



Research Article

Effect of different coconut sugar concentrations and fermentation times on the physicochemical and sensorial characteristics of shrimp paste “*Terasi*”

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Article Information

Received: 16 February 2023

Revised: 29 March 2023

Accepted: 28 April 2023

Academic Editor

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Keywords

Acetes sp., shrimp paste, coconut sugar, fermentation time, physicochemical and sensorial characteristics.

Abstract

Physicochemical and sensorial characteristics of shrimp paste *Terasi* as affected by different concentrations of coconut sugar (CS) and fermentation times were investigated. Shrimp paste was produced using CS at different concentrations (0%; 7.5%; 10% and 12.5%) and for varying times of fermentation (0, 15, 30 and 45 days). The lower concentration of CS showed the higher lightness of *Terasi*. The lowest a^* and b^* -value were observed in *Terasi* added with 7.5% CS fermented for 15 days (p -values < 0.05). Lower pH was noticed in *Terasi* when was fermented for 45 days at all concentrations of CS (p -values < 0.05). Moisture content increased along with the concentration of CS when fermentation time was performed for 15 days (p -values < 0.05). The increment of total sugar was noticed when CS concentration added at higher concentration, but total sugar decreased when fermentation time was lengthened at all concentrations (p -values < 0.05). The lower protein content was observed by *Terasi* added with higher concentration of CS. Concentrations of CS and fermentation times had different impacts on the organoleptic of *Terasi* (p -values < 0.05). The lower appearance and odor were denoted when *Terasi* was fermented for 45 days (p -values < 0.05). No differences on appearance and odor of *Terasi* were noticed when *Terasi* was fermented for 15 and 30 days at all concentrations of CS (p -values > 0.05). *Terasi* added with 7.5% CS and fermented for 30 days showed a higher organoleptic value in all specification compared to other treatments. Thus, *Terasi* added with CS at proper level and fermented for optimum time improved physicochemical and sensorial properties of resulted *Terasi*.

1. Introduction

Shrimp paste *Terasi* is a fermented fish product from Indonesia that has a typical odor and taste. Small type shrimp (*Acetes sp.*) is commonly used as the raw material for *Terasi*. However, fish or mixture of fish and shrimps are also used for *Terasi* production. Fresh shrimp (*Acetes sp.*) contains moisture (83.55%), crude protein (12.26%), fat (0.60%) and ash (2.24%) [1]. Balange *et al.* [2] reported sun-dried *Acetes sp.* contained moisture, crude protein, crude fat and ash

about 19, 48.29, 3.62, and 16.05%, respectively. Shrimp paste processing technology is low cost and simple, which commonly produces from combination of salting, drying and fermentation [3]. As generally in the food industry, salt in shrimp paste processing is used as preservative. However, in several regions in Indonesia, sugar can be used together with salt to improve the quality of *Terasi*.

Coconut sugar, commonly called brown sugar, is one of the sweetener which is generated from coconut sap. Coconut sugar contains sucrose, fructose and glucose of 74.68, 1.9 and 3.34%, respectively [4]. In the fermentation process, sugar addition can be used as energy (nutritional) source for lactic acid bacteria [5]. Rianingsih *et al.* [6] reported that sucrose addition had no effect on water activity and total of lactic acid bacteria but increased the panelist preference of shrimp paste. Muzaddadi dan Mahanta [7] reported that the length of fermentation, salt and sugar concentration affected on characteristics of the fish fermented product (*Shidal*) produced in Northeast India. Sarofa *et al.* [8] showed that salt concentrations and length of fermentation had effects on moisture content, protein content, texture, water activity and total plate count.

Sumardianto *et al.* [5] reported that shrimp paste *Terasi* added with different sugar concentrations and fermented for 7 days had different effects on their chemical and physical characteristics. However, no difference in the total count of lactic acid bacteria was observed among the samples. This might be due to the short fermentation time used. Sumardianto *et al.* [9] reported that the time of fermentation for 60 days resulted in shrimp paste *Terasi* with the best characteristics. Therefore, sugar addition might decrease the time of fermentation. Zou *et al.* [10] proved that the brown sugar addition can effectively increase the activities of microorganisms such as *Lactobacillus* and *Debaryomyces*, with more enriched sample due to the changes of microbial community, and accelerated microbial metabolism to produce more free acid in fermented vegetables of Yibin Yacai. Hence, the time of fermentation in this study was shortened (15, 30 dan 45 days). This study aimed to elucidate the effect of coconut sugar concentration and time of fermentation on the physical, chemical and sensorial characteristics of *Terasi*.

