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Physicochemical and sensory properties of terasi (an Indonesian fermented shrimp paste) produced using *Lactobacillus plantarum* and *Bacillus amyloliquefaciens*

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ABSTRACT

Terasi is an Indonesian shrimp paste that is traditionally fermented and is widely consumed by Indonesian people. *Terasi* is produced by utilizing endogenous bacteria from raw materials as starters. Due to the variation in endogenous bacteria during production, terasi of varying quality is produced. The objectives of this study were to investigate the effects of starters on the physicochemical and sensory properties of *terasi*. The effects of individual or combination inoculation of *Lactobacillus plantarum* SB7 and *Bacillus amyloliquefaciens* BC9 were compared to those of noninoculation during a two-week period of *terasi* production. The starters darkened the color of the terasi. The terasi produced with the starters had higher protein contents (62.93–64.80 %) than those of the noninoculated *terasi* (63.66–65.80 %). Although proteolysis was weakly affected by the starters, the starters reduced the *terasi* fermentation period. The combination starter inoculation resulted in a high glutamic acid level (44284.8 ± 231.22 mg/kg). Volatile alcohols were more abundant in the starter-inoculated *terasi* than in the noninoculated *terasi*. Assessments of the sensory parameters by panelists suggested a preference for inoculated *terasi*. In conclusion, the addition of starters (*L. plantarum* SB7 and *B. amyloliquefaciens* BC9) in *terasi* production improved the physicochemical and sensory properties of the *terasi*.

1. Introduction

Terasi is a native fermented product from Indonesia made of shrimp or fish. *Terasi* has an essential role in Indonesian cuisine as a condiment. This product occurs primarily in the form of fermented shrimp paste prepared from a krill-like shrimp. During the production of *terasi*, salt is added along with tapioca, rice, and wheat flours as fillers. The shrimp paste product is a brownish red, grey, or dark brown. *Terasi* is processed by spontaneous fermentation. The process of producing *terasi* varies among regions in Indonesia. On Java Island, the process involves repeated drying and fermentation steps (Wulandari et al., 2020). The mixture of shrimp, salt, and water is dried for 6 h before being fermented overnight. A second sun-drying step for 5−6 h then occurs before re-fermentation overnight. A third drying step for only 2−3 h is then conducted followed by the last fermentation step for 14–20 days (Karim et al., 2014).

Hydrolytic enzymes, such as protease, fibrinase, lipase, chitinase, and chitosanase, facilitate *terasi* fermentation. Among them, protease plays a vital role in the fermentation process and in determining *terasi* quality (Giyatmi and Irianto, 2017). Autolysis and the enzymatic processes are crucial in the production of fermented products. *Terasi* fermentation occurs under anaerobic conditions. Halophilic or halotolerant bacteria are the primary bacteria in *terasi* (Kobayashi et al., 2003).

The characteristics of shrimp paste depend on the freshness of the shrimp, the storage of the raw materials, the drying process, and the equipment used (Pongsetkul et al., 2015a, 2016; Khairina et al., 2016; Suwandi et al., 2017). As a result of these factors, the shrimp paste

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produced exhibits varied and complex flavor and aroma profiles. The taste profile and aroma vary depending on the ingredients and production methods used, regional and seasonal variations and other factors. Some peptides increase the umami flavor of *terasi* (Ambarita et al., 2019). The duration of sun drying, the amount of salt and the fermentation time will affect the final result due their effects on microbial and enzymatic activities.

Bacteria have a long history of use as starter cultures for various fermented products and are known to affect the characteristics of fermented food products (Visessanguan et al., 2006). The bacteria cultures in fermented foods are mainly dominated by lactic acid bacteria (LAB) and enzyme-producing hydrolytic bacteria (Chukeatirote et al., 2015). Several bacteria, such as Bacillus brevis, Bacillus pumilus, Bacillus megaterium, Bacillus coagulans, Bacillus subtilis, and Micrococcus kristinae, are commonly found in *terasi* (Surono and Akiyoshi (1994)). Most of them are proteolytic bacteria. Hence, the addition of LAB starter in the production of *terasi* likely affects the speed of fermentation and the physicochemical qualities of the product.

In this study, *Lactobacillus plantarum* SB7 and Bacillus amyloliquefaciens BC9 bacteria, which were isolated from mare's milk, were used as starters for *terasi* production. The purpose of this study was to determine the effects of the starters on the physicochemical and sensory properties of *terasi* products.

2. Materials and methods

2.1. Sample collection

Shrimp (*Acetes japonicus*) (average body length: 14.3 ± 1.2 mm; average wet weight: 0.0427 ± 0.0068 g; $n = 20$) were obtained from Tuban, East Java Province, Indonesia. The shrimp were sun dried to a water content of approximately 20–22 % before being transported to the laboratory in sterile polypropylene plastic bags.

