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# Terasi, exploring the Indonesian ethnic fermented shrimp paste

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**Abstract**

Terasi is an Indonesian traditional fermented shrimp paste commonly used as a condiment to enhance flavor in Indonesian cuisines. This product has distinctive sensory characteristics and is known by various names in Asian countries. The primary reaction that occurs during terasi fermentation is proteolysis by endogenous enzymes generated by microorganisms to produce taste and aroma compounds. This review elaborates on various aspects of terasi, including history, microbiology, fermentation process, nutritional properties, bioactivities, potential hazards, and the future, challenges, and prospects of terasi. Apart from limiting its nutritional value, the long-duration process and high salt content of terasi appear to prevent the formation of toxic biogenic amines. Therefore, this review article also discussed innovative bioprocesses such as low-salt fermentation and the use of novel starter cultures to speed up fermentation and produce terasi with better quality and safety for human consumption.

**Keywords** Fermentation, Flavor enhancer, Shrimp paste, Terasi, Traditional fermented food

## Introduction

Since ancient times, fermentation has been used to preserve food products, prolong the shelf life of foods, and improve their flavor and nutritional value [1]. Fermented shrimp products have been consumed since ancient times as the oldest condiments and have been produced all around the world [2]. As the world's largest archipelago, Indonesia has tremendous potential to generate vast quantities of fishery products. According to the Indonesian Ministry of Marine Affairs and Fisheries, Indonesia is the second largest producer of marine products in the world (24.85 million tons of marine products in 2022) [3]. However, around 55% of fishery products from Indonesia are still consumed fresh due to limitations on refrigerated storage and transportation facilities, so fishery products are also processed as dried, salted, smoked, or fermented products [4]. Particularly, planktonic fish or shrimp (called rebon) in Indonesia are salted and fermented to produce terasi. Terasi is commonly used in Indonesian cuisines as a flavor enhancer or incorporated into *sambal terasi*, a traditional Indonesian chili sauce [5].

Across Asian countries, related products of terasi are found with different names [6]. Their smell, color, and texture can vary depending on numerous factors, including specific ingredients, production methods, food culture, and consumer preferences, as well as regional climatic characteristics [7]. These fermented shrimp pastes are traditionally made by salting the shrimp, grinding them into a uniform mixture, sun drying, and fermentation for several weeks or months [8]. During the process of fermentation and prolonged maturation, a series of reactions take place, which include carbohydrate catabolisms, protein and lipid degradation, as well as Maillard and Stecker reactions and actions by microorganisms [9–12]. Typically, each

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of these biochemical and chemical transformations has distinct effects that contribute to the quality of the final product. Protein and lipid degradation would facilitate the formation of taste and flavor compounds, as well as nutrients that are more readily absorbed and digested [13]. All of these modifications contribute to the texture, flavor, and nutritional composition of the final product.

In general, the fermentation process of terasi is primarily driven by endogenous hydrolytic enzymes, particularly proteases, produced by microorganisms [14]. However, the long production process and high salt content of terasi necessitate multiple efforts to investigate accelerated fermentation methods and improve nutritional value, including the use of starter cultures and low-salt fermentation [7, 15, 16]. Furthermore, there is a growing interest in developing techniques for terasi production and its broader application. However, no review has systematically and comprehensively focused on terasi. In this regard, this review will focus to elaborate various aspects of terasi, including history, microbiology, production process, nutritional value, potential hazard, and bioactivities, as well as future challenges and prospects, which are also compared to other fermented shrimp pastes from another countries.

