0.05$). Montano et al [21] showed that the water activity of Fillipino fermented shrimp paste was 0.66–0.68, and that water activity should be < 0.7 for microbial stability. Therefore, this study shows that the water activity of belacan is low enough to allow microbial growth at room temperature. The water activity is known to be highly correlated with moisture content [25], and it decreases with the addition of salt and sugar [26]. The range of water activity that allows microbial growth differs depending on the type of microorganism. Most of the halophilic bacteria grow at 0.80–0.85, and some can even grow at 0.75 [27]. Some of the xerophilic mold and osmophilic yeasts can grow at levels as low as 0.65 or 0.6.

Bruneian shrimp paste had salinity of 14.94%, which was significantly higher than that of the Korean dried shrimp paste (12.87%) and Korean fermented and dried Saewoojeot paste (13.46%) ($p < 0.05$). Generally, salinity of shrimp pastes is ~17.5% [23], which is similar to the results of the present study [23]. Montano et al [21] reported that the salinity of Fillipino shrimp paste Alamang was 24.4%. According to Cho and Kim [24], the salinity of shrimp depends on the quantity and type of salt used during the manufacturing process. Therefore, it seems possible to control the salinity of fermented shrimp paste with the quantity and type of salt.

3.3. *Mineral content*

The mineral content of the Korean and Bruneian shrimp pastes are shown in Table 3. Korean dried shrimp paste had the highest levels of Ca, Fe, K, P and Zn ($p < 0.05$). The fermented and dried Saewoojeot paste tended to have higher Mg (438.80 mg/100 g) and Na (13,668.29 mg/100 g) levels than the other pastes. This finding can be explained by the fact that the Korean traditional fermented Saewoojeot paste commonly uses sun-dried salt, which contains a large quantity of Na and Mg [24]. Each paste had mineral levels in the following order: Na > Ca > P > K > Mg > Fe > Zn. Viwatpanich [28] claimed that Mon Food, which is traditional Thai shrimp food, is a good source for Ca and P.

Table 1
Proximate Composition of Korean and Bruneian Shrimp Pastes.

Parameters	A*	B	C
Moisture	47.92^{a}	26.96^{b}	21.13^{c}
Protein	30.38^{b}	21.70^{c}	56.59^{a}
Fat	0.63^{b}	4.89^{a}	0.82^{b}
Ash	19.15^{b}	45.83^{a}	13.95^{b}

All values are percentages and means of three replicates.
* Means within a row with different letters are significantly different ($p < 0.05$).
A, Traditional Bruneian belacan shrimp paste; B, Korean fermented and dried Saewoojeot shrimp paste; C, Korean dried shrimp paste.

Table 2
pH, Water Activity, and Salinity of Korean and Bruneian Shrimp Pastes.

Parameters	A*	B	C
pH	7.56^{c}	7.68^{b}	8.50^{a}
a_w	0.728^{c}	0.682^{b}	0.771^{a}
Salinity (%)	14.94^{a}	13.46^{b}	12.87^{c}

All values are means of three replicates.
* Means within a row with different letters are significantly different ($p < 0.05$).
A, Traditional Bruneian belacan shrimp paste; B, Korean fermented and dried Saewoojeot shrimp paste; C, Korean dried shrimp paste. a_w, water activity.

Table 3
Mineral Contents of Korean and Bruneian Shrimp Pastes.

Parameters	A*	B	C
Ca	1,457.82^{b}	931.07^{c}	3,598.05^{a}
Fe	2.09^{b}	2.26^{b}	28.90^{a}
K	345.98^{c}	548.87^{b}	751.12^{a}
Mg	193.33^{c}	438.80^{a}	254.65^{b}
Na	5,069.99^{b}	13,668.29^{a}	754.18^{c}
P	757.82^{b}	513.36^{c}	911.02^{a}
Zn	2.22^{b}	1.34^{c}	5.91^{a}

All values are mg/100 g and means of three replicates.
*Means within a row with different letters are significantly different ($p < 0.05$).
A, Traditional Bruneian belacan shrimp paste; B, Korean fermented and dried Saewoojeot shrimp paste; C, Korean dried shrimp paste.