2.2. Starter cultures

Two bacterial starters, *L. plantarum* SB7 and *B. amyloliquefaciens* BC9, that had been isolated previously from naturally fermented mare's milk were used (Mulyawati et al., 2019a, b). *L. plantarum* SB7 was cultured in De Man, Rogosa and Sharpe (MRS) broth (Merck, Darmstadt, Germany), whereas *B. amyloliquefaciens* BC9 was cultured in Luria–Bertani broth (Merck, Darmstadt, Germany). Both starters were incubated overnight on a shaking incubator (120 rpm) at 35 °C for 24 h. The bacterial density for inoculation of shrimp paste was adjusted to 10^4 CFU/mL.

2.3. Preparation of terasi

The *terasi* shrimp paste was produced according to the method of Wulandari (2020), with slight modification. Eight hundred grams of ground shrimp was mixed with salt, sugar and distilled water at a volume ratio of 25:15:10:50 shrimp: salt: sugar: water supplemented with or without inocula. The treatments consisted of no inoculation (A), inoculation with *L. plantarum* SB7 (B), inoculation with *B. amyloliquefaciens* BC9 (C), and inoculation with both *L. plantarum* SB7 and *B. amyloliquefaciens* BC9 (D). Each inoculum was added at a density of 10^4 CFU/mL before the first fermentation stage (Speranza et al., 2017; Thongruck et al., 2017). The process of *terasi* production is depicted in Fig. 1.

Fig. 1. [insert here]

The samples were fermented for 24 h at 30 °C in sealed jars and then sun dried for 6 h. Milling was then conducted before a second fermentation for 24 h at 30 °C. After the second fermentation, the mixture was formed and oven dried at 50 °C for 6 h. A third fermentation was then performed at 30 °C for one of several durations (0, 7, 14 days.

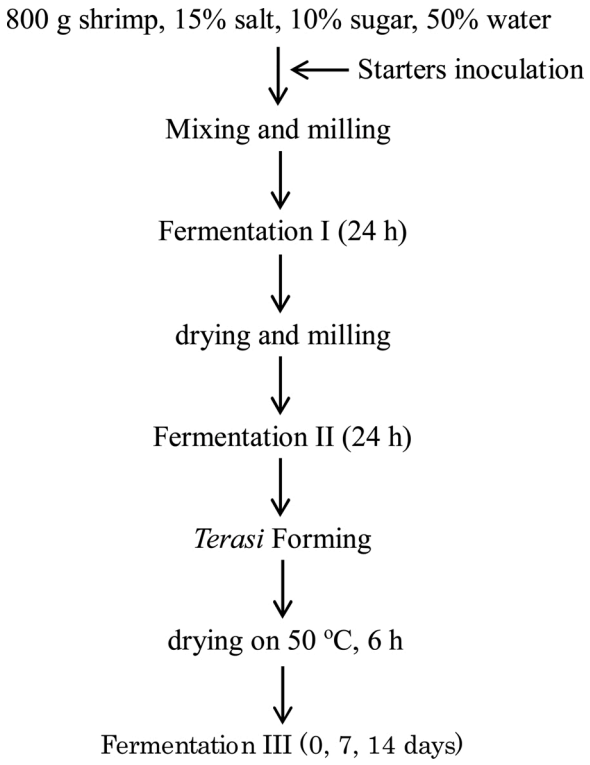

Fig. 1. *Terasi*-process production.

2.4. Color determination

An automatic colorimeter CS-10 (CHNSpec, Hangzhou, China) was used to analyze the color intensity of the *terasi*, expressed by the parameters L^* (lightness), a^* (redness/greenness), b^* (yellowness/blueness), ΔE^* (total color difference) and ΔC^* (total chroma difference) (Daroonpunt et al., 2016).

2.5. Protease activity assay

The proteolytic assay was carried out based on the method of Pongsetkul et al. (2016) and Prihanto et al. (2016) with modification. One gram of *terasi* was mixed with 10 mL of 1 M phosphate buffer (pH 8) and vortexed for 5 min. The supernatants were collected after centrifugation (10,000 rpm, 4 °C for 10 min) and dialyzed overnight against ten mM phosphate buffer (pH 8) using a cellophane membrane. Two hundred microliters of the dialyzed sample and 0.5 mL of 1.5 % casein were combined with 0.5 mL of distilled water in a 15-mL tube and placed in a water bath at 30 °C for 5 min. A dialyzed sample (0.5 mL) was added to the tube, and the tube was again heated in the water bath for 10 min. Then, 1.5 mL of 0.4 M TCA was added. After centrifugation at 2000 rpm for 10 min, 1 mL of supernatant was added to 2.5 mL of 0.55 M Na_2CO_3 and 0.5 mL of Folin–Ciocalteu reagent (Sigma-Aldrich, St Louis, MO, USA). The mixture was heated in a water bath for 30 min, and the absorbance at 660 nm was then measured using a UH 5300 spectrophotometer (Hitachi, Tokyo, Japan). The proteolytic activity was calculated as the number of micromoles of tyrosine generated per minute under the defined conditions.