## History of terasi

Terasi is an indigenous fermented shrimp paste in Indonesia used to enhance the flavor of Indonesian cuisines. This condiment is in the form of a black or reddish brown paste and produced through a fermentation process (Fig. 1). Terasi has existed since the pre-colonial era, which predates the historical period of the Java-based kingdoms of Cirebon and Sundanese. Terasi was then popularized by Prince Walangsungsang, or Prince Cakrabuana, a founder of the Cirebon Kingdom (1430–1479) (Fig. 2). Terasi was the main commodity in the Cirebon Kingdom, used as a tribute to the Sunda Galuh Kingdom. This product is very admirable, so it is given the name "terasih". In Sundanese, "asih" means admire, and the prefix "ter" means the most. According to the manuscript of Carita Purwaka Caruban Bahari, the Cirebon Kingdom was attacked by Sunda Galuh Kingdom after they stopped sending terasi, which had become the main contributor to the popularity of Sunda cuisine at the time. Terasi was then developed in many regions of Indonesia, including Belitung, Toboali, Lombok, and Puger [17]. Terasi was also known by various other names in Asian countries, such as Malaysia *Belacan*, Thai *Kapi*, Philippines *Bagoong-alamang*, Korea *Saeu-jeot*, etc. [18, 19]. These fermented foods are believed to have originated with the Cham and Mon people of Indochina, where they diffused southward to insular Southeast Asia


**Fig. 1** Documentation of Indonesian fermented shrimp paste fermentation process, terasi, typically used to enhance the flavor of Indonesian cuisines. Terasi is a paste that is usually molded and has a black or reddish brown color (retrived from Ma'ruf et al. [91])

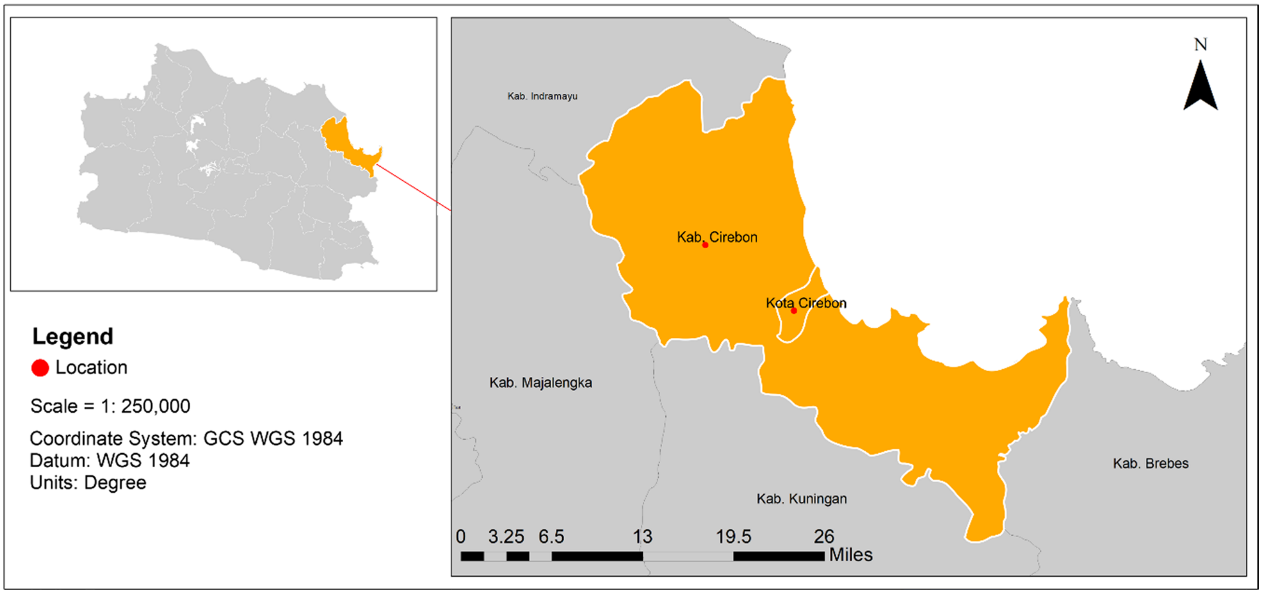


**Fig. 2** The location of Cirebon in West Java Province, as terasi-producing region (retrieved from: https://www.indonesia-geospasial.com/2020/05/download-data-peta.html). Terasi is a major contributor to the popularity of Sundanese cuisine which is a tribute from Cirebon

[19]. They were produced by using various raw materials and fermentation methods, so that each has unique characteristics (Table 1).