2. Materials and methods

2.1. Materials and chemicals

Dried salted shrimp with moisture content of 20% was obtained from the central of *Terasi* processing in Tambak Lorok Semarang. Salt and coconut sugar were purchased in the traditional market of Banyumanik Semarang Indonesia. Chemicals used for salt, sugar total and protein content analyses were H_2SO_4 , NaOH, H_3BO_4 , HCl, Kjeldal tablet, K_2CrO_4 , and $AgNO_3$

(Sigma-Aldrich Chemical Co., St. Louis, MO, USA).

2.2. Methods

2.2.1. Preparation of shrimp paste "*Terasi*"

Dried shrimp was washed using tap water to remove the dirt and filth. Cleaned shrimp was mixed with 5% salt (w/w). Different coconut sugar concentrations (0, 7.5, 10 and 12.5%) were added to the mixture and were ground gradually using grinder. Water (5%, v/w) was slowly added during grinding to avoid the agglomeration. The resulting doughs were put in a traditional drying tray made from bamboo which is called "*widig*" and were dried for 2 h in the sunlight. Every 30 min, the doughs were stirred to obtain totally dried dough. The dried doughs were re-ground and re-dried for 2 h. The third grinding was done before they were kept in the closed basin for 48 h. Then, the doughs were shaped into a silinder shaper with diameter of 3 cm and a length of 10 cm (250 g). The shaped doughs were subsequently dried for 2 days in the sunlight. The dried shaped doughs were wrapped with polyethylene plastic, kept in a closed container and fermented for different times (15, 30 and 45 days).

Terasi was then added with 0% coconut sugar and fermented for 15, 30 and 45 days were referred to as "*S0T15*", "*S0T30*" and "*S0T45*", respectively. *Terasi* added with 7.5% coconut sugar and fermented for 15, 30 and 45 days were referred as "*S7.5T15*", "*S7.5T30*" and "*S7.5T45*", respectively. Then, *Terasi* added with 10% coconut sugar and fermented for 15, 30 and 45 days were referred to as "*S10T15*", "*S10T30*" and "*S10T45*", respectively. Furthermore, *Terasi* added with 12.5% coconut sugar and fermented for 15, 30 and 45 days were referred to as "*S12.5T15*", "*S12.5T30*" and "*S12.5T45*", respectively. All *Terasi* samples were analysed for color, pH, moisture, salt, total sugar, protein content and organoleptic properties.

2.2.2. Analyses

2.2.2.1. Color

The color was determined as per the method of Kortei *et al.* [11] using chromameter (Hunterlab ColorFlex EZ spectrophotometer, Virginia, US). Color of *Terasi* was analyzed based on lightness (L^*), redness/greenness (a^*) and yellowness/blueness (b^*). White and black color were used for calibration in chromameter.

2.2.2.2. pH

Determination of pH was done using pH meter

(Hanna Instruments, Woonsocket, Rhode Island). Sample (5 g) was added with 10 mL of distilled water in a glass beaker and homogenized. The probe of pH meter was dipped in the homogenized sample and the pH was recorded [12].

2.2.2.3. Protein and moisture content.

Kjeldahl method was used for protein analysis and gravimetry using oven was done for moisture content analysis [13].

2.2.2.4. Salt content

The salt content was analyzed using Mohr titration method as described by Binici and Kaya [14]. The sample (5 g) was heated at 600°C for 6 h to obtain the ash. The ash was placed in erlenmeyer flask and was mixed with distilled water up to 250 mL. Further, 1 mL of potassium chromate (5%) as an indicator was added to the mixture. The mixture sample was titrated using 0,1 M AgNO₃. The titration was terminated when the first brick red was achieved. The volume of titration was recorded and salt content was calculated using the following formula:

$$\% \text{ Salt (NaCl)} = \frac{T \times M \times 5,84}{W}$$

T = titration volume; M = molarity of AgNO₃; W = weight of sample

2.2.2.5. Total sugar

Total sugar was quantified as per the method by Lam et al. [15]. The standard curve was prepared using D-glucose at concentrations of 0; 10; 20; 30; 40 dan 60 mg/100 mL. Each standard (1 mL) was added with 1.0 mL of 5% phenol and 1.0 mL of distilled water and mixed for 1 minute. Further, 5.0 mL of concentrated H₂SO₄ was then added and shaken for 3 minutes. The resulting solution was waited to precipitate for 30 minutes and cooled with water for 20 minutes before being measured at 940 nm by Ultraviolet-visible spectrophotometry (UV-Vis).