$$Enzyme\ activity\ \left(\frac{U}{mL}\right) = \frac{reaction\ vol}{supernatant} \times \frac{reaction\ vol}{sample} \times \frac{1}{reaction\ time} \quad (1)$$

2.6. Proximate composition

A sample of terasi was collected from each jar for proximate composition analysis. The proximate composition of the terasi (protein,

fat, water and ash) was determined based on the AOAC method (AOAC. (2005)). Protein content was calculated with the Kjeldahl method (method number 945.18). The Soxhlet extraction method with petroleum ether as the extracting agent was applied for fat content analysis (method number 945.18). To determine ash content, the sample was incinerated at 550 °C (method number 945.18). The water content was assayed using the oven-drying method at a temperature of 100 °C (Method number: 934.01).

2.7. Amino acid analysis

The amino acid profile of the terasi was determined using ultra-performance liquid chromatography. A total of 0.1 g of *terasi* was added to 5 mL of HCl (6 N), and the mixture was mixed evenly by an ionized vortex. Then, it was hydrolyzed at 110 °C for 22 h, cooled and transferred to a 50-mL volumetric flask. After the addition of double-distilled H_2O, the mixture was filtered through a 0.45-μm filter. Next, 500 μL of filtrate, 40 μm of alpha aminobutyric acid (AABA) and 460 μL of double-distilled H_2O were combined. After adding 10 μL of the solution to 70 μL of AccQ-Fluor borate buffer, the mixture was vortexed and left to stand for 1 min. Fluor A reagent (20 μL) was added, and the mixture was vortexed and left to stand for 1 min. Next, the mixture was incubated at 55 °C for 10 min, and 1 μL of the solution was injected into the ultra-performance liquid chromatograph equipped with an ACCQ-Tag Ultra C18 column (Waters Co., Milford, MA, USA). The chromatographic separation was achieved at 49 °C, and the mobile phase comprised two eluents, AccQ·Tag_{ultra} eluent A concentrate (5%, v/v) and water (95 %, v/v) and AccQ·Tag_{ultra} eluent B, each with a flow rate of 0.7 μL/min. The PDA detector (Water, Massachusetts, USA) set at a wavelength of 260 nm.

2.8. Volatile compound analysis

A total of 50 g of *terasi* was placed in a beaker with 150 mL of *n*-hexane, covered with aluminum foil and left for 48 h. Next, the sample was filtered through filter paper (Wonorahardjo et al., 2015). The extract was then reacted with NaOH to remove fat, generating two layers. The transparent layer was collected, and *n*-hexane was added and left to evaporate. A small amount of sample was then injected into the gas chromatography-mass spectrometry (GC–MS) device equipped with an Rtx 5 MS column (30 m in length) (Restek, Bellefonte, PA, USA). The carrier gas was helium. The column effluent was ionized by electron impact ionization at 70 eV.

2.9. Sensory evaluation

A panel of 50 semi-trained undergraduate students at the Faculty of Fisheries and Marine Science, Brawijaya University, served as panelists. The sensory properties (taste, aroma, texture, appearance and overall quality) of the terasi were evaluated. *Terasi* samples were randomly selected for evaluation at room temperature. A seven-point hedonic scale ("extremely dislike", "dislike", "slightly dislike", "neutral", "slightly like", "like" and "extremely like") was employed for evaluation (Chambers and Wolf (1996)).

2.10. Statistical analysis

All data were obtained from three independent replicate experiments. Data were analyzed by analysis of variance followed by Duncan's test. All statistical analyses were performed using SPSS version 16 (IBM Corp. USA).

3. Results and discussion

3.1. Color

The color parameters of the *terasi* shrimp paste resulting from the various treatments are presented in Table 1. The raw material displayed the highest L* (50.38 ± 0.18). The lowest L* was obtained in treatment D (38.03 ± 0.0.37), which also yielded high a^*, b^*, ΔE^* and ΔC. The noninoculated sample exhibited a lighter color than the samples from the other treatments (Fig. 2).