Terasi is commonly found in almost all Indonesian households, and the daily consumption of terasi ranges from 5 to 10 g per person [20]. Apart from being a flavor enhancer, terasi is also typically added to chili sauce to produce *sambal terasi*. *Sambal terasi* is extensively used in daily dishes in Indonesian, i.e., a main meal with rice, vegetables, or fruit salad [5]. Many restaurants even promote different types of *sambal terasi.* It can be assumed that consumption of terasi has not decreased, as the appreciation for traditional cuisines has increased in the present day.

**Table 1** Various of fermented shrimp paste worldwide

| Fermented shrimp paste | Origin | Shrimp species | Product characteristics | Fermentation period | Salt concentration (w/w) | References |
|---|---|---|---|---|---|---|
| Terasi | Indonesia | *Acetes japonicus*<br>*Acetes sibogaesibogae* | Soft paste with dark brown, gray, or red color | 6–9 months | 15% | [6] |
| Belacan | Malaysia | *Acetes japonicus*<br>*Acetes erythraeus*<br>*Acetes sibogaesibogae* | Thick paste with grayish pink to grayish purple color | 1–2 weeks | 5–20% | [6, 86] |
| Kapi | Thailand/Cambodia | *Acetes japonicus* | Semi-solid paste with pinkish purple to dark purple color | > 2 months | 25–35% | [6, 86] |
| Bagoong-alamang | Philippines | *Acetes erythraeus*<br>*Acetes intermedius*<br>*Acetes vulgaris* | Soft paste with pink color | 10 days–1 year | – | [6] |
| Mam ruoc/mam tom | Vietnam | – | Thick paste with light pinkish gray | 2–3 months | 2–5% | [6, 87] |
| Ngapi | Myanmar | *Acetes indicus*<br>*Acetes intermedius*<br>*Acetes vulgaris* | Paste with pink to reddish color | 4–6 months | 20–25% | [6, 86] |
| Saeu-jeot | Korea | *Acetes japonicus* | – | – | 20–30% | [37] |

## The occurance of fermented shrimp pastes worldwide

Asia is the most diverse and abundant continent in term of fish products, particularly in Southeast Asian countries. Among these products, fermented shrimp paste is a brown liquid that is widely used as condiment and characterized by a strong umami taste [21]. These products are widely available in both rural and urban markets [22]. The different varieties of fermented shrimp pastes were named in accordance with local traditions; hence, sometimes, the same food products have different terms [6]. Apart from terasi, another type of fermented shrimp paste is Belacan. This is one food ingredient unique to the local population in Malaysia, which can either be in paste or formed into blocks for selling [23]. Belacan usually used as the main ingredient in making *sambal Belacan* [24]. *Sambal Belacan* is normally relished by its consumers by adding it to various dishes, especially in melas containing rice [25]. In Malaysian cuisines, Belacan is also used in *laksa* (a cocounut curry broth-based noodle dish containing ground fish fillet), *nasi goreng Belacan* (fried rice containing Belacan), *sambal tumis* (spicy sautéed chili paste), *amped* (sweet and sour fish stew), and kangkung goreng Belacan (sautéed water convolvulus containing shrimp paste) [6].

The most popular fermented shrimp paste in Thailand is Kapi. It is widely used as a condiment in many Thai cuisines, in particular chili sauce know as *nam-prik Kapi* and curry pastes. Kapi is categorized into two distinct varieties in Thailand, Kapi Ta Dam (black paste) and Kapi Ta Deang (red paste), which are derived from mangrove canals and seagrass habitats, respectively [26]. Regarding Korean fermented shrimp products, the scientific literature reported some studies focusing on saeujeot. Saeujeot is the most commonly used salt substitutive seasoning. Saeujeot not only has been used as dipping sauce, but also as a folk remedy for digestive problems when consumed together with persimmon, meat, and other specific foods. It is also used as the key ingredient in kimchi [27]. In Phillipines, there is a fermented shrimp product called *bagoong-alamang*. Such a food preparation is frequently used as ingredient or condiment for many traditional Philipino dishes [28]. Finally, other fermented fish preparations from Myanmar (*Ngapi*), Vietnam (*Mam ruoc/Mam tom*), Cambodia (*Prahok*), Bangladesh (*Chepa Shutki*) were studied [6], although limited information on these preparations is available in the scientific literature.