3.4. Amino acid content

The amino acid content of the Korean and Bruneian shrimp pastes is shown in Table 4. The total amino acid content was highest in the Korean dried shrimp paste at 41,957 mg/100 g, and the EAA content was also highest with 16,763 mg/100 g, compared to those in the other pastes. The proportion of EAAs showed similar trends in all the pastes. The most abundant amino acid was glutamic acid in all the pastes, followed by aspartic acid and leucine. According to Mizutani et al [23], the content of glutamic acid was the highest in shrimp paste, which agrees with the present study. Kim and Lee [29] reported that aspartate, serine, arginine, threonine, proline, valine, isoleucine and lysine are related to taste and flavor. Amino acids related to sweet taste are glycine, alanine, serine, threonine and tyrosine, and valine, methionine, isoleucine, leucine, tryptophan, phenylalanine, histidine and arginine are related to bitter taste. The proportion of amino acids related to taste was similar for each paste in this study.

3.5. Fatty acid composition and cholesterol content

The fatty acid composition and cholesterol content of the Korean and Bruneian shrimp pastes are shown in Table 5. The Korean dried shrimp paste had the highest saturated fatty acid concentration at 34.76%, which was significantly higher ($p < 0.05$) than that of Bruneian belacan (31.16%) and Korean fermented and dried Saewoojeot paste (23.74%). The unsaturated fatty acid content of Saewoojeot paste showed highest proportion ($p < 0.05$). This result can be seen as an effect of fermentation. The monounsaturated fatty acid content was higher in the Korean dried shrimp paste, but the polyunsaturated fatty acid content was highest in the Korean fermented and dried Saewoojeot paste ($p < 0.05$). The ratio between unsaturated and saturated fatty acids was highest in the Korean Saewoojeot paste at 3.33. Also, the ratio between saturated and polyunsaturated fatty acids was highest in the Korean Saewoojeot paste, while the Korean dried shrimp paste had the lowest ratio. Peralta et al [30] reported that the fatty acid content of salt-fermented shrimp paste was high, and the content of palmitic acid, eicosapentaenoic acid, and decosahexaenoic acid was also high. Montano et al [21] reported that Fillipino shrimp paste had a saturated fatty acid content of 47.3%, 18.0% monounsaturated fatty acid, and 34.7% was polyunsaturated fatty acid.

The cholesterol content was highest in the Korean dried shrimp paste at 51.01 mg/100 g ($p < 0.05$), followed by Bruneian belacan (46.99 mg/100 g) and the Korean fermented and dried Saewoojeot paste (25.29 mg/100 g). Peralta et al [30] reported that the cholesterol content changes depending on the fermentation period of salt-fermented shrimp paste. Additionally, Bragagnolo and Rodriguez-Amaya [31] have suggested that shrimps have different cholesterol content depending on the species and environment.

In conclusion, this study evaluated the characteristics of Korean and Bruneian shrimp pastes. Korean fermented and dried Saewoojeot shrimp paste showed similar or better quality characteristics than Bruneian belacan. The results suggest that manufacture of belacan could be improved by using the process of Korean Saewoojeot.

Table 4
Amino Acid Composition of Korean and Bruneian Shrimp Pastes.