The raw materials, physicochemical reactions, storage conditions, and type of proteolytic bacteria affect the enzymatic activities of shrimp paste (Chukeatirote et al., 2015). During the fermentation process, free amino acids and short-chain peptides undergo Maillard reactions, which contribute to increasingly brown discoloration (Lopetcharat et al., 2001). This discoloration is detrimental consumers dislike a bright-colored product. The drying and heating process concentrates the astaxanthin derived from the shrimp shells (Pongsetkul et al., 2017), which leads to an increase in the a^* and b^* color parameters. During the fermentation process, ΔE^* tends to increase while L^* decreases. The addition of inoculants tends to decrease L^* and increase ΔE^*. Furthermore, during fermentation, *L. plantarum* SB7 and *B. amyloliquefaciens* BC9 produce proteases that cause the release of carotenoids, such as astaxanthin, from the matrix of *A. japonicus* shrimp. Hence, the starter inocula tend to increase the brown color of the *terasi*.

The dark brown color is caused by oxidation during drying. The free astaxanthin is released into the product by the action of protease enzymes. As a consequence, the product darkens and exhibits a brown-apricot color (Mezquita et al., 2014).

3.2. Proximate composition

Proximate analysis was carried out by measuring the composition of protein, fat, water and ash in the product. The results are shown in Table 2. The control shrimp paste contained 62.93–64.80 % protein. The addition of *L. plantarum* SB7 and *B. amyloliquefaciens* BC9 either individually or in combination increased the protein content (63.66–65.80 %). There was no difference among *L. plantarum* SB7 addition, *B. amyloliquefaciens* BC9 addition and the combination of both. Similar trends were observed for the contents of water, ash and fat.

L. plantarum is classified as a facultative heterofermentative microorganism that can convert 95 % of glucose into lactic acid (Siezen and van Hylckama Vlieg (2011)). In the process of shrimp paste production, the initial pH is 6.0 and rises to 6.5 during fermentation, subsequently decreasing when the *terasi* is formed (Daroonpunt et al., 2016),

The water content was lower in the *terasi* produced with starter bacteria than in the control *terasi*. According to Obadina et al. (2013), fermentation tends to decrease the water content because the water in the material is used to support microorganism activity. Hence, the higher the number of bacteria added, the lower the water content of the *terasi*.

The raw material influences the protein ratio in shrimp paste (Kleekayai et al., 2015). Dried shrimp has a high protein content and distinctive flavor (Akonor et al., 2016). The protein analysis revealed marked differences in protein content among the treatments, which were likely the result of differences in protein hydrolysis. Proteolytic bacteria hydrolyze protein into amino acids, causing the amount of soluble protein in *terasi* to increase (Daroonput et al., 2016). Lactic acid bacteria produce proteolytic enzymes that facilitate protein degradation. Hence, the higher the concentration of the LAB starter, the greater the extent of protein hydrolysis.

3.3. Protease analysis

Protease activity increased during the fermentation of *terasi* (Fig. 3). In all treatments, protease activity increased continuously from

Table 1
Measurement of color during the *terasi* fermentation. RM: Raw material, *Acetes japonicas*, A: control without inoculation, B: inoculated with *L. plantarum* SB7, C: inoculated with *B. amyloliquifaciens* BC9, D: inoculated with *L. plantarum* SB7 and *B. amyloliquifaciens* BC9.

Samples	Color				
	L*	a*	b*	ΔE*	ΔC*
RM	50.38 ± 0.18^{a}	9.02 ± 0.62^{ab}	26.43 ± 0.54^{a}	0.66 ± 0.63^{bc}	0.29 ± 0.11^{a}
A	43.19 ± 1.83^{b}	8.83 ± 0.41^{ab}	19.77 ± 1.06^{b}	0.91 ± 0.54^{a}	-0.24 ± 0.79^{c}
B	41.29 ± 2.67^{bc}	8.22 ± 0.93^{b}	20.33 ± 2.00^{b}	0.69 ± 0.73^{bc}	-0.88 ± 0.84^{c}
C	40.19 ± 3.61^{c}	8.40 ± 0.54^{b}	16.94 ± 0.29^{c}	0.32 ± 0.04^{c}	0.07 ± 0.24^{b}
D	38.03 ± 0.37^{d}	9.70 ± 1.39^{a}	19.42 ± 1.24^{bc}	0.84 ± 0.80^{b}	0.10 ± 0.38^{a}

Mean ± SD from independent triplicate measurements.
Means with different superscript within same column are significant different ($p < 0.05$).

