RESEARCH ARTICLE

A Comparative Study on Quality of Fermented Shrimp Paste (*Terasi*) of Pelagic Shrimp from Different Locations in Indonesia

Henny Helmi[1,2], Dea Indriani Astuti[1], Rudi Dungani[1], and Pingkan Aditiawati[1*]

OPEN ACCESS

[1] School of Life Sciences and Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia

[2] Department of Biology, Universitas Bangka Belitung , Kampus Terpadu Balunijuk, Jalan Raya Balunijuk, Merawang, Bangka 33172, Indonesia

* Corresponding Author: pingkan@sith.itb.ac.id

Received: 21 February 2022

Accepted: 22 April 2022

Published: 25 May 2022

Academic Editor: Agusman, MSc

 Accreditation Number:148/M/KPT/2020. ISSN: 2089-5690, e-ISSN: 2406-9272. https://doi.org/ 10.15578/squalen.631

Abstract

This study aims to determine and compare the quality of Indonesian fermented shrimp paste (*terasi*) produced from pelagic marine shrimp using a traditional preservation method (fermentation, drying, and salting). The quality of fermented shrimp pastes from different locations in Indonesia (Sungsang district, South Sumatra; Toboali district, Bangka Belitung Islands; Indramayu, West Java; Tegal, Central Java; Madura, East Java; Bontang, East Kalimantan and Sumbawa, West Nusa Tenggara) was determined by evaluating its parameters (i.e., physicochemical, microbiological, and sensory). This study found that the fermented shrimp pastes quality differed among locations due to the processing method used (i.e., fermentation, salting, and drying), not the raw material characteristics, as indicated by the Principal Component Analysis (PCA). The first group (Sumatra and Sumbawa *terasi* samples) with a similar added salt percentage and length of fermentation resulted in similar pH, salinity, salty taste, and more preferred taste. The second group (Java and Kalimantan *terasi* samples) with similar lengths of first and second sun-drying resulted in similar chemical compositions such as higher protein content, lipid content, moisture content, total amino acid, and bitter taste. *Terasi* from Toboali prepared using *Acetes japonicus* with 48 h of fermentation produced the most nutritious and preferred taste by the panelists.

Keywords: fermentation, shrimp paste, preservation, nutrition, taste, quality

Introduction

Pelagic marine shrimp are abundant during certain seasons in Indonesia (Mantiri et al., 2012). These shrimp are often preserved by fermentation to increase their economic value. Fermented shrimp products are widely consumed in China and Southeast Asian countries as food staples, side dishes, or condiments/ seasonings in daily foods (Hajeb & Jinap, 2012; Li et al., 2021; Pongsetkul et al., 2014). In Indonesia, the most widely used fermented shrimp paste product is called *terasi*. Other Asian countries also have similar products, such as *kapi* in Thailand and Cambodia, *belacan* in Malaysia and Brunei, *mamruoc* in Vietnam, *baggong alamang* in Philipina, *ngapi* in Myanmar, and *shiokara* in Japan (Hajeb & Jinap, 2012; Kim et al., 2014; Pongsetkul et al., 2014; Wittanalai et al., 2011).

Acetes and *Mesopdosis* are the two most common shrimp used as raw materials to prepare shrimp paste in Asia, including Indonesia (Mantiri et al., 2012; Pongsetkul et al., 2015). Shrimp paste has a nutritive value and serves as a delicacy because it contains high protein and high glutamic acid, aspartic acid, and leucine (Daroonpunt et al., 2016; Kim et al., 2014; Kleekayai et al., 2016; Surono & Hosono, 1994). Some shrimp fermentation products have been well-characterized, such as *kapi* in Thailand, *belacan* in Malaysia, or salt-fermented shrimp paste in China (Cai et al., 2017; Kim et al., 2014; Li et al., 2021; Pongsetkul et al., 2014; Pongsetkul et al., 2015). Although there are similarities in the processing techniques of shrimp paste (i.e., salting, fermentation, drying), studies revealed that the differences in the raw material, fermentation, and processes resulted in different amino acid compositions, sensory attributes, and other properties (Cai et al., 2017; Hajeb & Jinap, 2012; Kleekayai et al., 2016; Pongsetkul et al., 2015). For instance, the comparison of *kapi* quality from different regions in Thailand showed that there were differences in color, pH, salinity, proximate, sensory properties, amino acid

composition, and anti-oxidative activities (Pongsetkul et al., 2014; Pongsetkul et al., 2015).

Fermentation of *terasi* takes one to four weeks, faster than *kapi*, which is fermented for four to six months (Pongsetkul et al., 2014; Surono & Hosono, 1994). Studies on *terasi* in Indonesia showed that *terasi* contains several amino acids, mainly glutamic acid, aspartic acid, and high in protein content (Surono & Hosono, 1994). Amino acids such as glutamic acid and aspartic acid are known as precursors of umami taste (Lioe et al., 2010). Fermented shrimp paste produced by natural fermentation and sterilization is rarely done during its production. This can lead to the growth of pathogenic microorganisms (Lee et al., 2014 ; Li et al., 2021). Indeed, previous studies (Lingying et al., 2018; Li et al., 2021) have shown the presence of pathogenic bacteria in shrimp paste samples.

Terasi existed in Indonesia even before the country was established (Prihanto & Muyasyaroh, 2021). *Terasi* has been a part of Indonesian history as indicated by the presence of *terasi* centers that employ slightly varied processes on the island of Java (Northern coast of Java Island) and other regions (such as Belitung, Toboali, and Lombok) (Junianto, 2012; Prihanto & Muyasyaroh, 2021). However, there is still limited information on *terasi* production in Indonesia, such as raw material used, preparation and processing (including preservation) method, and properties of the resulted products (i.e., physicochemical characteristics, sensory receptions, and food safety). Therefore, this study aimed to determine and compare the quality of *terasi* from different locations in Indonesia represented by seven main *terasi* production centers in Indonesia. This study will provide basis data to produce *terasi* with the best quality in Indonesia.

Material and Methods

Collection of Shrimp and *Terasi* Samples

Samples of shrimp and *terasi* from different locations of *terasi* main centers in Indonesia were collected. The eight samples from seven *terasi* main centers and their corresponding codes were Sungsang district, South Sumatra (S1S1); Toboali district, Bangka Belitung Islands (S2T1 and S2T2); Bontang Utara district, East Borneo (K1B1); Pabean district, Indramayu, West Java (J1I1); Tegal, Central Java (J2T1); Klampis Timur district, Madura, East Java (J3M1); and Labuan Bontong district, Sumbawa, West Nusa Tenggara (N1S1). One sample was taken from each district, except for the Toboali district, two samples were obtained due to differences in the shrimp used. Each sample was taken 500 g. A questionnaire on ingredients used and process was prepared and distributed to the producers. After *terasi* samples were prepared, they were packaged in sterile plastic bag and directly brought to the laboratory and maintained at -4 °C for microbial analysis. Meanwhile, samples for physical, chemical and color analyses were maintained at -20 °C. Samples were stored no more than one month before physical and chemical analyses and no more than two days for microbial and color analyses. A total of 200 g of wet shrimp were dried and put into a plastic bag for the determination of moisture content.

Identification of Shrimp Species as the Raw Material of *Terasi*

A total of 150 g of shrimp were divided evenly into three plastic bags, then five shrimp were randomly taken from each bag and soaked in 100 mL of 70% alcohol for further identification. Shrimp were identified at the National Research and Innovation Agency, Zoology laboratory according to identification key as described by Omori (1975).

Quality Characterization of *Terasi*

Color Analysis of *Terasi*

All samples were subjected to CIELAB colorimetric L^* (lightness), a^* (redness-greenness), and b^* (yellowness-blueness) tests using Konica Minolta CR-400 in triplicates (Daroonpunt et al., 2016) to measure the difference in the color of *terasi*. All samples previously stored at -20 °C were placed on a white plate and left at room temperature for 2 h. The Konica Minolta CR-400 was calibrated using a white calibration plate before measuring the color of *terasi*. Each sample was given a target code starting from T01 to T08 for samples S1S1, S2T1, S2T2, J1I1, J2T1, J3M1, K1B1, and N1S1 by pressing the target button. Then, the head of the measuring instrument CR-400 was placed vertically above the sample. The measurement button of the measuring head was pressed and the measurement result was printed. The result of b^* value is interpreted as Maillard reaction products while a^* value indicates free astaxanthin as a result of lipoprotein degradation of shrimp.