Terasi sample was ground and further extracted by ethanol at a ratio of 1:2 at the room temperature. The extract was filtered by filter paper. A Rotary evaporator was used for solvent removal of the resulting filtrate. The resulting extract (0.25 g) was dissolved to make 100 mL using distilled water. The diluted sample was prepared in the same method as the standard solution before being measured using

UV-vis spectrophotometer at the wavelength at 940 nm. The blank sample was prepared in the same procedure.

2.2.2.6. Organoleptic value of *Terasi*

The organoleptic test of *Terasi* was performed according to Nation Standardization of Indonesia No. 2716-2016 [16]. The organoleptic test was done by 25 semi-trained panelists including: appearance, odor, taste, texture and fungi.

2.3. Experimental design and data analysis

Experimental design in this study was Factorial Completely Randomized Design (FCRD). The experiment was performed in triplicate. Data were analyzed by ANOVA and continued by the Duncan's multiple range tests for determination of the significant differences (p-values < 0.05). Organoleptic data were analyzed by *Kruskal-Wallis* method and continued by *multiple comparissons* for the means differences test. Statistical analysis was done using the Statistical Package for Social Science (SPSS 22.0 for Windows, SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1. Color

The color of shrimp paste *Terasi* added with coconut sugar (CS) at different concentrations and fermented at different times is shown in Table 1. Different concentrations and fermentation times had different effects on lightness (*L**), redness/greenness (*a**) and yellowness/blueness (*b**) of *Terasi* (p-values < 0.05). The lower concentration of CS showed the higher *L**-value of *Terasi*. The highest *L**-value was achieved for *Terasi* added with 0% CS and fermented for 30 days (S0T45). Meanwhile, a lower *L**-value was observed for *Terasi* added with 10% CS and fermented for 45 days (S10T45). However, no difference in *L**-value among S10T45, S10T15, S7.5T30 and S12.5T15 samples (p-values > 0.05). A higher *a**-value was found in S7.5T30 sample, but no differences *a**-value among S7.5T30, S0T15 and S0T45 samples (p-values > 0.05). S7.5T15 sample showed the lowest *a**-value, however, no difference of *a**-value was found among S7.5T15, S10T15, S12.5T30 and S12.5T45 samples (p-values > 0.05). The highest *b**-value was observed in S7.5T30 sample, but no difference in *b**-value was found between S7.5T30 and S0T45 (p-values > 0.05). S7.5T15 sample showed the lowest *b**-value compared to other samples (p-values < 0.05).

Table 1. Color of shrimp paste “*Terasi*” added with sugar at different levels and fermented for different times

Samples	<i>L*</i>	<i>a*</i>	<i>b*</i>
S0T15	48.12 ± 0.52 c	5.27 ± 0.36 a	3.51 ± 0.39 cde
S0T30	53.53 ± 1.13 a	3.79 ± 0.09 d	4.66 ± 0.25 b
S0T45	49.50 ± 0.35 b	5.27 ± 0.03 a	5.43 ± 0.06 a
S7.5T15	45.23 ± 0.91 de	3.16 ± 0.04 e	2.97 ± 0.18 e
S7.5T30	42.20 ± 0.34 g	5.58 ± 0.26 a	5.60 ± 0.13 a
S7.5T45	44.59 ± 0.80 e	4.67 ± 0.25 bc	4.74 ± 0.35 b
S10T15	42.46 ± 0.24 fg	3.52 ± 0.18 de	3.26 ± 0.15 d
S10T30	43.43 ± 0.26 f	4.79 ± 0.22 b	4.58 ± 0.37 b
S10T45	41.70 ± 0.14 g	3.69 ± 0.25 d	4.47 ± 0.32 b
S12.5T15	42.73 ± 0.31 fg	4.32 ± 0.12 c	3.69 ± 0.11 cd
S12.5T30	44.44 ± 0.44 e	3.49 ± 0.15 de	4.78 ± 0.25 b
S12.5T45	46.04 ± 0.57 d	3.40 ± 0.31 de	3.79 ± 0.14 c

