Supplementation of Torch Ginger (*Etlingera elatior*) Flowers Improves the Quality and Safety of Traditional Fermented Shrimp Paste

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Abstract. *Terasi,* a traditional fermented shrimp paste from Indonesia, is commonly made from salted planktonic shrimp (*Acetes japonicus*) undergoing spontaneous lactic acid fermentation. In spite of its broad use and appreciated distinctive flavor, consuming *terasi* could be injurious for human consumption due to the presence of toxic compounds that are related to its deterioration and quality decrease, such as the allergenic histamine and probably carcinogenic acrylamide. These compounds are formed during fermentation of *terasi* due to a plethora of chemical reactions and microbial activities. This study aimed to improve the quality and safety of shrimp paste by incorporating during its fermentation torch ginger (*Etlingera elatior*) flowers, locally known as *bunga kecombrang*, that are rich in antioxidants and antimicrobial compounds. These flowers are widely utilized in Indonesian cuisine. The supplementation of torch ginger flowers (5%(w/w) and 10% (w/w)) significantly reduced microbial growth, lipid peroxidation, as well as the formation of histamine and acrylamide in *terasi* fermented over a period of 30 days. In addition, the supplementation of 10% torch ginger flowers improved the sensory acceptance of *terasi*. Therefore, this study suggests the potential of torch ginger flowers as an additional ingredient to improve the safety and quality of *terasi*.

1 Introduction

Terasi is an ethnic Indonesian fermented shrimp paste produced using salted crushed planktonic shrimp (*Acetes indicus*) as raw material [1]. Similar products are commonly found across other Southeast Asian countries, such as *belacan* in Malaysia, *kapi* in Thailand, *bagoong alamang* in the Philippines, and *mam tom* in Vietnam [2]. In Indonesian food culture and culinary practice, *terasi* is an essential flavor enhancer incorporated in a plethora of traditional dishes, including chili paste, soup, and salad [3].

Terasi exhibits a complex flavor due to the fermentation process involving microbial activities and a series of chemical reactions [4]. Lactic acid bacteria are mainly responsible

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for flavor development owing to the production of organic acids and other flavor components [5]. Despite being essential for flavor development in *terasi*, many chemical reactions often lead to reduction in its quality and safety, such as lipid oxidation and the formation of toxic compounds including acrylamide and histamine [6]. Acrylamide is a probable carcinogen [7] while histamine can evoke allergic reactions in humans known as scombroid poisoning [8]. Therefore, it is essential to seek strategies to improve the quality and safety of *terasi* through the inhibition of lipid peroxidation as well as the formation of toxic compounds.

Torch ginger (*Etlingera elatior*) or locally known as *bunga kecombrang* is a species of ginger plant belonging to the family Zingiberaceae, native to Southeast Asia and New Guinea [9]. Its flowers are an important ingredient in Southeast Asian culinary practice and traditional medicine [9]. Some major bioactive compounds present in the flower of torch ginger are chlorogenic acid, flavonoids (quercitrin, isoquercitrin, and catechin), α-pinene, caryophyllene, 1-dodecanol, dodecanoic acid, and dodecanal [10]. Torch ginger flowers have been reported to exhibit antioxidant and antimicrobial properties [11].

This study aimed to explore the possibility of improving the safety and quality of *terasi* by incorporating torch ginger flowers in the production process. Torch ginger flowers were mixed with fresh shrimp under two different concentrations (5% and 10%) prior to grinding and further processes. Total microorganisms, lipid peroxidation byproducts, acrylamide, and histamine present in *terasi* were analyzed at the beginning of fermentation (day 0) and on the 30th day of fermentation (day 30). In addition, an organoleptic analysis was carried out to analyze the consumer's acceptance towards *terasi* supplemented with torch ginger flowers.

2 Material and methods

2.1 Preparation of *terasi*

Terasi was traditionally prepared as previously described [6] with some modifications. The planktonic shrimp and torch ginger flowers were procured from a traditional market in Cirebon, West Java, Indonesia. Briefly, fresh shrimp underwent a blanching process in boiling water for 5 min, followed by draining and mixing with solar salt (15 g salt for every 100 g shrimp). The salted shrimp underwent a fermentation process by being placed in a sealed jar for 48 h at room temperature (25°C). Following this, finely chopped torch ginger flowers were added at two concentrations: 5% (w/w) and 10% (w/w), before the mixture was blended to achieve a uniform paste consistency. Subsequently, the paste was shaped into flattened balls manually (diameter 10 cm, thickness 2 cm), and dried using an oven (50°C, 4 h) to decrease the moisture content. The dried shrimp paste was then covered with banana leaves and left to ferment at room temperature (25°C) for a duration of 30 days.