## The microbiology of terasi and other fermented shrimp pastes

As shrimp pastes are produced under spontaneous fermentation conditions and no specific microorganisms are inoculated into the shrimp pastes [29], various microorganisms from the raw materials and the environment present in the shrimp paste (Table 2). However, the growth of microorganisms can be steered in a particular

**Table 2** Microorganism found in various fermented shrimps paste

| Fermented shrimp paste | Origin | Microorganisms | References |
| --- | --- | --- | --- |
| Terasi | Indonesia | *Tetragenococcus halophilus*, *Tetragenococcus muriaticus*, *Bacillus cereus* | [33] |
| | | *Tetragenococcus*, *Aloicoccus*, *Atopostipes*, *Alkalibacillus* and *Alkalibacterium* | [41] |
| | | *Staphylococcus, Bacillus, Proteus* | [88] |
| Belacan | Malaysia | *Staphylococcus*, *Tetragenococcus* | [34] |
| | | *Bacillus, Pediococcus, Lactobacillus, Micrococcus, Sarcina, Clostridium, Brevibacterium, Flavobacterium,*<br>*Bacillus cereus, Staphylococcus aureus, and Corynebacterium* | [88] |
| Kapi | Thailand/Cambodia | *Lentibacillus, Salinococcus, Salimicrobium, Alkalibacterium, Staphylococcus, Jeotgalicoccus psychrophilus*, and *Bacillus* | [38] |
| Bagoong-alamang | Philippines | *Bacillus* sp., *Pediococcus* sp. *Leuconostoc mesenteroides*, *Lactobacillus plantarum* | [89] |
| Ngapi | Myanmar | *Bacterial population found in Hmyin are Aeromonas liquefaciens, Alcaligenes faecalis, Bacillus alvel, Bacillus badius, Bacillus brevis, Bacillus cereus, Bacillus circulans, Bacillus polymyxa, Bacillus firmus, Bacillus laterosporus, Bacillus lentus, Bacillus macerans, Bacillus pantothenticus, Bacillus stearothermophilus. Bacillus subtilis, Corynebacterium hoffmanni, Kurthia sp., Lactobacillus, Streptobacterium, Pseudomonas fluorescens, Serratia marcescens and Staphylococcus epidermidis* | [90] |
| Saeu-jeot | Korea | *Vibrio, Photobacterium, Psychrobacter, Pseudoalteromonas, Enterovibrio, Salinovibrio, Staphylococcus, Halomonas, Salimicrobium, Halanaerobium* | [36] |
| | | *Pseudoalteromonas*, *Staphylococcus*, *Salimicrobium*, and *Alkalibacillus* | [37] |
| | | *Staphylococcus equorum*, *Halanaerobium saccharolyticum*, *Salimicrobium luteum*, and *Halomonas jeotgali* | [40] |
| Shajiang | China | *Pseudoalteromonas*, unclassified *Pseudoalteromonadaceae, Tetragenococcus, Staphylococcus, Oceanobacillus*, unclassified *Bacillaceae* | [9] |

direction by adjusting environmental conditions, such as temperature, oxygen, salt concentration, and pH. In these fermented shrimp pastes, in which salt fermentation is the primary process, the majority of microorganism populations are halophiles or halotolerant, whereby they thrive in saline conditions [30]. Surya et al. [31] reported that terasi had 6.5 log CFU/g of total viable count (TVC) at the beginning of fermentation. The TVC continuously increased during fermentation and reached 8.9 log CFU/g after 90 days of fermentation. The TVC was highly dominated by halophilic bacteria and increased after the salting and fermentation processes from 4.1 to 6.9 log CFU/g in 90 days. The high-salt environment supported the growth of halophilic bacteria during fermentation.