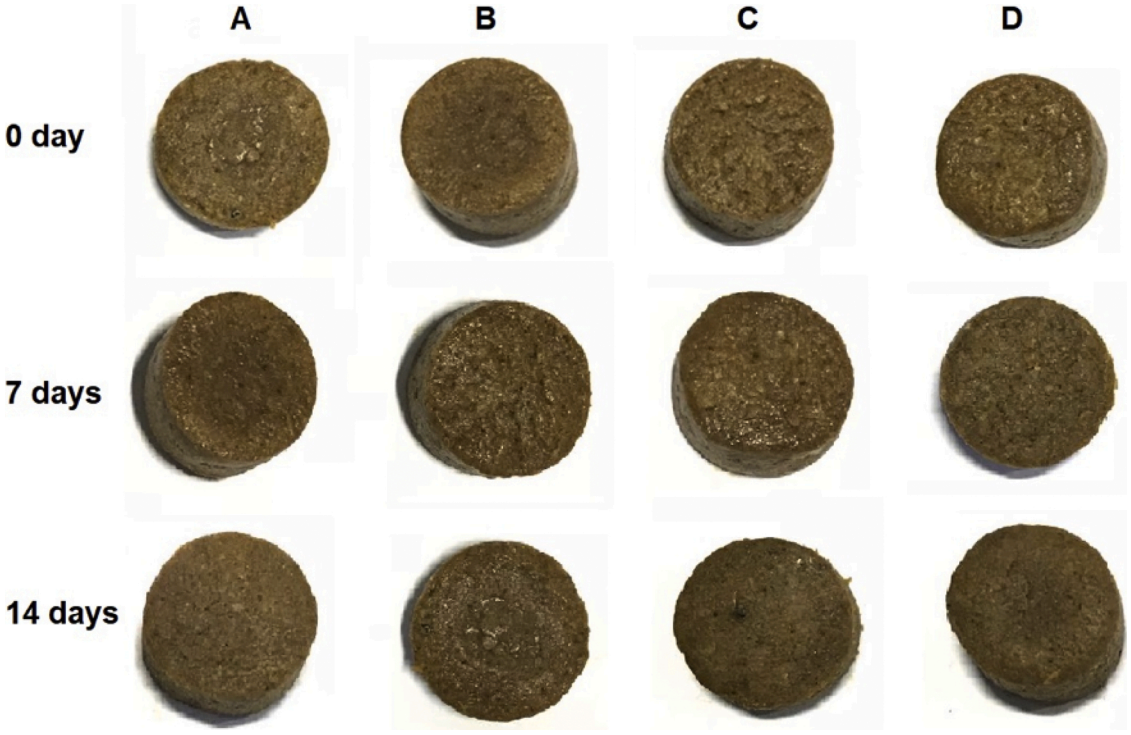

Fig. 2. Appearance of *terasi* product during Fermentation. Time - A: control without inoculation, B: inoculated with *L. plantarum* SB7, C: inoculated with *B. amyloliquifaciens* BC9, D: inoculated with *L. plantarum* SB7 and *B. amyloliquifaciens* BC9.

Table 2
Proximate component of *terasi*. A: control without inoculation, B: inoculated with *L. plantarum* SB7, C: inoculated with *B. amyloliquifaciens* BC9, D: inoculated with *L. plantarum* SB7 and *B. amyloliquifaciens* BC9.

Sample	Fermentation length	A	B	C	D
Water (%)	0 day	29.35 ± 1.12^{a}	28.83 ± 2.32^{a}	29.11 ± 3.12^{a}	26.68 ± 2.19^{a}
	1 week	28.59 ± 3.10^{a}	28.34 ± 3.02^{a}	28.44 ± 1.72^{a}	27.75 ± 1.72^{a}
	2 week	25.77 ± 1.15^{a}	25.5 ± 1.54^{a}	27.4 ± 1.66^{a}	27.06 ± 1.92^{a}
Ash (%)	0 day	1.30 ± 0.21^{a}	1.23 ± 0.32^{a}	1.25 ± 0.82^{a}	1.20 ± 0.33^{a}
	1 week	1.34 ± 0.18^{a}	1.30 ± 0.31^{a}	1.31 ± 0.18^{a}	1.25 ± 0.55^{a}
	2 week	1.40 ± 0.27^{a}	1.36 ± 0.75^{a}	1.39 ± 0.50^{a}	1.31 ± 0.43^{a}
Fat (%)	0 day	4.27 ± 1.01^{a}	4.11 ± 0.78^{a}	4.08 ± 1.01^{a}	4.05 ± 1.11^{a}
	1 week	3.89 ± 0.31^{a}	3.62 ± 0.32^{a}	3.70 ± 1.02^{a}	3.52 ± 0.88^{a}
	2 week	3.45 ± 0.82^{a}	3.31 ± 0.76^{a}	$3.25 \pm 0.72b^{a}$	2.63 ± 0.99^{a}
Protein (%)	0 day	62.93 ± 1.16^{a}	63.66 ± 1.22^{a}	64.12 ± 1.44^{a}	63.68 ± 1.86^{a}
	1 week	62.93 ± 1.02^{a}	65.37 ± 1.87^{ab}	65.23 ± 0.78^{ab}	65.80 ± 1.12^{b}
	2 week	64.80 ± 0.87^{a}	65.37 ± 1.05^{a}	65.23 ± 0.72^{a}	65.80 ± 0.55^{a}

Mean ± SD from Independent triplicate measurements.
Means with different superscript within the same row are significantly different ($p < 0.05$).

observation days 0–14. The addition of bacterial inoculants did not noticeably affect the 14-day fermentation process. Enzyme activity increased extensively on day 7. On day 14, the protease enzyme content did not show a large difference among the treatments.