Chemical Composition

The AOAC procedure (AOAC, 2000) was used to determine pH, salt, moisture and ash contents. The pH of the sample was measured using pH meter (Ohaus ST 2100-F, USA). Salinity was determined by Mohr method. Moisture (oven drying methods) and ash

(furnace methods) were determined by thermogravimetry method. The crude protein was measured by the Kjeldahl method principle with 6.25 conversion factor using Foss Tecator Kjeltec 8400 instrument (Persson et al., 2008). Crude fat was determined by the hydrolysis/Weibull method (SNI-01-2891-1992; Alika & Atma, 2018). Carbohydrate content was calculated by subtracting 100% to the sum of water, protein, ash, and fat contents. All of the aforementioned measurements were performed in triplicates.

Free Amino Acid Quantification

The free amino acids of the tested samples were analyzed using UPLC Shimadzu (H-Class with the Waters product TUV detector, Shimadzu, Japan). The column used was AccQ-Tag Ultra C18, with 49 °C temperature for mobile phase gradient composition system, flow rate 0.7 mL per min, detector PDA with λ 260 nm, and injection volume 1 µL. The samples for analysis were prepared by hydrolyzing 0.1 g of sample in 5 mL of 6 N HCl, heated at 110 °C for 22 h. After cooling, the samples were transferred to a 50 mL volumetric flask, and aquabidest was added until it reached the boundary mark. The samples were then filtered with a 0.45 µm Whatman filter. A solution containing 500 µL filtrate, 40 µL AABA, and 460 µL aquabidest was prepared, then 70 µL of AccQ-Flour Borate and 20 µL of reagent flour A were added. The solution was incubated at 55 °C for 10 min and then injected into the UPLC system. The measurement for free amino acid quantification of eight fermented shrimp paste samples were done in triplicates.

Microbial Cell Count

Total Viable Count (TVC) was carried out according to Maturin and Peeler (2020), with modification. *Terasi* (1 g) was dissolved with 9 mL of 0.85% NaCl and crushed using a mortar. The suspension was poured into a reaction tube and was homogenized using a vortex (Thermoscientific, US). A 10-fold serial dilution was carried out to 10^{-4} dilution and 0.1 mL of dilution 10^{-1} to 10^{-4} was spread on plate count agar (PCA). The number of colonies on agar plate was calculated after the plates were incubated at 35 °C for 48 h in an incubator (Memmert, Germany). Colony forming unit (CFU) was only counted from plate with range 25-250 colonies. The analyses were done in triplicates.

Detection of Pathogen

The detection of coliform, fecal coliform, and *Escherichia coli* in *terasi* samples was done according to Feng et al. (2011) with modification and performed in triplicates. A total of 25 g of shrimp paste was weighed and added with 25 mL Butterfield Phosphate Buffer (BPB), then crushed in a mortar. The mixture was poured into a sterile plastic bag and added with 200 mL BPB prior to shaking for 25 times. A 10-fold serial dilution was carried out, and 1 mL of dilutions 10^{-1}, 10^{-2}, and 10^{-3} were transferred to Lactose Broth (LB) medium with Durham tube inside and incubated at 35±1 °C for 24-48 h in an incubator (Memmert, Germany). After incubation, growth from positive LB tubes (with gas) was transferred to Brilliant Green Lactose Bile Broth (BGLBB) and Endo Broth medium. BGLBB was incubated at 35±1 °C for 48±2 h, while Endo Broth was incubated in a water bath shaker at 45±1 °C for 48±2 h. Positive results in BGLBB (gas-formation) denoted coliform numbers, while the positive results in the Endo Broth represented fecal coliform numbers. A loopful of positive results in Endo Broth media were streaked on the Eosin Methylene Blue Agar (EMBA) medium. Dark centered and flat, with or without metallic sheen on EMBA medium suspected as *E. coli*, was streaked on a PCA slant. Indole, Methyl Red, Voges, Proskauer and Simon citrate (IMVIC) test and Gram staining were done to confirm the result.

Detection of *Salmonella* was done according to Andrews et al. (2014) with modification. Each of shrimp paste samples was crushed in a mortar and was added with 25 µL of LB. The mixture was then poured into a sterile plastic bag and diluted with 200 mL of LB. The diluted mixture was shaken, and then transferred to a sterile Erlenmeyer flask and left at room temperature for 60 min. Before being incubated at 35 ±1°C for 24±2 h, the Erlenmeyer flask was gently shaken and then covered with a cotton lid. After incubation, 1 mL of incubated LB was transferred to 10 mL of Tetrathionate Broth (TTB) medium and incubated at 35±1 °C for 24±2 h. Then, 3 mm loopful of incubated TTB was streaked on Salmonella Shigella Agar (SSA) and Xylose Lysine Deoxycholate (XLD) agar before reincubation at 35±1 °C for 24±2 h. Positive results were indicated by transparent colonies with a black center on SSA and pink colonies with a black center on XLD Agar. For further test, slant agar of Triple Sugar Iron Agar (TSIA) and Lysine Iron Agar (LIA) were used by stabbing the bottom of the tube and streaking the slant media using an inoculum needle. Positive results were indicated by yellow butt with brick-red slant on TSIA medium and yellow butt with purple slant on LIA. All of test were done in triplicates.

Sensory Attributes Evaluation of *Terasi*

A sensory test was conducted using the descriptive and hedonic test with scale. *Terasi* samples for sensory test were prepared according to Meilgaard et al. (2015)

and Pongsetkul et al. (2015) with slight modifications. Fermented shrimp samples were cut into cuboids (1 cm x 2 cm x 2 cm). The samples were then wrapped with aluminum foil and heated in a hot air oven at 60 °C for 30 min. Fermented shrimp samples were served on white paper at room temperature. Both of hedonic and descriptive tests were performed by semi-trained panelists of 25 people by assessing the specifications present in the flavor intensity score sheets, which included sweet, salty, sour, and bitter on a 1-9 scale, showing the intensity of flavors from the weakest (1) to the strongest (9). For the hedonic test, the panelists were asked to assess samples for color-liking, odor-liking, flavor-liking, texture-liking, and overall-liking using a 9-point hedonic scale (1= Dislike extremely, 2= Dislike very much, 3= Dislike moderately, 4= Dislike slightly, 5=Neither like nor dislike, 6= Like slightly, 7= Like moderately, 8= Like extremely, 9= Like very much).

Data Analysis

A one-way analysis of variance (ANOVA) at a 95% confidence level followed by Duncan's multiple range test (DMRT) post hoc were used to analyze the data of physical, chemical, total microbial, and sensory evaluations using SPSS 23.0 (IBM, Illinois, US). To find the correlation among variables, we built multivariate correlation using Principal Component Analysis (PCA) and Minitab 19.0 statistical software (Minitab Inc., USA) based on the Pearson's correlation with a 95% confidence level. The significant value was set at $p < 0.05$.

Results and Discussion

Terasi Processing in Seven *Terasi* Centers in Indonesia

The raw materials and processing methods from seven *terasi* centers in Indonesia are shown in Table 1. The raw material used consisted of shrimp from two families, i.e., Sergestidae (*Acetes japonicus, A. indicus, A. vulgaricus,* and *A. sibogae*) and Penaidae (*Metapenaeus*). Other studies showed that shrimp from the genus *Acetes* and *Mesopodopsis* are commonly used for fermented shrimp pastes (Mantiri et al., 2012; Pongsetkul et al., 2015; Kleekayai et al., 2016).

Table 1 showed that the producers prepared *terasi* using fermentation, salting, and drying to preserve the shrimp. Fermentation is a common food preservation method (Hajeb & Jinap, 2012), similar to salting and drying (Koo et al., 2016). The capacity of salt (sodium chloride) to reduce moisture content has an important preservative and antimicrobial effect. Furthermore, salt also enhances taste, by producing meaty flavor and other functional properties of food (Albarracín et al., 2011; Steinkraus, 2002; Stringer & Pin, 2005). Table 1 shows that only two samples were prepared without salt (J3M1 and K1B1). To prevent product spoilage, samples J3M1 and K1B1 were sundried for a longer period than others. Similar to salting, the purpose of sun-drying is to preserve the shrimp by reducing moisture content (Ajifolokun et al., 2019) thus preventing microbial growth and increasing the product shelf-life (Akonor et al., 2016). Some *terasi* samples were prepared through repeated sun-drying process: pre- and post-fermentation.