2.2 Microbiological and chemical analysis

For the microbiological examination, *terasi* samples underwent serial tenfold dilution in peptone water supplemented with 10% NaCl before being spread onto agar plates. Total viable count was determined utilizing standard plate count agar containing 10% NaCl (pH 7.5), following the protocols outlined in the Bacteriological Analytical Manual (BAM) as detailed previously [12]. Incubation of all samples was conducted at 35°C for 5x24 h prior to counting.

The chemical analysis was done using commercial assay kits and spectrophotometry as previously described [6]. The examinations included thiobarbituric acid reactive substances

(TBARS), acrylamide, and histamine analysis in the *terasi* samples on day-0 and day-30 of fermentation. All the results were expressed as mg compound per kg dry sample.

2.3 Organoleptic analysis

Different sessions of hedonic rating analysis took place at five traditional markets in Jakarta, Indonesia on 29-30 April 2023. The analysis involved 139 untrained local household women aged 22-55 years old who previously claimed to consume *terasi* on regular basis in separate screening interview sessions. Briefly, each panelist was instructed to rate four attributes (color, aroma, texture, and overall characteristics) of *terasi* samples based on their personal preference using the hedonic scale of 1-9 (1 for strongly dislike and 9 for strongly like). Each session was held through a one-on-one interview session between a panelist and an interviewer.

2.4 Statistical analysis

All data (n≥3), reported as mean±SD in the figures, were analyzed using one-way Anova followed by Tukey's HSD post hoc test in case of significant difference ($p<0.05$). The software IBM SPSS Statistics 26 was used to perform statistical data analysis.

3 Results and discussion

The supplementation of torch ginger flowers inhibited the growth of microorganisms in *terasi* as shown in Fig.1A. Higher concentration of torch ginger flowers in *terasi* was associated with lower total microorganisms in *terasi* at day 30. This phenomenon could be due to the antimicrobial properties of torch ginger flowers [11]. Interestingly, the essential oil of torch ginger flower has been reported to exert strong antimicrobial properties against pathogenic bacteria including *Salmonella typhimurium* and *Staphylococcus aureus* [13], thus suggesting the potential of torch ginger flowers to improve the safety of *terasi*. However, the influence of torch ginger flowers on the growth of lactic acid bacteria and other beneficial microorganisms that are essential in the fermentation of *terasi* requires further analysis. The modulation of microbial ecosystem in fermented food products could have an important impact on the characteristics and chemical constituents of the final products [14]. Several dominant bacterial genera in *terasi* are *Tetragenococcus*, *Bacillus*, *Aloicoccus*, and *Lactobacillus* [15].

Fig. 1B-D demonstrates the concentration of lipid peroxidation byproducts, acrylamide, and histamine in *terasi*. The supplementation of torch ginger flowers led to a lower formation of these compounds in *terasi* during fermentation. The thiobarbituric acid reactive substances (TBARS) reflect the degree of lipid oxidation in food matrix [16]. The products of lipid oxidation, such as malondialdehyde (MDA), are strongly associated with rancidity and quality reduction in lipid-rich foods [17]. Histamine is derived from amino acid histidine in seafood and exposure to an excessive amount of oral histamine may lead to an allergy-resembling reactions in humans known as scombroid food poisoning [8]. According to the U.S. Food and Drugs Administration (FDA), seafood products containing 35 ppm or more histamine are considered as adulterated while the ones containing 200 ppm or more histamine are injurious to humans [18]. Acrylamide, a toxic compound classified as probably carcinogenic (Group 2A) according to the World Health Organization (WHO) [19], is likely to result from heat-catalyzed browning reaction between reducing sugars and amino acid asparagine during the drying process of *terasi* [6]. The tolerable daily intake of acrylamide is 2.6 µg/kg body weight [20]. In this study, the inhibition of formation of TBARS, histamine, and acrylamide during the fermentation of *terasi* could be associated with the inhibition of microbial growth as presented in Fig. 1A.