Values are presented as mean ± SD (n=3). Different lowercase letters in the same column indicate significant differences (P < 0.05). S0T15; S0T30 and S0T45: *Terasi* without sugar and fermented for 15, 30 and 45 days, respectively. S7.5T15; S7.5T30 and S7.5T45: *Terasi* added with sugar 7.5% and fermented for 15, 30 and 45 days, respectively. S10T15; S10T30 and S10T45: *Terasi* added with sugar 10% and fermented for 15, 30 and 45 days, respectively. S12.5T15; S12.5T30 and S12.5T45: *Terasi* added with sugar 12.5% and fermented for 15, 30 and 45 days, respectively.

Lightness (*L**) is associated with the measurement of luminosity between black and white where each colour can be reflected as the greyscale equivalency [17]. The lower *L** -value of *Terasi* added with CS compared to control (without CS) might be due to the dark color of coconut sugar (CS) with low *L**-value resulting in low lightness. Suseno *et al.* [18] reported coconut sugar showed dark brown color with *L**-value of 32.68. Brown color absorbs light more than yellow color resulting in lower *L**-value. Positive *a**-value noticed in all samples showed the redness color of *Terasi* with or without CS which was fermented different times. Redness of *Terasi* is more likely due to astaxanthin which was released during fermentation as the effect of autolysis resulting in the release of carotenoid from carotenoprotein [19]. Astaxanthin is a carotenoid pigment with dark-red color, mainly found in the marine world of algae and aquatic animals including shrimp, trout, salmon, red sea bream, and lobster [20]. The lower *a**-value of *Terasi* added with CS might be due to the dilution effect of CS addition. The longer fermentation the lower *a**-value might be due to the degradation of astaxanthin at some level. Zahrah *et al.* [21] reported that *a**-value

of *Terasi* decreased for 4 weeks of storage due to the instability of astaxanthin. All of *Terasi* samples had positive *b**-value which showed yellowness color. Concentration seemed to have no effect on *b**-value (p-values >0.05). Meanwhile, fermentation time showed different impact on *Terasi* with or without CS (p-values <0.05). Fermentation time tended to increase *b**-value of *Terasi* without CS. However, *Terasi* with CS increased in *b**-value when was fermented for 30 days and then it decreased after fermented for 45 days. The increase of *b**-value during fermentation might be due to the changes of astaxanthin and Maillard Reaction Products (MRPs) content of *Terasi* [22]. During fermentation, lipid oxidation led to browning mediated by Maillard reaction and its oxidation products, ketone and carbonyl groups of aldehydes, could react with amino groups of peptides or free amino acids yielded during hydrolysis, resulting in yellow or brown color development [23]. Prolonged fermentation time up to 45 days slightly decreased *b**-value of *Terasi* added with CS might be due to astaxanthin /carotenoids degradation. Kleekayai *et al.* [24] reported that the degradation of carotenoids was noticed in salt-fermented shrimp sauce during prolonged fermentation.

3.2. pH

pH value of *Terasi* added with CS at different concentrations and fermented for different times is displayed in Table 2. *Terasi* added with CS at different concentrations and fermentation times had a range pH value of 6.23-7.03 (Table 2). No interaction between CS concentration and time of fermentation on pH of *Terasi* (p-values > 0.05). Concentration of CS had no effect on pH *Terasi* (p-values > 0.05). However, the time of fermentation had different effect on pH of *Terasi* (p-values < 0.05). *Terasi* fermented for 45 days showed lower pH value compared to those fermented for 15 and 30 days (p-values < 0.05). Nevertheless, no difference on pH was observed between *Terasi* fermented for 15 days and those fermented for 30 days. No differences in pH among *Terasi* added with CS at different concentrations showed that the level of CS gave no impact on pH. Zhang *et al.* [25] reported that the type of sugar had a significant effect on pH, meanwhile the concentration and their interaction did not effect on pH of fermented turi-milk. Glucose addition resulted in lower pH of the fermented product than sucrose addition, showing that lactic

Table 2. pH, moisture, protein, salt, and total sugars content of shrimp paste “*Terasi*” added with sugar at different levels and fermented for different times