Most *terasi* samples were prepared using one step of fermentation and only S2T2 was prepared using two steps of fermentations (Table 1). The fermentation period for sample preparation in this study was carried out for a shorter period (12 h to 48 h) than other shrimp paste products such as *bagoong alamang* that is usually fermented for 10 days (Hajeb & Jinap, 2012) or *kapi* between four to six months (Pongsetkul et al., 2014). Table 1 shows that S2T1 was fermented longer than other samples. Fermentation provides preservation effects to extend the shelf life of the foods (Hajeb & Jinap, 2012; Kleekayai et al., 2015). Fermentation can also improve the nutritional and functional properties of foods (Steinkraus, 2002; Kleekayai et al., 2015). During fermentation of shrimp paste, specific amino acids, fatty acids, antioxidant compounds, and volatile compounds were synthesized (Hajeb & Jinap, 2012; Pongsetkul et al., 2015; Peralta et al., 2008; Daroonpunt et al., 2016; Kim et al., 2014).

Based on interviews with the locals, the processing of *terasi* in this study involved one or two grinding steps. During the first grinding, the shrimp shell was crushed to ensure the salt and shrimp tissue were mixed properly. The second grinding was done to create a homogenized *terasi.* Crushing the shrimp solves the texture problem of shrimp paste caused by the presence of shrimp shell (Hajeb & Jinap, 2012). The detailed *terasi* processes are shown in Table 1 and Supplementary Data (Figure S1).

Color and Chemical Compositions of *Terasi*

The color, proximate composition, pH, and salinity of *terasi* samples are shown in Table 2. Each *terasi* sample used in this study has its unique color (Figure 1) ranging from 39.93-47 for lightness (L^*), 3.17-8.70 for redness (a^*), and 3.11-8.81 for yellowness (b^*). The difference of L^*, a^*, b^* value among *terasi* samples gave different color appearance. The characteristic color of *terasi* (Figure 1) showed that *terasi* was varied i.e. grayish, pink, purplish, yellowish-

brown to dark brown. Different pigment content in shrimp, ingredients added, and processing samples might be attributed to the difference in *terasi* color (Figure 1). Statistically, for *L** value, all samples had different lightness with S2T2 had the highest *L** value (8.70), while J1I1 sample had the lowest one (3.17). The lowest *L** value indicating that the latter has the darkest color across the tested samples. The added palm sugar during the preparation for J1I1 was responsible for the dark brown color of this sample. The brown color could also be a result of the Maillard reaction (Kleekayai et al., 2015; Pongsetkul et al., 2015; Pongsetkul et al., 2014; Daroonpunt et al., 2016).

As indicated by the *a** value (Figure 1), N1S1 had the highest redness color, that might be caused by high free astaxanthin liberated from lipoprotein (Pongsetkul et al., 2014). Free astaxanthin functions as antioxidant (Pongsetkul et al., 2014; Cai et al., 2017). The *b** value for S2T2 and N1S1 were the highest among samples, though insignificantly different. The *b** value indicates the yellowness color of shrimp paste that presumably resulted from Maillard reaction products in the samples. These products are also known as the taste precursor in shrimp paste (Cai et al., 2017)

The range of *terasi* colors was different from another shrimp paste such as *kapi*. *Kapi* had *L**, *a**, *b** values which ranged from 29.6-39.48, 6.01-9.15, and 8.33-17.91, respectively (Daroonpunt et al., 2016). Additionally, Pongsetkul et al. (2014) reported that *kapi* had *L**, *a**, *b** values which ranged from 34.13-51.84, 5.24-15.39, and 4.56-17.59, respectively. The difference in *terasi* and *kapi*'s color might be caused by the different pigment contents from the raw materials, process and ingredients added.

The moisture content of *terasi* samples in this study varied from 24.14-50.83% (Table 2). K1B1 had the lowest moisture content among all *terasi* samples. Presumably, this was caused by the intense of sun-drying during processing (21 h sun-drying II; Table 1). According to Ajifolokun et al. (2018), the moisture content can affect the odor, color, texture, and taste, and shelf life of food.

All samples contained a high amount of protein, which varied from 23.68-44.37%. The fat content of all *terasi* samples was relatively low (0.17-4.38%). The K1B1 had the highest protein and fat contents due to low moisture content. The variation of protein and fat contents might be caused by the difference in the source of raw materials (i.e., shrimp) or the process of *terasi* production. Indeed, previous studies showed that shrimp contains over 20% of protein and low-fat contents (Ajifolokun et al., 2018; Akonor et al., 2016). Previous study showed that *terasi* made with 15% salt and fermented for four weeks, contained 29.1% ash, 1.9% carbohydrate, 6.1% fat, 25% protein, and 16.8% salinity (Surono & Hosono, 1994).

The carbohydrate content in the tested samples ranged from 2.64-14.82%. Statistically, sample J1I1 showed the highest carbohydrate content (14.82%) due to the addition of palm sugar. The pH of *terasi* samples ranged between 7.17 and 8.14 which is neutral to slight alkaline. Volatile basic compounds such as ammonia

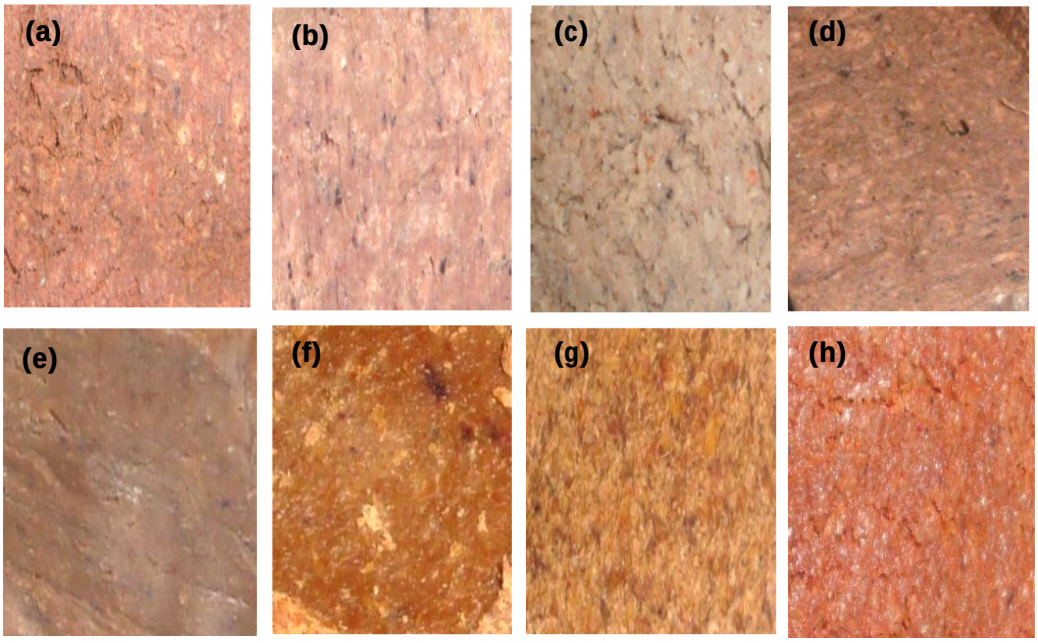

Figure 1. The color of *terasi* samples. (a) S1S1 (Sungsang); (b) S2T1 (Toboali 1); (c) S2T2 (Toboali 2); (d) J1I1 (Indramayu); (e) J2T1 (Tegal); (f) J3M1 (Madura); (g) K1B1 (Bontang); (h) N1S1 (Sumbawa).

Table 1. The origin of samples, raw materials and processing of *terasi* from seven main centers in Indonesia