In contrast with the halophilic bacteria, lactic acid bacteria (LAB) were present at a low level (1.6–2.8 log CFU/g) due to insufficient carbohydrates as growth substrates for LAB in terasi [31]. This similar result was also observed in *Kapi,* where halophilic bacteria were continuously increased during fermentation for up to 30 days. The increased halophilic bacteria coincided well with the increasing TVC, while LAB did not play an important role in *Kapi* fermentation with the extended fermentation time [32]. Kobayashi et al. [33] also revealed that the halophilic bacteria genera *Tetragenococcus halophilus*, *Tetragenococcus muriaticus,* and *Bacillus cereus* were the predominant microorganisms found in terasi. However, Chuon et al. (2014) reported that *Staphylococcus* and *Tetragenococcus* were found in *Kapi* from Cambodia [34].

In order to investigate the microorganisms that persist and are involved in the fermentation process of various shrimp species, culture-dependent methods have been one of the traditional means of investigation [35–37]. Lee et al. (2014) found during *Saeujeot* fermentation that *Vibrio, Photobacterium, Psychrobacter, Pseudoalteromonas*, and *Enterovibrio* were identified as the initially dominant genera, and the microbial communities involved were significantly different depending on the salt concentration. *Salinivibrio* dominated the initial phase of fermentation in the 20% salted samples. Meanwhile, *Staphylococcus*, *Halomonas*, and *Salimicrobium* dominated the 24% salted samples. Eventually, *Halanaerobium* predominated in the 20% and 24% salted samples. As fermentation progressed, the initially dominant genera in the 28% and 32% salted samples progressively diminished, and *Salimicrobium* eventually became predominant in the 28% salted samples. However, the initially dominant genera persisted until the end of fermentation in the 32% salted samples [36]. Another study by Jung et al. [37] also revealed during *Saeujeot* fermentation that *Proteobacteria* were displaced dramatically by halophilic *Firmicutes*, and the members of *Pseudoalteromonas*, *Staphylococcus*, *Salimicrobium*, and *Alkalibacillus* were successively predominant. *Halanaerobium* eventually predominated after 66 days of fermentation.

Culture-based approaches have produced a limited amount of information because of the presence of many unculturable microorganisms and their ineffectiveness for diverse microbial communities. As such, culture-independent approaches such as next-generation sequencing and traditional sequencing involving the analysis of 16S rRNA genes through temperature gradient gel electrophoresis or denaturing have been utilized [38, 39]. Multiple samples can be rapidly and simultaneously interpreted using PCR-denaturing gradient gel electrophoresis (PCR-DGGE). The microbial DGGE profile of *Saeujeot* demonstrated that the predominant species of bacteria were *Staphylococcus equorum*, *Halanaerobium saccharolyticum*, *Salimicrobium luteum*, and *Halomonas jeotgali* [40]. Next-generation sequencing, which can quantify millions of species inhabiting a microbial ecosystem, has made it possible to reveal the succession and dynamics of the microbial community in shrimp paste fermentation ecosystems. The microbial succession and dynamics in terasi were observed using Ilumina sequencing of the V3-V4 variable region of 16S rRNA. The genera *Tetragenococcus*, *Aloicoccus*, *Atopostipes*, *Alkalibacillus,* and *Alkalibacterium* were found in Terasi as dominant microorganisms [41]. The bacterial community of *Shajiang* shrimp paste from China also varied with fermentation time. It was found that *Pseudoalteromonas* and unclassified *PFFseudoalteromonadaceae* were the dominant genera present during the entire fermentation, but were quickly replaced by *Tetragenococcus* after 30 days of fermentation. *Staphylococcus, Oceanobacillus,* and unclassified *Bacillaceae* became the predominant genera as fermentation progressed [9].