Samples	pH	Moisture (%)	Protein (%)	Salt (%)	Total sugars (%)
S0T15	6.97 ± 0.06 a	32.34 ± 0.74 f	31.88 ± 0.70 d	22.08 ± 0.71 d	5.64 ± 0.44 h
S0T30	7.03 ± 0.06 a	30.69 ± 0.67 g	33.64 ± 0.15 b	23.49 ± 0.86 c	5.94 ± 0.57 g
S0T45	6.37 ± 0.25 b	32.78 ± 0.22 ef	36.41 ± 0.26 a	26.88 ± 0.38 a	1.22 ± 0.11 g
S7.5T15	6.97 ± 0.06 a	33.77 ± 0.32 cd	30.69 ± 0.18 e	17.85 ± 0.04 e	12.40 ± 0.54 d
S7.5T30	6.97 ± 0.06 a	33.39 ± 0.14 de	32.49 ± 0.23 c	21.86 ± 0.62 d	11.28 ± 0.83 e
S7.5T45	6.23 ± 0.15 b	34.50 ± 0.11 c	32.93 ± 0.57 c	25.74 ± 0.44 b	7.36 ± 0.34 f
S10T15	6.93 ± 0.06 a	35.73 ± 0.71 b	29.23 ± 0.12 g	18.70 ± 0.25 e	14.62 ± 0.43 b
S10T30	6.90 ± 0.00 a	32.61 ± 0.21 f	31.33 ± 0.03 d	21.68 ± 0.15 d	13.60 ± 0.33 c
S10T45	6.50 ± 0.10 b	31.34 ± 0.18 g	29.38 ± 0.36 g	24.84 ± 0.59 b	10.60 ± 0.02 e
S12.5T15	7.00 ± 0.00 a	39.58 ± 0.52 a	28.53 ± 0.14 h	18.30 ± 0.74 e	15.98 ± 0.86 a
S12.5T30	6.90 ± 0.00 a	32.46 ± 0.22 f	30.09 ± 0.35 f	21.94 ± 0.33 d	14.87 ± 0.50 b
S12.5T45	6.50 ± 0.26 b	34.41 ± 0.18 c	28.50 ± 0.10 h	23.57 ± 0.8 c	12.57 ± 0.33 d

Values are presented as mean ± SD (n = 3). Different lowercase letters in the same column indicate significant differences (P < 0.05). S0T15; S0T30 and S0T45: *Terasi* without sugar and fermented for 15, 30 and 45 days, respectively. S7.5T15; S7.5T30 and S7.5T45: *Terasi* added with sugar 7.5% and fermented for 15, 30 and 45 days, respectively. S10T15; S10T30 and S10T45: *Terasi* added with sugar 10% and fermented for 15, 30 and 45 days, respectively. S12.5T15; S12.5T30 and S12.5T45: *Terasi* added with sugar 12.5% and fermented for 15, 30 and 45 days, respectively.

acid bacteria are more likely to use glucose than sucrose for yielding lactic acid [25]. In this study, sugar type used was coconut sugar which contained high sucrose (86.86%) with low glucose (4.64%) [4], hence the resulting pH of *Terasi* was quite high. Furthermore, the slightly high pH of *Terasi* (6.23-7.03) might be due to volatile basic compounds and other degradation products released during fermentation [26]. Lv *et al.* [27] reported that shrimp paste shrimp from the Chinese Jinzhou region had pH of around 6.61-7.43 depending on fermentation time.

A slightly lower pH was observed when prolonged fermentation was performed due to various organic acids produced during the fermentation process such as acetic acid, lactic acid, and propionic acid [28]. The benefit of a low pH environment in *Terasi* is the preservation effect through inhibition of spoilage bacteria and pathogens growth. However, pH alteration may occur depending on the methods used during production and the time of fermentation [27, 29].

3.3. Moisture content

The different concentrations of CS and time of fermentation showed varying effects on the moisture content of *Terasi* (p-values < 0.05). The moisture content of *Terasi* added with CS at different concentrations and fermented for different times

varied from 30.69% to 39.58% (Table 2). Moisture content of *Terasi* increased along with the concentration of CS when fermentation time was performed for 15 days (p-values < 0.05). The highest moisture content was observed for S12.5T15 sample (p-values < 0.05). Meanwhile, the lowest moisture content was shown by S0T30 sample (p-values < 0.05). However, no difference in moisture content was noticed between S0T30 and S10T45 samples (p-values > 0.05).