Sample	Origin	Raw material	Additives	Processing				Processing steps [(a)]
				Washing	Sun drying I	Fermentation Frequency & time	Sun drying II	
S1S1	Sungsang, South Sumatra	*Metapenaeus lysianassa*	20% coarse salt, 2% food coloring	Fresh water	6-7 h until moisture content 16.63%	once, 36 h	6-7 h until moisture content 15.57%	Shrimp → 1→ 2 → 4→ 5 → 7 → 9 → 10 → 12 → terasi
S2T1	Toboali, Bangka Belitung Islands	*Acetes japonicus*	33% coarse salt	Sea water	3-6 h until moisture content 58.62%	once, 48 h	3-6 h until moisture content 44.31%	Shrimp → 1 → 4 → 5,6 → 7 → 9 → 10 → 12 → terasi
S2T2	Toboali, Bangka Belitung Islands	*Acetes indicus*	23% coarse salt	Sea water	2-6 h until moisture content 54.7%	twice, each 24 h	4-6 h until moisture content 23.74%	Shrimp → 1 → 6 → 7 → 4 → 5 → 8 → 9 → 10 → 12 → terasi
J1I1	Indramayu, West Java	*Acetes vulgaricus*	10% coarse salt, 20% brown sugar, a little of flavoring enhancer	No washing, drained	6-8 h until moisture content 28.52%	once, 12 h (overnight)	6-8 h until moisture content 16.46%	Shrimp → 3 → 4 → 5,6 →7→ 9 → 10 → 11 → 12 → terasi
J2T1	Tegal, Central Java	*Acetes vulgaricus*	20% coarse salt	No washing	4-8 h until moisture content 30.15%	once, 24 h	12 h until moisture content 26.9%	Shrimp → 4 → 5,6 → 7 → 9 → 10 → 12 → terasi
J3M1	Madura, East Java	*Acetes sp.1*	no additive	No washing, drained	until moisture content 34.42%	once, 12 h (overnight)	14-21 h until moisture content 30.14%	Shrimp → 3 → 7 → 4 → 5 → 9 → 12 → terasi
K1B1	Bontang, East Borneo	*A.sibogae, Acetes sp.1*	a little of overnight precipitated sea water	No washing, drained	6-7 h until moisture content 18.23%	once, 12 h (overnight)	7-21 h until moisture content 24.14%	Shrimp → 7 → pressing → 4 → adding sea water, 5 → 9 →12 -> terasi
N1S1	Sumbawa, West Nusa Tenggara	*A.sibogae*	16% coarse salt	No washing	4-5 h until moisture content 11.09%	once, 12 h (overnight)	-	Shrimp→ 6 → 7 → 4 → 5 → 12 → terasi

Note: [(a)]1= washing; 2= mixing salt and food coloring; 3= draining; 4= sun drying I; 5= grinding/pounding I; 6= salting; 7= fermentation I; 8= fermentation II; 9= sun drying II; 10= grinding/pounding II; 11= adding sugar and flavoring; 12= packaging. S1S1 (Sungsang); S2T1 (Toboali 1); S2T2 (Toboali 2); J1I1 (Indramayu); J2T1 (Tegal); J3M1 (Madura); K1B1 (Bontang); N1S1 (Sumbawa)

Table 2. Physical and chemical characteristics of *terasi* from seven main centers in Indonesia

Sample	L*	a*	b*	pH	Salinity (%)	Moisture (%)	Ash (%)	Insoluble acid ash (%)	Protein (%)[a)]	Fat (%)[b)]	Carbohydrate (%)
S1S1	45.17±0.00^{c}	6.64±0.13^{b}	5.31±0.04^{de}	7.77±0.01^{c}	15.41±0.07^{c}	43.68±0.10^{d}	22.40±0.10^{a}	0.26±0.04^{c}	27.47±0.46^{e} (30.00)	0.56±0.01^{e} (0.61)	5.88±0.27^{d}
S2T1	46.75±0.29^{b}	3.23±0.09^{e}	3.11±0.08^{f}	8.14±0.00^{a}	9.18±0.12^{d}	48.57±0.09^{b}	15.83±0.08^{b}	0.35±0.05^{c}	29.13±0.22^{d} ((35.36)	0.17±0.00^{f} (0.21)	6.3±0.21^{d}
S2T2	54.31±0.57^{a}	6.09±0.28^{bc}	8.81±0.20^{a}	7.79±0.01^{c}	22.90±0.03^{a}	50.83±0.10^{a}	21.53±0.07^{a}	0.36±0.02^{c}	23.68±0.44^{g} (30.10)	1.32±0.04^{c} (1.32)	2.64±0.45^{e}
J1I1	39.93±0.42^{f}	5.58±0.71^{cd}	6.07±0.08^{cd}	7.17±0.00^{f}	8.72±0.10^{e}	37.39±0.06^{f}	15.92±0.09^{b}	0.32±0.04^{c}	29.59±0.45^{d} (27.67)	2.28±0.08^{b} (2.13)	14.82±0.40^{a}
J2T1	41.51±0.49^{e}	5.02±0.10^{d}	7.17±0.76^{b}	7.47±0.01^{d}	2.41±0.10^{h}	37.73±0.10^{e}	12.41±0.09^{c}	0.71±0.08^{a}	38.28±0.80^{c} (36.28)	0.72±0.02^{d} (0.72)	10.86±1.01^{b}
J3M1	44.23±0.19^{d}	3.17±0.03^{e}	4.80±0.65^{e}	7.4±0.021^{e}	2.96±0.08^{g}	30.14±0.14^{g}	14.32±0.09^{b}	0.57±0.08^{b}	42.77±0.45^{b} (42.77)	4.38±0.12^{a} (4.38)	8.40±0.38^{c}
K1B1	47.00±0.21^{b}	5.09±0.01^{d}	6.85±0.05^{bc}	7.38±0.00^{e}	7.52±0.06^{f}	24.14±0.10^{h}	15.91±0.08^{b}	0.05±0.04^{d}	44.37±0.48^{a} (26.77)	4.26±0.10^{a} (2.57)	11.32±0.56^{b}
N1S1	45.00±0.03^{c}	8.70±0.04^{a}	8.02±0.01^{a}	8.01±0.00^{b}	18.97±0.15^{b}	46.29±0.26^{c}	22.88±0.11^{a}	0.06±0.03^{d}	25.80±0.36^{f} ((29.85)	1.47±0.05^{c} (1.69)	3.56±0.56^{e}

Note: Means in triplicates ±SD. Different superscripts letters in the same column indicate the significant difference (p<0.05). S1S1 (Sungsang); S2T1 (Toboali 1); S2T2 (Toboali 2); J1I1 (Indramayu); J2T1 (Tegal); J3M1 (Madura); K1B1 (Bontang); N1S1 (Sumbawa).

and other degradation products that were released during fermentation might affect the slightly basic pH of shrimp paste (Pongsetkul et al., 2014; Daroonpunt et al., 2016). Statistically, S2T1 samples had the highest pH due to the longest fermentation time that led to the increased degradation of protein and production of ammonia. All samples contained salt from 2.41 to 22.90%. Impurity of the coarse salt used during processing might caused discrepancy with the measured salinity in the *terasi* samples. Coarse salt is derived from the evaporation of sea water, in the form of crystal, and without iodine. This salt is used for curing and the manufacture of fermented foods such as shrimp paste and cheese (Albarracín et al., 2011; Wolfe et al., 2014; Pongsetkul et al., 2017; Ali et al., 2020)

The ash contents of *terasi* samples were high (12.41-22.88%) and positively correlated with the salinity (Figure 2a). The ash content in *terasi* derived from salt and some inorganic substance from the shells of shrimp used (Pongsetkul et al., 2014; Daroonpunt et al., 2016). The insoluble acid ash content of samples was low (0.05-0.71%). Acid insoluble ash was analyzed to determine the amount of silica (Satter et al., 2014). The process of sun-drying on the ground causes sand or silica to be carried into *terasi*. The low content of insoluble acid ash showed that silica or sand did not contaminate the *terasi* samples during processing.

Free Amino Acid Profile of *Terasi*

Table 3 presents the free amino acid composition of *terasi*. The total amino acids of *terasi* samples ranged from 229.34 to 315.01 mg/g. Several amino acids, i.e., aspartate, lysine, leucine, glycine, and alanine, were abundant in *terasi* samples. The abundance of these amino acids was probably related to the length of the fermentation process, where amino acids were generated as a result of the degradation of protein and peptide (Surono & Hosono, 1994; Pongsetkul et al., 2014; Pongsetkul et al., 2015; Daroonpunt et al., 2016). The fermentation process also produces glutamic acid, which contributes to the umami taste of fermented products (Jinap et al., 2010). The composition of various amino acids showed that samples have a high nutritional value. Compared to other similar products, *terasi* showed higher amount of free amino acids. Kim et al. (2014) mentioned the total amino acids in *belacan* was 27.174 mg/100 g. Daroonpunt et al. (2016) showed that the most common free amino acids present in *kapi* were glutamic acid (70.1-593.9 μg/g), lysine (112.7-546.3 μg/g), and leucine (29.5-544.9 μg/g). In this study, the glutamic acid content was correlated with the moisture content (Figure 2b). The results of this study is in agreement with those by Jinap et al. (2010) that showed similar findings in *belacan* of various brands.