The addition of starter does not always correlate with an increase in protease activity. Research by Pongsetkul et al. (2018) showed that the

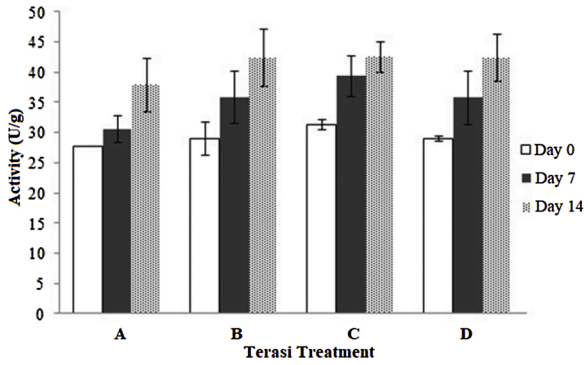

Fig. 3. Protease activity of *terasi* during fermentation. A: control without inoculation, B: inoculated with *L. plantarum* SB7, C: inoculated with *B. amyloliquifaciens* BC9, D: inoculated with *L. plantarum* SB7 and *B. amyloliquifaciens* BC9.

addition of inoculant *Bacillus subtilis* K-C3 did not result in a marked increase in proteolytic activity. On the 30th day of fermentation, the proteolytic activity had decreased. The similarities among treatments in pH value at the end of fermentation (Table 1) indicated that the dynamics of the microorganisms in the shrimp paste might have been similar among the treatments at the end of fermentation.

3.4. Amino acids

Treatment D yielded the highest glutamic acid level (44284.8 ± 231.22 mg/kg) (Table 3). This result was caused by the LAB, which are among the most glutamic acid-producing microorganisms in fermentation products. All treatments yielded largely stable amino acid contents over time. Among the amino acids, the four dominant ones were L-glutamic acid, L-aspartic acid, L-arginine, and L-leucine.

Glutamic acid and aspartic acid impart an essential taste to shrimp paste and most seafood-based products (Sarower et al., 2012). However, when glutamic acid is present in the form of a sodium salt, that is, monosodium glutamate, it confers a savory or umami taste to shrimp paste. Glutamic acid contains glutamic ion, which can stimulate several types of nerves on the human tongue. Glutamate present at high levels in shrimp paste has potential as a flavoring component, according to Kurihara (2009). In the present study, the highest levels of glutamic acid were found in the *terasi* prepared using the combination of *Lactobacillus plantarum* SB7 and *Bacillus amyloliquefaciens* BC9. Glutamic acid is commonly found in high-protein foods, such as wheat flour, soy, and corn. During the fermentation process, the breakdown of proteins into amino acids, one of which is glutamic acid, contributes to the umami or savory flavor of shrimp paste (Hajeb and Jinap, 2015).

3.5. Volatile compounds

The volatile compounds in the raw material (shrimp) are presented in Table 4. The *terasi* in treatments C and D each contained 13 types of volatile compounds. The control *terasi* (treatment A) contained 22 types of volatile compounds, whereas that in treatment B contained 23 types of volatile compounds. All treatments yielded volatile compounds from several different groups, namely, acids, aldehydes, alcohols, and amides.

The quality of shrimp paste is influenced by its aroma and volatile compounds, which are formed during the fermentation process (Udomsil et al., 2010; Pratama et al., 2018). Volatile compounds affect the flavor of the food product (Kosowska et al., 2017). Enzymatic reactions, fat autoxidation, microbial activity, heat-induced reactions, fermentation and storage all trigger the production of and changes in volatile compounds.

Volatile flavor compounds include alcohols, aldehydes and acids (Pratama et al., 2018). The degradation of fat and amino acids produces alcohol and aldehydes, which confer specific flavors and aromas to fermented products. Some aldehydes are produced by the oxidation of oleic and linoleic acids. The contents of volatile compounds from the aldehyde group in salted shrimp paste are low and likely result from fat oxidation during fermentation. Branched short-chain aldehydes or aromatic aldehydes are produced from amino acid deamination. A previous study demonstrated that shrimp contain omega-3 fatty acids, which are highly susceptible to fat oxidation, and thus contribute to the flavor of the product (Pongsetkul et al., 2015b).