Moisture contents of *Terasi* in this study were slightly similar with the moisture content of *Terasi* produced at different places in Indonesia (24.14-50.83%) [3] and *Kapi*, fermented shrimp paste produced in Thailand (33.95-52.19%) [30]. All of *Terasi* in this study met the National Standard of Indonesia for *Terasi* which should have moisture content of around 30-50% [16]. The small increase of moisture content with the increase of sugar concentration might be due to the moisture absorption capacity of CS. Sucrose in the CS can absorb water from the air depending on the relative humidity of the environment [31]. Nurhadi *et al.* [32] reported that the monolayer moisture content of coconut sugar indicates the amount of absorbed water to specific sites at the food surface. The lower moisture content of *Terasi* after extended fermentation was more likely due to the use of water by microorganisms for their metabolism [33].

3.4. Protein content

The protein content of *Terasi* added with CS at different concentrations and fermented for different times is shown in Table 2. The concentration of CS and time of fermentation gave different effects on the protein content of *Terasi* (p-values < 0.05). The highest protein content (36.41%) was found in S0T45 sample (p-values < 0.05). Meanwhile, the lowest protein content (28.52%) was observed for S12.5T15. However, no difference in protein content was noticed between S12.5T15 and S12.5T45 samples (p-values > 0.05).

Protein content *Terasi* with or without CS in this study was slightly similar with *Terasi* generated by different producers at varying places which had protein content around 23.68-44.37% [3]. The higher protein content of *Terasi* without CS might be due to the higher protein content of dried shrimp used in this study. Sun-dried *Acetes* sp contained protein of around 48.29% with moisture content of 19% [2]. Meanwhile, the decrease of protein content of *Terasi* with the increase of CS concentration is more likely due to the dilution effect of CS. The increase of CS concentration resulted in the decrease proportion of protein content in *Terasi*. The longer fermentation time up to 30 days showed the higher protein content of *Terasi* possibly due to the decrease of moisture content during fermentation, hence protein content increased proportionally. However, the decreases of protein content were observed for all *Terasi* added with CS when fermentation was performed for 45 days. This might be due to protein degradation by microorganisms during fermentation, resulting in the slightly decrease of protein content. Protein degradation contributes the release of free amino acids throughout *Terasi* production yielding specific flavour and aroma. The decrease or fluctuation of protein might be from the utilization of amino acids by microorganisms for their growth [34].

3.5. Salt Content

The concentration of CS and the length of fermentations showed different effects on the salts content of *Terasi* (p-values < 0.05). Salt content of *Terasi* added with CS at different concentrations and fermented for different times varied from 17.85%-26.88% (Table 2). The higher salt content was found when *Terasi* was fermented for longer time at all concentrations of CS (p-values < 0.05). Salt content of *Terasi* decreased when CS was added (p-values < 0.05).

However, no difference in salt content was observed among *Terasi* added with CS at all concentration when they were fermented for similar time. The highest salt content was found in S0T45 (p-values < 0.05). S7.5T15 showed the lowest salt content. However, no difference in salt content among S7.5T15, S10T15 and S12.5T15 were noticed (p-values > 0.05).

Terasi in this study used dried salted *Acetes* around 20-25% and 5% coarse salt was added during *Terasi* production, hence high salt content was observed in all samples. The higher salt content along with the longer fermentation might be due to the lower of other components such as moisture and total sugar content, hence salt content increased proportionally. The salt content of this study was slightly similar with *Terasi* produced at different places in Indonesia (2.41-22.9%) which was processed with coarse salt 0-33% [3]. Lower salt concentration was found in *Kapi*, fermented shrimp paste from Thailand which contained salt around 7.00 -10.85 % [30].