Total Microbial Count and Detection of Microbial Pathogen in *Terasi*

Total microbial count showed *terasi* samples containing bacteria ranged from 7.8×10^1 to 2.53×10^6 CFU/g (Table 4). *Terasi* samples did not harbor major pathogens such as *E. coli* and *Salmonella*. The coliforms and fecal coliform counts indicated no fecal contamination, except for J2T1. Meanwhile, S2T1 contained higher microbial count (2.53×10^6) compared to those of *terasi* samples from other study (Surono & Hosono, 1994) with a total microbial count of 4×10^5 CFU/g. Generally, the limit of total microbial count in fishery food is less than 10^5 (Pal et al., 2016). In this study, the total microbial counts in the samples were determined using plate count agar to determine the number of viable aerobic mesophilic bacteria with an optimum temperature of 25-40 °C in food (Peniasih et al., 2020). Therefore, the total microbial count can be interpreted as aerobic plate count (APC). The APC may be used to assess the quality and safety of food by detecting microbial contamination (Kim et al., 2018). The microbial contaminant could be derived from the water used to wash the shrimp, tools, containers or the microorganism on the ground during the sun-drying process.

Sensory Evaluation

Descriptive organoleptic test for saltiness in *terasi* samples ranged between 2.82-5.34. Based on the Duncan test, S1S1, S2T1, S2T2, and N1S1 were saltier than J1I1, J2T1, J3M1, and K1B1 (Table 5). Furthermore, the results showed that there were no significant difference between sweet and sour attributes among samples (Table 5). The bitter taste of the *terasi* samples ranged between 1.24-5.33. Samples J3M1, J2T1, and K1B1 were bitter than S1S1, S2T1, S2T2, J1I1, and N1S1. Pearson's correlation test showed a negative correlation between salinity and bitter taste (Figure 2c). The bitter taste might have resulted from excessive drying.

The semi-trained panelists slightly disliked the color, texture, aroma, taste and overall acceptability of *terasi* samples. Probably because *terasi* is usually used as a condiment in flavorful dishes, such as fried rice or chilli sauce. Sensory evaluation for taste indicated that panelists preferred J1I1, which was prepared by adding palm sugar and flavor enhancer. PCA based on Pearson correlation (Figure 3) showed that although glutamic acid and aspartic acid are known as precursors of umami taste, there were no correlation between

Table 3. Free amino acid composition of *terasi* from several main centers in Indonesia

Type of amino acid	Amino Acid Content (mg/g)							
	S1S1	S2T1	S2T2	J1I1	J2T1	J3M1	K1B1	N1S1
L-Serine	9.03±0.02 (9.86)	7.25±0.04 (8.80)	9.01±0.08 (11.46)	5.95±0.03 (5.56)	6.95±0.06 (6.55)	9.02±0.07 (6.80)	10.81±0.11 (6.52)	7.95±0.09 (9.19)
L-Glutamic Acid	38.07±0.14 (41.57)	45.24±0.4 (54.92)	38.86±0.27 (49.39)	42.07±0.31 (39.32)	44.75±0.40 (42.21)	44.25±0.40 (33.35)	54.27±0.49 (32.75)	41.23±0.43 (47.71)
L-Phenyl alanine*	16.00±0.08 (17.47)	13.26±0.13 (16.09)	13.89±0.13 (17.65)	12.40±0.08 (11.59)	11.56±0.10 (10.90)	19.44±0.16 (14.64)	18.83±0.17 (11.36)	13.20±0.15 (15.27)
L-Isoleucine*	13.87±0.04 (15.15)	12.71±0.13 (15.43)	11.24±0.10 (14.29)	11.86±0.09 (11.08)	13.27±0.12 (12.52)	13.23±0.12 (9.97)	16.72±0.14 (10.09)	13.13±0.14 (15.19)
L-Valine*	14.29±0.04 (15.60)	13.35±0.12 (16.20)	11.16±0.08 (14.18)	12.90±0.09 (12.06)	14.00±0.13 (13.21)	13.96±0.12 (10.52)	17.53±0.15 (10.58)	12.92±0.13 (14.95)
L-Alanine	15.97±0.05 (17.44)	18.98±0.18 (23.05)	14.67±0.05 (18.69)	17.22±0.12 (16.09)	19.62±0.18 (18.51)	23.32±0.21 (17.57)	22.02±0.20 (13.29)	15.08±0.16 (17.45)
L-Arginine	10.88±0.01 (11.88)	7.06±0.07 (8.57)	17.51±0.15 (22.25)	6.28±0.05 (5.87)	4.96±0.04 (4.68)	9.47±0.08 (7.14)	15.21±0.16 (9.18)	10.50±0.12 (12.15)
Glycine	20.52±0.05 (22.41)	18.93±0.18 (22.98)	14.17±0.10 (18.01)	16.19±0.12 (23.77)	17.28±0.16 (16.30)	23.46±0.21 (17.68)	17.27±0.17 (10.42)	21.87±0.23 (25.30)
L-Lysine HCl*	21.39±0.07 (23.35)	27.92±0.26 (33.90)	23.55±0.17 (29.93)	25.43±0.16 (15.13)	29.07±0.20 (27.42)	32.42±0.29 (24.43)	32.36±0.28 (19.53)	27.12±0.29 (31.38)
L-Aspartic Acid	19.48±0.05 (21.28)	23.42±0.23 (28.43)	22.38±0.16 (28.45)	20.65±0.15 (19.31)	24.23±0.22 (22.86)	26.64±0.24 (20.07)	28.88±0.25 (17.43)	23.12±0.24 (26.76)
L-Leucine*	22.23±0.07 (24.27)	20.48±0.20 (24.87)	19.57±0.22 (24.87)	19.68±0.18 (18.39)	21.93±0.20 (20.68)	20.99±0.19 (15.82)	27.35±0.24 (16.51)	20.49±0.22 (23.70)
L-Tyrosine	13.50±0.04 (14.74)	10.04±0.10 (12.19)	11.10±0.08 (14.10)	9.33±0.08 (8.72)	9.46±0.09 (8.92)	17.08±0.15 (12.87)	13.45±0.11 (8.12)	11.44±0.11 (13.24)
L-Proline	9.89±0.03 (10.80)	10.22±0.08 (12.41)	8.19±0.04 (10.42)	9.43±0.06 (8.82)	8.81±0.07 (8.31)	12.85±0.11 (9.68)	12.72±0.11 (7.68)	9.66±0.10 (11.18)
L-Threonine*	11.65±0.04 (12.73)	11.32±0.10 (13.75)	10.68±0.07 (13.57)	9.23±0.07 (8.66)	9.03±0.08 (8.52)	11.33±0.10 (8.54)	13.04±0.11 (7.87)	11.23±0.11 (12.99)
L-Histidine*	5.32±0.00 (5.81)	4.11±0.04 (4.99)	5.25±0.04 (6.66)	4.24±0.02 (3.96)	3.79±0.03 (3.57)	4.29±0.04 (3.23)	6.45±0.06 (3.89)	5.16±0.07 (5.97)
L-Cystine	1.01±0.00 (1.10)	0.87±0.01 (1.06)	0.92±0.01 (1.17)	0.58±0.01 (0.54)	0.53±0.00 (0.50)	0.72±0.01 (0.54)	0.88±0.01 (0.53)	0.75±0.01 (0.87)
L-Methionine*	6.39±0.02 (6.98)	6.39±0.06 (7.76)	6.00±004 (7.63)	5.87±0.65 (5.49)	5.55±0.05 (5.24)	9.63±0.08 (7.26)	7.22±1.35 (4.36)	6.33±0.64 (7.32)
Total	249.50.00 (272.45)	251.56.00 (305.40)	238.15.00 (302.69)	229.34.00 (214.37)	244.79 (230.90)	292.09.00 (220.09)	315.01.00 (190.11)	251.20.00 (290.64)
EAA[a)]	111.14.00 (121.36)	109.54.00 (132.99)	101.34.00 (128.80)	92.40.00 (86.37)	108.21.00 (102.07)	125.28.00 (94.40)	139.50.00 (84.19)	109.58.00 (126.78)

Note: Means of three replicates ±SD. Means in bracket: conversion to moisture content 40%. [a)] Essential Amino Acids) *= amino acids categorized as EAA. S1S1 (Sungsang); S2T1 (Toboali 1); S2T2 (Toboali 2); J1I1 (Indramayu); J2T1 (Tegal); J3M1 (Madura); K1B1 (Bontang); N1S1 (Sumbawa).

glutamic acid and aspartic acid to taste preference. Figure 3 also shows that salinity influenced the preference of taste. Salt can bind to glutamic acid to form monosodium glutamate (MSG) which causes an increase in savory taste (Frankowski et al., 2014).

Based on the hedonic test of color, panelists preferred *terasi* samples with a low *L** value (i.e., J3M1, N1S1, and S1S1; Table 5) or *terasi* with dark color. In terms of aroma, panelists preferred the aroma of J2T1. Kleekayai et al. (2016) stated that fat acts as a precursor for aroma compounds in *kapi*. In contrast, this study showed that fat content did not correlate (p>0.05) with panelist preferences for aroma (Figure 2d). The analysis showed correlations (p<0.05) between color, aroma, and texture with the overall preference; but there was no correlation (p>0.05) of taste with overall preference (Figure 2e and Table S2). In line with *kapi* (Pongsetkul et al., 2015), the overall panelists' reception of *terasi* samples was affected by color appearance and volatile compounds.