Parameters	A*		B		C	
	Content†	Ratio‡	Content	Ratio	Content	Ratio
Aspartic acid	2,842.8	10.5	2,142.9	11.6	4,741.6	11.3
Threonine	1,290.3	4.7	864.8	4.7	1,889.4	4.5
Serine	951.2	3.5	606.5	3.3	1,907.7	4.5
Glutamic acid	5,284.6	19.4	3,133.7	17.0	6,951.4	16.6
Proline	1,173.0	4.3	918.7	5.0	1,889.6	4.5
Glycine	1,565.2	5.8	1,239.5	6.7	2,815.7	6.7
Alanine	1,703.3	6.3	992.8	5.4	2,464.8	5.9
Valine	1,417.1	5.2	962.7	5.2	2,071.2	4.9
Methionine	923.6	3.4	592.2	3.2	1,209.6	2.9
Isoleucine	1,259.5	4.6	854.7	4.6	1,845.6	4.4
Leucine	2,450.4	9.0	1,457.6	7.9	3,272.8	7.8
Tyrosine	1,011.5	3.7	641.1	3.5	1,513.0	3.6
Phenyl alanine	1,300.3	4.8	912.3	5.0	1,917.4	4.6
Lysine	2,468.1	9.1	1,385.0	7.5	3,072.3	7.3
Histidine	491.2	1.8	320.8	1.7	1,049.3	2.5
Arginine	1,042.6	3.8	1,382.8	7.5	3,345.7	8.0
Total	27,174.7^b	100.0	18,408.1^c	100.0	41,957.1^a	100.0
EAAs§	11,145.3^b	40.8	7,029.3^c	38.1	15,278.3^a	36.4
Tasteless‖	12,444.6^b	45.8	9,118.1^c	49.5	20,763.1^a	49.5
Sweet and bitter taste¶	6,061.5^b	22.3	4,059.0^c	22.1	9,732.2^a	23.2
Meaty taste**	6,208.2^b	22.8	3,725.9^c	20.2	8,161.0^a	19.5

All values are means of three replicates.
A, shrimp paste in traditional Brunei's belacan; B, Korean's fermented and dried *Saewoojeot* shrimp paste; C, Korean's dried shrimp paste. AAs, essential amino acids.
* Means within a row with different letters are significantly different ($p < 0.05$).
† mg/100 g.
‡ Percentages.
§ Met, Phe, Thr, Ile, Leu, Lys, Val, Trp.
‖ Asp, Ser, Arg, Thr, Pro, Val, Iso, Lys.
¶ Ala, Gly, His, Thr, Trp.
** Glu, Cys, Met.

Table 5
Fatty acid Composition and Cholesterol Content in Korean and Bruneian Shrimp Pastes.

Parameters	A*	B	C
Myristic acid (C14:0)	3.31	1.19	3.70
Pentadecanoic acid (C15:0)	0.72	–†	1.32
Palmitic acid (C16:0)	18.96	16.28	19.66
Palmitoleic acid (C16:1)	13.90	7.46	10.33
Margaric acid (C17:0)	1.13	0.88	1.87
Margaroleic acid (C17:1)	–	0.64	1.03
Stearic acid (C18:0)	6.15	3.91	8.20
Oleic acid (C18:1n9)	6.20	7.39	12.66
Linoleic acid (C18:2n6)	2.10	1.60	2.15
γ-Linolenic acid (C18:3n6)	0.70	–	–
Linolenic acid (C18:3n3)	0.83	0.95	–
Arachidonic acid (C20:0)	0.44	0.75	–
Eicosatrienoic acid (C20:3)	–	0.57	0.97
Eicosenoic acid (C20:1)	–	2.11	–
Arachidonic acid (C20:4)	–	3.50	6.46
Eicosapentaenoic acid (C20:5n3)	21.73	26.92	14.02
Erucic acid (C22:1n9)	0.57	–	–
Tricosanoic acid (C23:0)	0.45	0.73	–
Nervonic acid (C24:1)	0.97	1.39	1.03
Docosahexaenoic acid (C22:6n3)	21.84	23.74	16.59
SFA	31.16^b	23.74^c	34.76^a
USFA	68.84^b	76.26^a	65.24^c
MUFA	21.63^b	18.99^c	25.05^a
PUFA	47.21^b	57.27^a	40.19^c
USFA/SFA	2.22^b	3.33^a	1.89^c
PUFA/SFA	1.52^b	2.50^a	1.16^c
Cholesterol content	46.99^b	25.29^c	51.01^a

All values are means of three replicates.
A, shrimp paste in traditional Brunei's belacan; B, Korean's fermented and dried *Saewoojeot* shrimp paste; C, Korean's dried shrimp paste. MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; USFA, unsaturated fatty acid.
* Means within a row with different letters are significantly different ($p < 0.05$).
† Not detected.

Conflicts of interest

All authors have no conflicts of interest to declare.

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