3.6. Total sugar

The total sugar of *Terasi* added with varying concentrations of CS and fermented at different times is shown in Table 2. The higher concentration of CS, the higher total sugar was noticed (p-values < 0.05). At similar concentrations, the longer the fermentation time, the lower the total sugar was observed (p-values < 0.05). The lowest total sugar was noticed for S0T45 sample (p-values < 0.05). Meanwhile, the highest total sugar was found in *Terasi* added with highest concentration of CS (12.5%) and fermented for shortest time (15 days) (S12.5T15). The total sugar observed for *Terasi* without CS was possibly come from the carbohydrate content of *acetes* shrimp as raw material. Sumardianto et al. (2019) reported that *Terasi* without sugar addition and fermented for 7 days contained higher total sugar (8.97%) which was come from the *Acetes* sp as raw material. This might be due to the longer time of fermentation in this study, hence total sugar was slightly lower. *Terasi* with CS at different concentrations and fermented for different times had total sugar from 7.36-15.98%. The higher concentration of CS yielded *Terasi* with higher total sugar. The longer fermentation produced *Terasi* with lower total sugar. The increase of total sugar of *Terasi* along with the rise of CS addition showed that CS contains high total sugars such as sucrose (86.86%), glucose (4.64%) and fructose (3.70%) [4].

Table 3. Organoleptic value of shrimp paste “*Terasi*” added with sugar at different levels and fermented for different times

Samples	Appearance	Odour	Taste	Texture	Fungi	Overall
S0T15	8.03 ± 1.27 a	7.97 ± 1.02 a	6.93 ± 0.36 c	7.34 ± 1.32 c	9.00 ± 0.00 a	7.36 ± 0.79b
S0T30	8.31 ± 0.97 a	7.90 ± 1.01 a	7.29 ± 0.97 b	7.97 ± 1.02 bc	9.00 ± 0.00 a	7.47 ± 0.51b
S0T45	7.48 ± 0.74 b	6.45 ± 0.91 c	7.34 ± 1.60 b	8.31 ± 0.97 bc	9.00 ± 0.00 a	7.68 ± 0.20b
S7.5T15	8.03 ± 1.15 a	8.24 ± 0.99 a	7.21 ± 1.45 b	8.10 ± 1.01 ab	9.00 ± 0.00 a	8.12 ± 0.64a
S7.5T30	8.17 ± 1.00 a	8.03 ± 1.02 a	7.90 ± 1.01 a	8.24 ± 0.99 b	9.00 ± 0.00 a	8.27 ± 0.43a
S7.5T45	6.72 ± 1.58 b	7.14 ± 1.51 b	7.55 ± 1.40 b	8.45 ± 1.06 b	9.00 ± 0.00 a	7.37 ± 0.24b
S10T15	8.10 ± 1.01 a	7.69 ± 1.44 a	7.48 ± 1.27 b	8.24 ± 0.99 b	9.00 ± 0.00 a	8.10 ± 0.59a
S10T30	8.10 ± 1.01 a	7.69 ± 1.44 a	7.97 ± 1.02 a	7.83 ± 1.36 bc	9.00 ± 0.00 a	8.12 ± 0.52a
S10T45	6.72 ± 1.75 b	7.41 ± 1.55 ab	7.34 ± 1.32 b	8.52 ± 0.87 ab	9.00 ± 0.00 a	7.70 ± 0.33b
S12.5T15	7.76 ± 1.35 a	8.17 ± 1.00 a	7.07 ± 1.46 c	7.34 ± 1.42 c	9.00 ± 0.00 a	7.97 ± 0.36ab
S12.5T30	7.97 ± 1.02 a	7.90 ± 1.14 a	8.10 ± 1.01 a	8.03 ± 1.02 ab	9.00 ± 0.00 a	8.20 ± 0.45a
S12.5T45	6.79 ± 1.63 b	7.21 ± 1.54 b	7.28 ± 1.49 c	8.66 ± 0.77 a	9.00 ± 0.00 a	7.39 ± 0.28b

Values are presented as mean ± SD (n = 25). Different lowercase letters in the same column indicate significant differences (P < 0.05). S0T15; S0T30 and S0T45: *Terasi* without sugar and fermented for 15, 30 and 45 days, respectively. S7.5T15; S7.5T30 and S7.5T45: *Terasi* added with sugar 7.5% and fermented for 15, 30 and 45 days, respectively. S10T15; S10T30 and S10T45: *Terasi* added with sugar 10% and fermented for 15, 30 and 45 days, respectively. S12.5T15; S12.5T30 and S12.5T45: *Terasi* added with sugar 12.5% and fermented for 15, 30 and 45 days, respectively.

However, Total sugar decreased when fermentation time increased at all concentrations, which might be due to sugar utilization by lactic acid bacteria during fermentation [5].