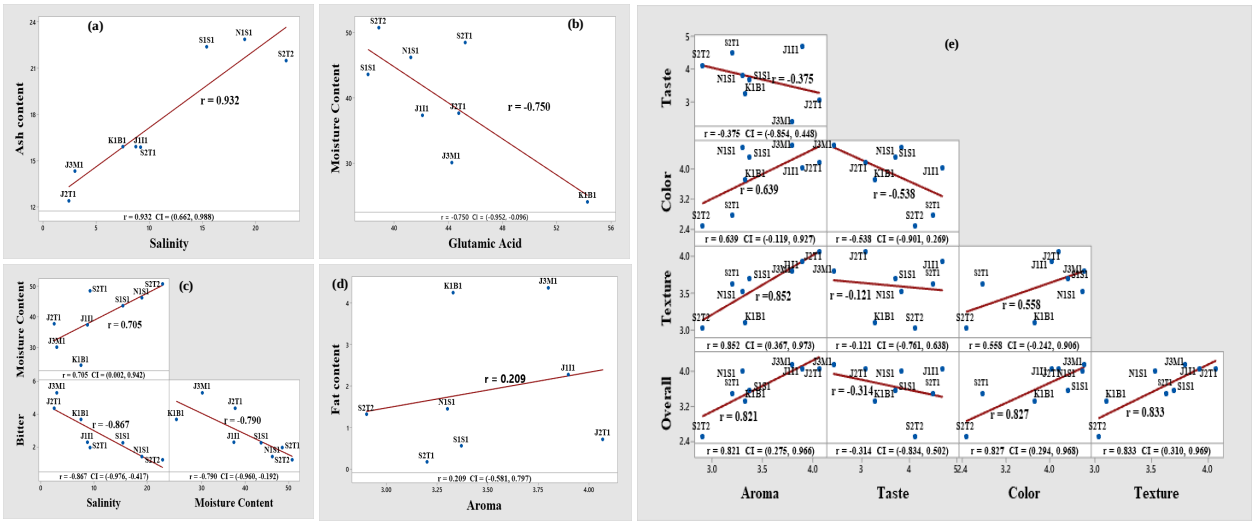

Figure 2. Pearson's correlation. (a) Matrix correlation of ash content and salinity; (b) Matrix correlation of moisture content and glutamic content; (c) Matrix correlation of salinity and bitter taste as well as moisture content; (d) Matrix correlation of fat content and aroma; (e) Matrix correlation of color, aroma, texture, taste to overall preference. S1S1 (Sungsang); S2T1 (Toboali 1); S2T2 (Toboali 2); J1I1 (Indramayu); J2T1 (Tegal); J3M1 (Madura); K1B1 (Bontang); N1S1 (Sumbawa). r-correlation value in sample, Cl=correlation interval range, the stronger the correlation the narrower the interval range.

Correlation between Preservation Methods and Food Quality

The PCA analysis (Figure 4a) showed that preservation methods (i.e fermentation, salting and drying) influenced the properties of *terasi*. The first group (i.e., S1S1, S2T1, S2T2, and N1S1) shared similarities in the frequency and length of fermentation, pH, salt percentage, salinity, taste preference, salty taste, and moisture. The second group (i.e., K1B1, J1I1, J2T1, and J3M1) was similar in their length of first and second sun-drying; the contents of protein, fat, total amino acid, total essential amino acid, glutamic acid; and the panelist preferences of color, aroma, bitter taste, and sour taste.

Each *terasi* sample in this study had different moisture content. Therefore, a comparison of the samples with equivalent moisture content was required. As shown in Tables 2 and 5, if the moisture content was lower than 40%, the *terasi* samples would be bitter such as J2T1, J3M1, and K1B1 containing 37.73%, 30.14%, and 24.14% of moisture, respectively. The

Table 4. Total microbial count, total of coliform, total of fecal coliform, and detection of *E. coli* and *Salmonella* of *terasi* samples from different locations in Indonesia

Sample[a)]	Total Plate Count	Most Probable Number of Coliform	Most Probable Number of Fecal Coliform	Escherichia coli	Salmonella
S1S1	7.8x101±0.25 (d)	<3	<3	-	-
S2T1	2.53x106±0.08 (a)	<3	<3	-	-
S2T2	2.19x102±0.18 (d)	<3	<3	-	-
J1I1	7.47x104±0.12 (b)	<3	<3	-	-
J2T1	6.52x104±0.41 (b)	7.4	<3	-	-
J3M1	1.12x102±0.13 (d)	<3	<3	-	-
K1B1	1.85x102±0.03 (d)	<3	<3	-	-
N1S1	3.01x103±0.55 (c)	<3	<3	-	-

Note: Means of triplicates ±SD. Different superscript letters in the same row indicate the significant difference (p<0.05). S1S1 (Sungsang); S2T1 (Toboali 1); S2T2 (Toboali 2); J1I1 (Indramayu); J2T1 (Tegal); J3M1 (Madura); K1B1 (Bontang); N1S1 (Sumbawa)

Table 5. Sensory evaluation of *terasi* from different locations in Indonesia

Parameter	S1S1	S2T1	S2T2	J1I1	J2T1	J3M1	K1B1	N1S1
Descriptive Organoleptic Test								
Sweet	2.48±0.46^{a}	2.17±0.35^{a}	1.71±0.05^{a}	2.65±0.09^{a}	1.58±0.28^{a}	1.75±0.07^{a}	1.96±0.21^{a}	2.58±0.05^{a}
Sour	2.52±0.19^{a}	2.63±0.10^{a}	2.47±0.24^{a}	2.47±0.02^{a}	2.36±0.39^{a}	2.84±0.15^{a}	3.04±0.44^{a}	2.28±0.09^{a}
Salty	5.19±0.39^{a}	5.16±0.55^{a}	6.09±0.01^{a}	3.62±0.63^{b}	2.95±0.38^{b}	2.82±0.15^{b}	3.01±0.08^{b}	5.34±0.93^{a}
Bitter	2.27±0.28^{c}	1.98±0.22^{c}	1.24±0.08^{c}	2.3±0.18^{c}	4.38±1.00^{ab}	5.33±0.02^{a}	3.68±0.24^{b}	1.43±0.09^{c}
Hedonic Organoleptic Test								
Color	4.33±0.28^{a}	2.77±0.33^{c}	2.47±0.00^{c}	4.03±0.24^{ab}	4.17±0.33^{ab}	4.63±0.33^{a}	3.73±0.00^{b}	4.6±0.19^{a}
Aroma	3.37±0.14^{ab}	3.2±0.00^{b}	2.9±0.24^{c}	3.9±0.24^{ab}	4.07±0.00^{a}	3.8±0.009^{ab}	3.33±0.57^{ab}	3.3±0.05^{ab}
Texture	3.7±0.33^{ab}	3.63±0.24^{ab}	3.03±0.14^{c}	3.93±0.09^{a}	4.07±0.09^{a}	3.8±0.09^{ab}	3.1±0.05^{b}	3.53±0.47^{ab}
Taste	3.7±0.05^{ab}	4.5±0.05^{ab}	4.13±0.28^{ab}	4.7±0.33^{a}	3.07±0.19^{bc}	2.4±0.00^{c}	3.27±0.38^{b}	3.83±0.61^{ab}
Overall	3.57±0.05^{ab}	3.5±0.05^{ab}	2.5±0.28^{c}	4.07±0.33^{a}	4.07±0.19^{a}	4.17±0.00^{a}	3.33±0.38^{b}	4.03±0.61^{a}

Note: Means of triplicates ±SD. Different superscripts letters in the same row indicate significant difference (p<0.05) Sungsang (S1S1); Toboali 1 (S2T1); Toboali 2 (S2T2); Indramayu (J1I1); Tegal (J2T1); Madura (J3M1); Bontang (K1B1); Sumbawa (N1S1)

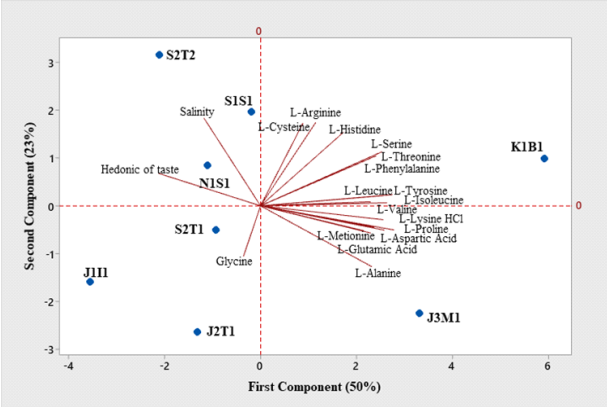

Figure 3. PCA of hedonic test of taste, amino acids and salinity. S1S1 (Sungsang); S2T1 (Toboali 1); S2T2 (Toboali 2); J1I1 (Indramayu); J2T1 (Tegal); J3M1 (Madura); K1B1 (Bontang); N1S1 (Sumbawa)

conversion results (Tables 2 and 3) showed that *terasi* S2T1 had the highest glutamic acid content of 54.92 mg/g, followed by S2T2 (49.39 mg/g). The highest protein content was found in J2T1 (36.11%) followed by S2T1 (35.36%).