The composition and dynamics of microbial populations in fermented shrimp pastes tend to vary due to their origin, composition, processing process, and environmental conditions, which may lead to final products of different characteristics, particularly in aroma and taste [37]. Their impacts need further investigation, as their roles could be associated with the specific metabolites that give either a desirable or undesirable taste, flavor, or safety to the shrimp products. Apart from understanding the microorganisms taking part in the fermentation, investigation of microbial communities can also be used in predicting the taste of fermented products and improving fermentation processes [38, 42].

## Production of terasi

Traditional shrimp pastes are commonly produced through spontaneous or natural fermentation, in which shrimp are converted into products through endogenous enzymatic activities and microbial action without the use of a starter cultures [43]. An additional method of optimizing natural fermentation involved back-slopping, which involved inoculating a small quantity of a previously successful fermentation into the basic material. It unconsciously represents a method of applying a selected starter culture to minimize the risks associated with natural fermentation [44]. Back-slopping method accelerated the initial phase of fermentation and resulted in the success of the best adapted strains [45]. The production of traditional fermented shrimp pastes could also be conducted using starter, which are frequently added directly along with the raw material and aid in controlling the fermentation process, thereby facilitating the standardization of quality characteristics [16, 46]. Various kinds of microorganisms, such as bacteria and fungi, could be used to make starter cultures. However, the selection of starter culture is crucial, and the microorganisms chosen must be able to thrive in a fermentation environment that contains only nonpathogenic microorganisms [47].

Fermentation of shrimp by itself would not have substantial preservative effects and may even expose the shrimp to risks of spoilage microorganisms due to the production of peptides and amino acids as microbial nutrients [48]. Consequently, the addition of salt is essential to reduce water activity and eliminate harmful microorganisms [49]. Fermented shrimp paste processing technology is simple and low cost, relying on a combination of salting, drying, and natural fermentation [6, 32, 46]. Take the manufacturing process for terasi as an example. Terasi is commonly processed according to traditional practices through spontaneous fermentation. The main raw material, planktonic shrimps known as *rebon*, was washed from foreign materials (stones, woods, branches, plastics) and boiled in water for 5 min. After that, the water was drained, and the shrimp were mixed with 15% solar salt (15 g salt for 100 g shrimp). The fermentation process took place in two stages. The salted shrimps were first fermented in an enclosed container for 48 h at room temperature (25 °C) [31]. Spontaneous fermentation occurs during this process, which reduces the pH of fermented shrimp. Under these conditions, pathogenic and spoilage microorganism growth is limited due to the preservative properties of solar salt addition [50]. Then, they were ground with a blender and shaped manually into flattened spheres (diameter 8–10 cm). The formed paste was then oven-dried (50 °C, 4 h) to reduce its moisture content prior to the second fermentation stage, which consisted of allowing the paste to ferment at room temperature for an additional 30–90 days. Finally, it turns a reddish brown or brown color. Traditional terasi was usually sold after being fermented for 25–30 days and could still be sold for 60–90 days [31].

The quality and safety requirements for terasi sold in Indonesia must also follow the Indonesian National Standard (SNI 2716:2016), including sensory score min. 7, moisture content max. 45% for terasi paste, max. 35% for dry terasi, and max. 10% for powdered terasi, acid insoluble ash max. 1.5%, salt content 12–20%, protein content min. 15%, *Escherichia coli* contamination not more than 3 MPN/g, and negative *Salmonella* [51].

## Nutritional properties of terasi and other fermented shrimp pastes

Fermented shrimp pastes are commonly produced by utilizing endogenous bacteria from raw materials as starters. Unfortunately, the ingredients used and the production process of the evaluated samples are often not documented thoroughly, so the findings are frequently fragmented. Due to these variations, fermented shrimp pastes of varying nutritional properties are produced (Table 3). The moisture content of the fermented shrimp pastes varies largely, which can be attributed to an applied drying process or the different formulation of the products. The water activity of these products was usually in the range of 0.6–0.8 [43, 52]. Protein is present in a high amount in fermented shrimp pastes since shrimp, as its raw material, is also a source of protein and essential amino acids [53]. These products are lower in fat and carbohydrates than the other components.