3.6. Sensory analysis

Sensory analysis was applied to identify the treatment yielding the product most preferred by consumers. The factors investigated were taste, aroma, texture, appearance, and overall quality. The results of the sensory evaluation showed that the panelists preferred the shrimp paste products created with the addition of bacterial inoculants (Fig. 4).

The control treatment received the lowest scores for almost all the sensory attributes. Addition of the inoculant *L. plantarum* led to high scores for the texture, aroma, and taste parameters, whereas the addition of *B. amyloliquefaciens* resulted in a high score for appearance. Overall, the panelists preferred the shrimp paste with the combination of *L. plantarum* and *B. amyloliquefaciens*. The combination of the two bacteria led a greater glutamic acid content than the other treatments. Glutamic acid is a precursor of monosodium glutamate, which is known as the main umami factor (Kurihara, 2015; Bernas, 2017). The addition of inoculants influenced the consumers' preference for *terasi*. Starters addition resulted in not only better characteristics but also more acceptable *terasi*.

Table 3
Amino acid content on *terasi*. -A: control without Inoculation, B: iInoculated with *L. plantarum SB7*, C: Inoculated with *B. amyloliquifaciens* BC9, D: inoculated with *L. plantarum* SB7 and *B. amyloliquifaciens* BC9.

Amino Acids	Unit	A	B	C	D
L-Serine	mg / kg	11139.30 ± 125.12^{a}	10747.24 ± 236.12^{a}	10683.12 ± 192.03^{a}	11246.37 ± 234.72^{a}
L-Glutamic acid	mg / kg	41552.99 ± 112.3^{a}	39939.11 ± 241.02^{a}	41717.19 ± 218.06^{a}	44284.8 ± 231.22^{ab}
L-Phenylalanine	mg / kg	17161.22 ± 80.56^{a}	14557.48 ± 132.23^{a}	14305.18 ± 187.76^{a}	15811.53 ± 211.55^{a}
L-Isoleucine	mg / kg	12144.67 ± 176.02^{a}	11842.21 ± 341.12^{a}	12063.44 ± 152.23^{a}	12540.92 ± 171.09^{a}
L-Valine	mg / kg	12811.87 ± 281.87^{a}	12622.57 ± 123.13^{a}	12698.74 ± 221.22^{a}	13220.36 ± 213.21^{a}
L-Alanine	mg / kg	18021.66 ± 321.76^{a}	17287.4 ± 211.34^{a}	17906.67 ± 123.87^{a}	18822.24 ± 221.22^{a}
L-Arginine	mg / kg	23364.11 ± 231.10^{ab}	21259.68 ± 212.32^{a}	20949.34 ± 182.87^{a}	22808.54 ± 118.59^{a}
Glycine	mg / kg	18011.83 ± 121.34^{a}	17271.56 ± 128.87^{a}	17070.46 ± 233.34^{a}	18376.19 ± 249.10^{a}
L-Lysine	mg / kg	18726.64 ± 172.86^{a}	18554.14 ± 167.98^{a}	19658.47 ± 230.66^{a}	20023.86 ± 231.12^{a}
L-Aspartic acid	mg / kg	25312.98 ± 311.12^{a}	24239.75 ± 155.08^{a}	25608.31 ± 282.12^{a}	26996.3 ± 281.98^{a}
L-Leucine	mg / kg	21938.12 ± 212.12^{a}	21245.33 ± 128.87^{a}	21761.69 ± 112.75^{a}	22666.83 ± 187.87^{a}
L-Tyrosine	mg / kg	11884.36 ± 131.22^{a}	10141.85 ± 124.78^{a}	9971.55 ± 222.54^{a}	10953.18 ± 230.00^{a}
L-Proline	mg / kg	11240.33 ± 321.39^{a}	10830.43 ± 313.87^{a}	10918.23 ± 213.83^{a}	11738.84 ± 282.31^{a}
L-Threonine	mg / kg	12982.96 ± 132.21^{a}	12400.73 ± 210.32^{a}	12093.89 ± 219.82^{a}	12915.3 ± 172.99^{a}
L-Histidine	mg / kg	5106.28 ± 69.98^{ab}	4985.26 ± 121.66^{a}	4779.61 ± 112.65^{a}	4921.21 ± 131.09^{a}

Table 4
Volatile compounds from *terasi*. -A: control without Inoculation, B: inoculated with *L. plantarum* SB7, C: inoculated with *B. amyloliquifaciens* BC9, D: inoculated with *L. plantarum* SB7 and *B. amyloliquifaciens* BC9.