Figure 4b shows the PCA analysis and correlation between protein, amino acids and *terasi* taste. The PCA result showed that *terasi* S2T1, S1S1, N1S1, and S2T2 belong to the group with higher level of variables tested. Moreover, the highest level was obtained by sample S2T1; thus, this *terasi* is the most nutritious across all samples based on the protein and glutamic acid contents. S2T1 was prepared by using *A. japonicus* and coarse salt with final salinity of 9.18%, 48 h fermentation, and 3-6 h of sun-drying. Although the microbial content in S2T1 was high, the total bacteria

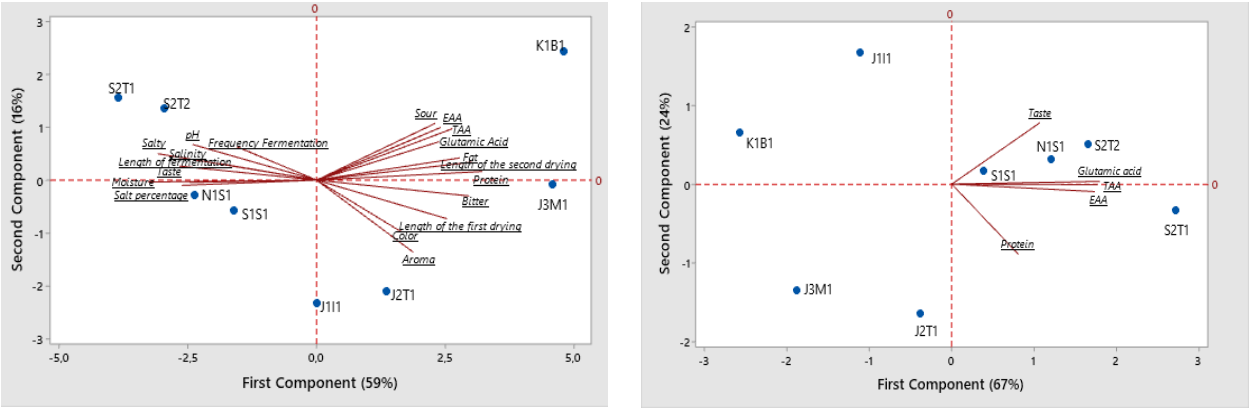

Figure 4. Principle Component Analysis of properties of *terasi* sampes (blue dots= the code of *terasi* samples, TAA= total amino acids, EAA=essential amino acids), (a) Correlation between the preservation methods and some properties of food; (b) Corellation between *terasi* samples and taste, protein, glutamic acid, total amino acid, and total essensial amino acid after conversion into moisture 40%. Sungsang (S1S1); Toboali 1 (S2T1); Toboali 2 (S2T2); Indramayu (J1I1);
Tegal (J2T1); Madura (J3M1); Bontang (K1B1); Sumbawa (N1S1)

can be reduced by applying a more hygienic production process.

Conclusion The fermented shrimp paste collected across Indonesia showed different quality. The differences were affected by the processing method (i.e., fermentation, salting, and drying), but not the raw material used. The similar preservation method (i.e., salting and length of fermentation) used at the *terasi* centers in Sungsang district (South Sumatra), Toboali district (Bangka Belitung Islands), and Sumbawa (West Nusa Tenggara) resulted in similar *terasi* characteristics (i.e., pH, salinity, taste preference, salty taste, and moisture). Similar length of the first and second sun-drying processes used at *terasi* centers in Bontang Utara district (East Kalimantan), Indramayu (West Java), Tegal (Central Java), and Madura (East Java) resulted in *terasi* with a similar profile of protein, fat, total amino acid, total essential amino acid, glutamic acid, color, aroma, bitter taste, and sour taste. All of the tested *terasi* had acceptable microbiology (did not contain *E. coli* and *Salmonella*) and good nutritional contents (high protein content and amino acids). Among all of the tested samples, S2T1 was the most nutrititious with a salinity content of 9.8%, produced via fermentation for 48 h and sufficient sun-drying to reach a product moisture content of 40%.

Acknowledgment

Henny Helmi is thankful to the Ministry of Research, Technology and Higher Education of the Republic Indonesia (Kemenristekdikti) - Indonesia Endowment Fund for Education (LPDP) scholarship (Number PRJ-5717/LPDP.3/2016) for supporting her doctoral study at ITB. We would thank Dr. Sastia Prama Putri from Department of Biotechnology, Graduate School of Engineering, Osaka University for her insightful discussion.

Supplementary Material

Supplementary materials are available online at the Journal's website.

References

Ajifolokun, O. M., Basson, A. K., Osunsanmi, F. O., & Zharare, G. E. (2019). Effects of drying methods on quality attributes of shrimp. *Journal of Food Processing & Technology*, *10*(1), 1–5. https://doi.org/10.4172/2157-7110.1000772

Akonor, P. T., Ofori, H., Dziedzoave, N. T., & Kortei, N. K. (2016). Drying characteristics and physical and nutritional properties of shrimp meat as affected by different traditional drying techniques. *International Journal of Food Science*, *2016*. https://doi.org/10.1155/2016/7879097

Albarracín, W., Sánchez, I. C., Grau, R., & Barat, J. M. (2011). Salt in food processing; usage and reduction: A review. *International Journal of Food Science and Technology*, *46*(7), 1329–1336. https://doi.org/10.1111/j.1365-2621.2010.02492.x

Ali, M., Kusnadi, J., Aulanni'am, A., & Yunianta, Y. (2020). Amino acids, fatty acids and volatile compounds of Terasi Udang, an Indonesian Shrimp paste, during fermentation. *AACL Bioflux*, *13*(2), 938–950.

Alika, V. A., & Atma, Y. (2018). The organoleptic and physicochemical characteristic of gelato by fish bone gelatin addition. *Journal of Applied Science and Advanced Technology*, *1*(1), 31–38.

Andrews, W.H., Wang, H., Jacobson, A., Ge, B., Zhang, G., & Hammac, T. (2014). *BAM Chapter 5: Salmonella. November 2019*, 1–24. https://www.fda.gov/food/laboratory-methods-food/bam-chapter-5-salmonella

AOAC. (2000). *Official methods of analysis* (17th ed.). AOAC International.

Cai, L., Wang, Q., Dong, Z., Liu, S., Zhang, C., & Li, J. (2017). Biochemical, nutritional, and sensory quality of the low salt fermented shrimp paste. *Journal of Aquatic Food Product Technology*, *26*(6), 706–718. https://doi.org/10.1080/10498850.2016.1276111

Daroonpunt, R., Uchino, M., Tsujii, Y., Kazami, M., Oka, D., & Tanasupawat, S. (2016). Chemical and physical properties of Thai traditional shrimp paste (*Kapi*). *Journal of Applied Pharmaceutical Science*, *6*(5), 58–62. https://doi.org/10.7324/JAPS.2016.60509

Feng, P., Weagant, S. D., Grant, M. A., & Burkhardt, W. (2011). *BAM Chapter 4 Enumeration of Escherichia coli and the Coliform Bacteria*. *6*, 1–7. https://www.fda.gov/food/laboratory-methods-food/bam-chapter-4-enumeration-escherichia-coli-and-coliform-bacteria

Frankowski, K. M., Miracle, R. E., & Drake, M. A. (2014). The role of sodium in the salty taste of permeate. *Journal of Dairy Science*, *97*(9), 5356–5370. https://doi.org/10.3168/jds.2014-8057

Hajeb, P., & Jinap, S. (2012). Fermented shrimp products as source of umami in Southeast Asia. *Journal of Nutrition & Food Sciences*, *01*(S10), 1–5. https://doi.org/10.4172/2155-9600.s10-006