Terasi produced by spontaneous fermentation contains 25.8–29.4% moisture, 1.30–1.40% ash, 62.9–64.8% proteins, 3.45–4.27% fats, and 2.15–4.58% carbohydrates [54]. The most significant change in the proximate during terasi and other fermented shrimp paste production was

**Table 3** Nutritional properties of terasi and other fermented shrimp pastes from different countries

| Fermented shrimp paste | Moisture (%) | Ash/Mineral (%) | Protein (%) | Fat (%) | Carbohydrate (%) | References |
|---|---|---|---|---|---|---|
| Terasi (spontaneous fermentation) | 25.8–29.4 | 1.30–1.40 | 62.9–64.8 | 3.45–4.27 | 2.15–4.58 | [54] |
| Terasi (starter culture fermentation) | 25.5–29.1 | 1.20–1.39 | 63.7–65.8 | 2.63–4.11 | 1.32–4.46 | [54] |
| Belacan | 47.9 | 19.15 | 30.4 | 0.63 | 1.92 | [56] |
| Kapi | 36.8–49.9 | 24.1–29.0 | 20.1–25.1 | 1.53–2.22 | 2.84–15.6 | [57] |
| Bagoong-alamang | 33.2–39.6 | 37.1–46.0 | – | 0.60–1.57 | – | [55] |
| Saeu-jeot | 27.0 | 45.8 | 21.7 | 4.89 | 0.91 | [56] |

the mineral content due to the addition of salt [31]. The mineral content was mainly composed of salt minerals, notably sodium and chloride. Compared to terasi innoculated by straters, the addition of starters improved their nutritional properties, especially protein contents (63.7–65.8%) [54]. Terasi also showed a higher protein content compared to other fermented shrimp pastes. Among the fermented shrimp pastes, *Bagoong-alamang* from Philippine contained the highest minerals, and their mineral content was in accordance with the high salt content (19.0–24.4%) [55].

Fermented shrimp pastes generally have a slightly alkaline pH (7.2–7.8) [56–58]. The formation of volatile base compounds such as ammonia, the degradation products generated during fermentation, might contribute to a slightly basic pH. Moreover, a wide range of carbohydrate content (0.91–15.6%) was noticeable (Table 3). Some producers might add some flour to increase the yield of the products and lower the production cost. Therefore, the composition found in these products varied with the types of products, producers, ingredients, and processes used. Some organic acids, such as lactic acid, acetic acid, malic acid, and succinic acid, were also found in fermented shrimp pastes [59]. These organic acids were used as pH control agents and contributed to the flavor of fermented shrimp pastes [60]. In particular, succinic acid was also reported to contribute to the umami taste of seafoods [61]. Fermented shrimp pastes also contains minerals, mainly sodium, calcium, potassium, magnesium, and phosphor, as a result of the salt used during the salting process [5].

During fermented shrimp paste production, proteolytic bacteria also hydrolyze proteins into peptides and amino acids [52], causing the amount of these compounds to increase. Peptides and amino acids will also have an impact on the taste, although the taste generally depends on the hydrophobicity of the side chains of the amino acids [62]. The major free amino acids found in fresh and fermented shrimp were proline, arginine, alanine, glycine, lysine, glutamic acid, and leucine [32, 63]. Peralta et al. [63] found that the fresh shrimp initially had 3.6% total free amino acids and increased to 8.2% (dominated by glutamine, leucine, lysine, and citrulline) after salting and fermentation. It is not remarkable, given these variations, that the free amino acid content of fermented shrimp pastes may vary from country to country (Table 4), notably when the primary materials, fermentation period, or other production process parameters differ from each other.