Volatile compound	Peak area (Abundance) x 10^6			
	A	B	C	D
Alcohols				
1-Hexacosanol	87.87	186.12	206.01	nd
1-Tetracosanol	21.22	35.73	45.55	132.22
3-Tetradecanol	nd	23.21	nd	13.87
1-Eicosanol	nd	203.12	nd	159.08
3-nonanol	nd	8.98	nd	nd
Eucalyptol	nd	nd	23.86	nd
Cholesterol	nd	nd	32.44	nd
Nerolidol Z and E	nd	nd	8.24	nd
Hexanol	nd	nd	21.33	nd
Aldehydes				
Octadecanal	nd	23.12	nd	nd
Pentanal	nd	49.98	nd	nd
3-Methylbutanal	nd	45.67	nd	nd
Ketones				
7-Tridecanone	nd	291.11	nd	nd
Estran-3-one	22.65	nd	nd	nd
2-Butanone	nd	nd	23.87	nd
Hydrocarbons				
Octadecane	89.76	117.13	98.65	99.01
1-Undecene	nd	34.22	nd	nd
Pentadecane	33.77	76.87	23.76	76.23
Tetradecane	23.67	29.99	71.54	78.32
1-Dodecene	nd	54.23	nd	nd
Tridecane	nd	8.98	nd	nd
Isooctane	52.22	nd	23.43	23.87
Undecane	23.65	nd	56.65	nd
Octane	nd	nd	54.66	nd
Decane	nd	nd	87.65	nd
2-Methylundecane	nd	nd	77.43	nd
Acids				
Dicholesteryl succinate	8.09	34.12	21.12	31.2
9-Octadecenoic Acid	66.65	74.57	nd	34.87
9.12.15-Octadecatrienoic Acid	nd	32.11	nd	26.87
N-containing compounds				
9-Octadecenamide	211.87	198.23	206.519	223.08
Oleoamide	nd	nd	131.74	nd
2,5Dimethylpyrazine	nd	64.31	nd	nd
Trimethylamine	201.12	213.31	245.76	239.09
S-containing compounds				
Silane	nd	31.22	18.20	nd
Dimethyl-disulfide	nd	37.44	42.23	nd
Others				
1.8-Cineole	nd	nd	19.28	nd
Phenol	67.87	nd	76.43	91.06

nd: not detected.

4. Conclusion

The results indicated that inoculation with the starters *L. plantarum* SB7 and *B. amyloliquefaciens* BC9 affected the physicochemical and sensory properties of the *terasi* and that the panelists preferred the starter-inoculated *terasi*. Hence, these strains have the potential to be used as starter inocula for *terasi* production.

Consent for publication

All authors reviewed and agreed to the final version of the manuscript. The authors agree to the contents and the contribution.

Consent to participate

All agree.

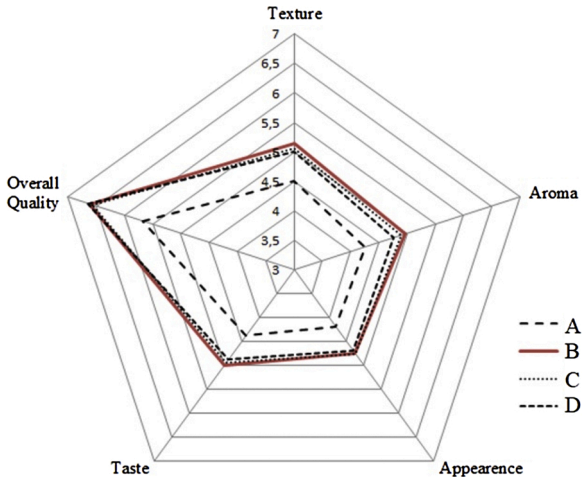

Fig. 4. Spider web for likeness score of *terasi*. - A: control without Inoculation, B: inoculated with *L. plantarum* SB7, C: inoculated with *B. amyloliquifaciens* BC9, D: inoculated with *L. plantarum* SB7 and *B. amyloliquifaciens* BC9.

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Ethics approval

Not applicable.

Availability of data and material

All data are provided in the result and are deposited in the figshare repository at https://doi.org/10.6084/m9.figshare.12197745.v1.

CRediT authorship contribution statement

Asep A. Prihanto: Conceptualisation, Methodology, Investigation, Validation, Formal analysis, Data curation, Writing - original draft, Writing - review & editing. **Rahmi Nurdiani:** Formal analysis, Visualisation, Writing - original draft, Writing - review & editing. **Yoga D. Jatmiko:** Methodology, Investigation, Validation, Writing - original draft, Writing - review & editing. **Muhamad Firdaus:** Formal analysis, Visualisation, Writing - original draft, Writing - review & editing. **Titis S. Kusuma:** Formal analysis, Visualisation, Writing - original draft.

Declaration of Competing Interest

The authors declare no commercial or financial conflict of interest.

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