Jinap, S., Ilya-Nur, A. R., Tang, S. C., Hajeb, P., Shahrim, K., & Khairunnisak, M. (2010). Sensory attributes of dishes containing shrimp paste with different concentrations of glutamate and 5'-nucleotides. *Appetite*, *55*(2010), 238–244. https://doi.org/10.1016/j.appet.2010.06.007

Junianto. (2012). Studi karakterisasi pengolahan terasi Cirebon dalam upaya mendapatkan perlindungan indikasi geografis. *Akuatika*, *2*(1), 1–4. http://jurnal.unpad.ac.id/akuatika/

Kim, H. J., Kim, D., Kim, H. J., Song, S. O., Song, Y. H., & Jang, A. (2018). Evaluation of the microbiological status of raw beef in Korea: Considering the suitability of aerobic plate count guidelines. *Korean Journal for Food Science of Animal Resources*, *38*(1), 43–51. https://doi.org/10.5851/kosfa.2018.38.1.043

Kim, Y.-B., Choi, Y.-S., Ku, S.-K., Jang, D.-J., Ibrahim, H. H. binti, & Moon, K. B. (2014). Comparison of quality characteristics between *belacan* from Brunei Darussalam and Korean shrimp paste. *Journal of Ethnic Foods*, *1*(1), 19–23. https://doi.org/10.1016/j.jef.2014.11.006

Kleekayai, T., Pinitklang, S., Laohakunjit, N., & Suntornsuk, W. (2016). Volatile components and sensory characteristics of Thai traditional fermented shrimp pastes during

fermentation periods. *Journal of Food Science and Technology*, *53*(3), 1399–1410. https://doi.org/10.1007/s13197-015-2142-3

Kleekayai, T., Saetae, D., Wattanachaiyingyong, O., Tachibana, S., Yasuda, M., & Suntornsuk, W. (2015). Characterization and *in vitro* biological activities of Thai traditional fermented shrimp pastes. *Journal of Food Science and Technology*, *52*(3), 1839–1848. https://doi.org/10.1007/s13197-014-1528-y

Koo, O. K., Lee, S. J., Chung, K. R., Jang, D. J., Yang, H. J., & Kwon, D. Y. (2016). Korean traditional fermented fish products: jeotgal. *Journal of Ethnic Foods*, *3*(2), 107–116. https://doi.org/10.1016/j.jef.2016.06.004

Lee, S. H., Jung, J. Y., & Jeon, C. O. (2014). Microbial successions and metabolite changes during fermentation of salted shrimp (saeu-jeot) with different salt concentrations. *PLoS ONE*, *9*(2), 1–12. https://doi.org/10.1371/journal.pone.0090115

Li, W., Lu, H., He, Z., Sang, Y., & Sun, J. (2021). Quality characteristics and bacterial community of a Chinese salt-fermented shrimp paste. *Lwt*, *136*(P2), 110358. https://doi.org/10.1016/j.lwt.2020.110358

Lingying, D., Limei, W., Jiang, S., Lixue, Z., & Bin, Q. (2018). Microbial community structure and diversity of shrimp paste at different fermentation stages 2. *BioRxiv*. https://doi.org/10.1101/334136

Lioe, H. N., Selamat, J., & Yasuda, M. (2010). Soy sauce and its umami taste: A link from the past to current situation. *Journal of Food Science*, *75*(3). https://doi.org/10.1111/j.1750-3841.2010.01529.x

Mantiri, R. O. S. E., Ohtsuka, S., & Sawamoto, S. (2012). Fisheries on *Mesopodopsis* (Mysida: Mysidae) and *Acetes* (Decapoda: Sergestidae) in Indonesia. *Kuroshio Science*, *5*(2), 137–146.

Maturin, Larry; Peeler, J. T. (2020). *BAM Chapter 3: Aerobic Plate Count | FDA*. *January 2001*, 1–11. https://www.fda.gov/food/laboratory-methods-food/bam-chapter-3-aerobic-plate-count

Meilgaard, M. C., Civille, G. V, & Carr, B. T. (2015). *Sensory Evaluation Techniques* (Fifth Edit). CRC Press. https://doi.org/10.1201/b19493

Peniasih, N. K., Pandit, I. G. S., & Edi, D. G. S. (2020). Analysis of microbial contamination in *Oreochromis niloticus* in Waduk Muara Nusa Dua. *SEAS (Sustainable Environment Agricultural Science)*, *4*(1), 53–59. https://doi.org/10.22225/seas.4.1.1688.53-59

Omori, M. (1975). The systematics, biogeography, and fishery of epipelagic shrimp of the genus *Acetes* (Crustacea, Decapoda, Sergestidae). *Bulletin of the Ocean Research Institute, University of Tokyo*, *7*(7), 1–89.

Pal, M., Ketema, A., Anberber, M., Mulu, S., & Dutta, Y. (2016). Microbial quality of fish and fish products. *Microbial Quality of Fish and Fish Products*, *43*(2), 1–4.

Peralta, E. M., Hatate, H., Kawabe, D., Kuwahara, R., Wakamatsu, S., Yuki, T., & Murata, H. (2008). Improving antioxidant activity and nutritional components of Philippine salt-fermented shrimp paste through prolonged fermentation. *Food Chemistry*, *111*(2008), 72–77. https://doi.org/10.1016/j.foodchem.2008.03.042

Persson, J. A., Wennerholm, M., & O'Halloran, S. (2008). Handbook for Kjeldahl Digestion. In *FOSS, Hilleroed, Denmark*. FOSS, Hilleroed, Denmark. https://doi.org/10.3168/jds.2009-2906

Pongsetkul, J., Benjakul, S., Sampavapol, P., Osako, K., & Faithong, N. (2014). Chemical composition and physical properties of salted shrimp paste (*kapi*) produced in Thailand. *International Aquatic Research*, *6*(3), 155–166. https://doi.org/10.1007/s40071-014-0076-4

Pongsetkul, J., Benjakul, S., Sampavapol, P., Osako, K., & Faithong, N. (2015). Chemical compositions, sensory and antioxidative properties of salted shrimp paste (*Kapi*) in Thailand. *International Food Research Journal*, *22*(4), 1454–1465.

Pongsetkul, J., Benjakul, S., Vongkamjan, K., Sumpavapol, P., & Osako, K. (2017). Microbiological and chemical changes of shrimp *Acetes vulgaris* during *Kapi* production. *Journal of Food Science and Technology*, *54*(11), 3473–3482. https://doi.org/10.1007/s13197-017-2804-4

Prihanto, A. A., & Muyasyaroh, H. (2021). The Indonesian fermented food product terasi/history and potential bioactivities. *Systematic Reviews in Pharmacy*, *12*(2), 378–384.

Satter, M., Ara, H., Jabin, S., Abedin, N., Azad, K., Hossain, A., & Ara, U. (2014). Nutritional composition and stabilization of local variety rice bran BRRI-28. *International Journal of Science and Technology*, *3*(5), 306–313. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1060.5889&rep=rep1&type=pdf

SNI. (1992). *Standar Nasional Indonesia: SNI 01-2891-1992 tentang Cara Uji Makanan dan Minuman*. Badan Standarisasi Nasional.

Steinkraus, K. H. (2002). Fermentations in *World Food Processing. Comprehensive Reviews in Food Science and Food Safety*, *1*, 23–32. https://doi.org/https://doi.org/10.1111/j.1541-4337.2002.tb00004.x

Stringer, S., & Pin, C. (2005). Microbial risks associated with salt reduction in certain foods and alternative options for preservation. Technical Report. In *Institute of Food Research* (Issue April). http://multimedia.food.gov.uk/multimedia/pdfs/acm740a.pdf

Surono, I. S., & Hosono, A. (1994). Chemical and aerobic bacterial composition of "*terasi*", a traditional fermented product from Indonesia. *Journal of the Food Hygienic Society of Japan*, *35*(3), 299. https://doi.org/10.3358/shokueishi.35.299

Wittanalai, S., Rakariyatham, N., & Deming, R. L. (2011). Volatile compounds of vegetarian soybean *kapi*, a fermented Thai food condiment. *African Journal of Biotechnology*, *10*(5), 821–830. https://doi.org/10.5897/AJB10.1533

Wolfe, B. E., Button, J. E., Santarelli, M., & Dutton, R. J. (2014). Cheese rind communities provide tractable systems for *in situ* and *in vitro* studies of microbial diversity. *Cell*, *158*(2), 422–433. https://doi.org/10.1016/j.cell.2014.05.041