3.7. Organoleptic value

The organoleptic value of *Terasi* with or without CS and fermented at different times is presented in Table 3. All *Terasi* in this study fulfilled Indonesia's National Standard of *Terasi* which has overall organoleptic value of at least 7 [5]. However, the concentration of CS and fermentation time had different effects on the appearance, odor, taste, texture and overall, of *Terasi* (p-values < 0.05). Further, no differences in fungi were noticed among all samples (p-values > 0.05). At all concentrations of CS, no differences in appearance and overall score of *Terasi* were found when they were fermented for 15 or 30 days (p-values > 0.05). The lowest appearance and overall score were noticed for *Terasi* fermented for 45 days at all concentrations (p-values < 0.05). No differences in odor were observed when *Terasi* was fermented for 15 or 30 days (p-values > 0.05), but a lower score was noted when *Terasi* was fermented for 45 days (p-values < 0.05). S0T45 sample showed the lowest odor score compared to all *Terasi* samples (p-values < 0.05). The lower score of taste was found in *Terasi* fermented for 15 days at all concentrations (p-values < 0.05). The higher taste score was noticed in *Terasi* fermented for 30 days compared to those fermented for 15 or 45 days. Fungi were not

detected in all samples, hence no differences in fungi scores were noted among all samples.

When fermentation was lengthened up to 45 days, the appearance of *Terasi* with or without CS slightly decreased as an effect of protein and sugar degradation resulting in undesirable color which might be from astaxanthin reduction [35]. The lowest score of odor in *Terasi* without CS and fermented for 45 days (S0T45) might be due to the decrease of desirable volatile compounds such as N-containing compounds (amines, pirazines, etc.) and the formation of undesirable volatile compounds such as S-containing compounds including dimethyl disulfide and dimethyl trisulfide [27]. Fermented for 30 days gave a better taste might in this period of fermentation generating more glutamic acid which give specific savory or *umami* taste of *Terasi* [32]. Sumardianto *et al.* [5] reported that *Terasi* with or without CS addition and fermented for 7 days contained glutamic acid as dominant amino acid. All of *Terasi* samples had solid and compact textures with the score of more than 7. However, more solid and compact texture observed for *Terasi* fermented for 30 days might be related to the moisture content. Fungi couldn't be detected in all samples more likely due to the preservation effect of salt and sugar which can prohibit the fungi growth. Overall, *Terasi* with or without CS and fermented at varying times in this study met the requirement for consumption as

Indonesian National Standard. However, CS addition tended to shorten fermentation time with higher organoleptic scores.

4. Conclusions

Coconut sugar (CS) concentration and fermentation time had a significant effect on color, moisture, protein, salt, and total sugar content (p-values < 0.05). The concentration of CS had no significant effect on pH (p-values > 0.05). but the length of fermentation gave varying impact on pH (p-values < 0.05). The lower concentration of CS showed the higher lightness of *Terasi*. The lowest a* and b*-value were observed in *Terasi* added with 7.5% CS fermented for 15 days (p-values < 0.05). Lower pH was noticed in *Terasi* when was fermented for 45 days at all concentrations of CS (p-values < 0.05). Protein and total sugar content decreased with the increase of fermentation time. The moisture content increased at the shorter fermentation time and then decreased at the longer fermentation time. Salt content increased when fermentation was performed for longer time. The lower appearance and odor were denoted when *Terasi* was fermented for 45 days (p-values < 0.05). *Terasi* added with 7.5% CS and fermented for 30 days showed a higher organoleptic value in all specifications compared to other treatments. Thus, *Terasi* added with CS at the proper level and fermented for optimum time improved the physicochemical and sensorial properties of *Terasi*.

Authors' contributions

Conceptualization, resources, funding acquisition, supervision, project administration, S.U.; Investigation, Methodology, formal analysis, software, data curation, writing – original draft preparation; I.W.; Validation, writing – review & editing, visualization, supervision, F.S.

Acknowledgement

Acknowledgement was conveyed to FPIK Universitas Diponegoro for funding the research.

Funding

FPIK Universitas Diponegoro was acknowledged for funding this research through “the Results-based Research Scheme” in the 2018 Fiscal year.

Availability of data and materials

All data will be made available on request according

to the journal policy.

Conflicts of interest

The authors state that they have no personal interests or financial that would impact the objectivity of the study presented in this work.

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