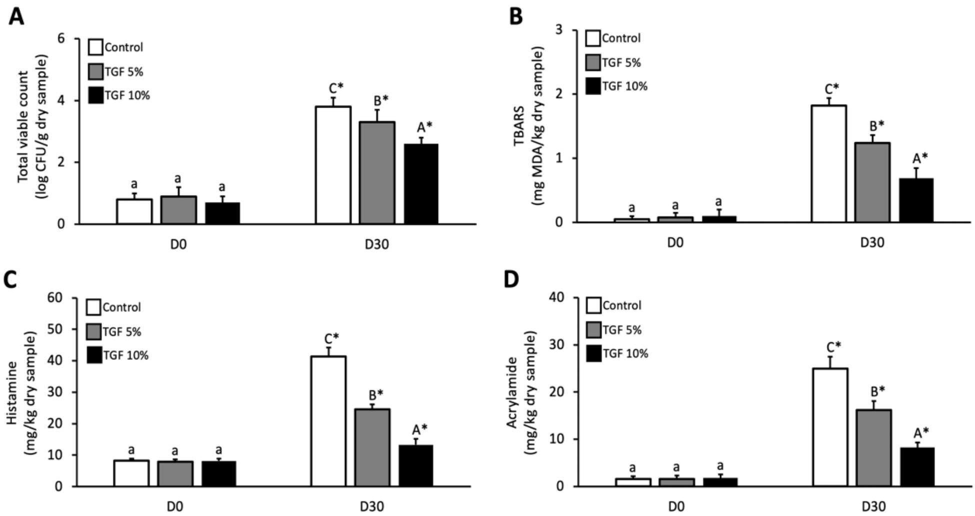

Fig. 1. Microbiological and chemical characteristics of *terasi* supplemented or not with torch ginger flowers (TGF) at the beginning of fermentation (D0) and day 30 (D30). A) Microbial load or total viable microorganisms, B) concentration of thiobarbituric acid reactive substances (TBARS), C) concentration of histamine, and D) concentration of acrylamide. Data (n=3) are expressed as mean±SD. Different lowercase and uppercase letters indicate significant difference among samples at D0 and D30 respectively (p<0.05). Asterisk signs (*) indicate significant difference between a sample at D0 and D30 (p<0.05). CFU: colony forming unit. MDA: malondialdehyde.

To investigate whether the supplementation of torch ginger flowers affected the organoleptic acceptance of *terasi*, a sensory testing was performed on *terasi* samples fermented for 30 days involving 139 household women in traditional markets as panelists. The results are presented in Fig. 2. The supplementation of 5% torch ginger flowers did not alter the acceptance towards the sensory properties of *terasi*. However, the supplementation of 10% torch ginger flowers improved the acceptance of *terasi* with regard to aroma and its overall characteristics.

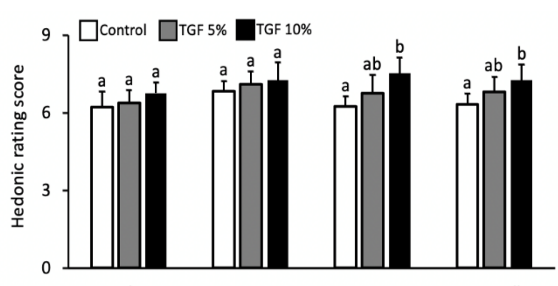

Fig. 2. Sensory acceptance of *terasi* supplemented or not with torch ginger flowers (TGF) following a 30-day fermentation. Data (n=139) are expressed as mean±SD. Different letters indicate significant difference among samples ($p<0.05$) regarding a sensory attribute.

4 Conclusions

To conclude, our findings suggest that the supplementation of torch ginger flowers could be opted for improving the quality and safety of fermented shrimp paste (*terasi*). In addition, the supplementation of torch ginger flowers also improved the sensory acceptance of *terasi*, particularly with regard to aroma and overall characteristics. Some suggestions for further studies would include the characterization of microorganisms and metabolomics of chemical compounds present in torch ginger flowers-supplemented *terasi*.

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