In terasi, the four dominant amino acids were glutamic acid, aspartic acid, arginine, and leucine. The higher content of glutamic acid was found in terasi innoculated by starters compared to non-innoculated terasi. Glutamic acid and aspartic acid impart an essential taste to shrimp

**Table 4** Amino acids content of terasi and other fermented shrimp pastes from different countries

| Amino acids | Terasi (spontaneus fermentation) | Terasi (starter culture fermentation) | Belacan | Saeujeot | Terasi | Belacan | Kapi | Bagoong-alamang | Saeujeot |
|---|---|---|---|---|---|---|---|---|---|
| | Total-AA[a] (mg/g) | Total-AA (mg/g) | Total-AA (mg/g) | Total-AA (mg/g) | Free-AA (mg/g) | Free-AA (mg/g) | Free-AA (mg/g) | Free-AA (mg/g) | Free-AA (mg/g) |
| Asp | 25.3 | 24.2–27.0 | 28.4 | 21.4 | 11.9 | 54.6 | 0.10–0.28 | 0.33–0.61 | 29.3 |
| Glu | 41.6 | 39.9–44.3 | 52.8 | 31.3 | 20.6 | 101 | 0.07–0.59 | 0.40–1.40 | 42.9 |
| Ala | 18.0 | 17.2–18.8 | 17.0 | 9.92 | 14.0 | 32.7 | 0.09–025 | 25.4–4.33 | 13.6 |
| Gly | 18.0 | 10.7–11.2 | 15.7 | 12.4 | 8.57 | 30.1 | 0.08–0.22 | 22.2–38.3 | 17.0 |
| Ser | 11.1 | 17.1–18.4 | 9.51 | 6.06 | 4.94 | 18.3 | – | 0.47–18.10 | 8.31 |
| Thr | 13.0 | 12.1–12.9 | 12.9 | 8.64 | 6.84 | 24.8 | – | 0.91–26.8 | 11.8 |
| Val | 12.8 | 12.6–13.2 | 14.2 | 9.62 | 10.53 | 27.2 | 0.03–0.27 | 12.7–49.9 | 13.2 |
| Met | – | – | 9.23 | 5.92 | 4.64 | 17.7 | 0.00–016 | 0.72–20.5 | 8.11 |
| Ile | 12.1 | 11.8–12.5 | 12.6 | 8.54 | 9.40 | 24.2 | 0.02–0.36 | 10.5–44.8 | 11.7 |
| Leu | 21.9 | 21.2–22.7 | 24.5 | 14.6 | 17.49 | 47.0 | 0.03–0.54 | 24.1–88.9 | 20.0 |
| Tyr | 11.9 | 9.97–10.95 | 10.1 | 6.41 | 8.33 | 19.4 | – | 0.93–17.3 | 8.78 |
| Phe | 17.2 | 14.3–15.8 | 13.0 | 9.12 | 6.42 | 25.0 | 0.01–0.26 | 0.92–37.4 | 12.5 |
| His | 5.11 | 47.8–49.9 | 4.91 | 3.20 | – | 9.43 | 0.01–0.04 | 0.24–0.75 | 4.39 |
| Arg | 23.4 | 20.9–22.8 | 10.4 | 13.8 | 2.74 | 20.0 | 0.01–0.22 | 36.3–41.2 | 18.9 |
| Pro | 11.2 | 10.8–12.7 | 11.7 | 9.18 | – | 22.5 | 0.03–0.14 | 13.3–31.4 | 12.6 |
| Lys | 18.7 | 18.5–20.0 | 24.7 | 13.9 | 16.24 | 47.4 | 0.11–0.55 | 24.1–62.5 | 19.0 |
| References | [54] | [54] | [20] | [20] | [59] | [56] | [52] | [32] | [56] |

[a] AA, amino acid

pastes [54]. Glutamic acid in the form of a sodium salt, that is, monosodium glutamate, confers a umami taste and has potential as a flavoring component [64]. Despite the nutritional properties of terasi, it is typically used in small quantities as a flavor enhancer. Therefore, terasi would not contribute substantially to the daily nutritional requirements of humans.

## Potential bioactivities of terasi and other fermented shrimp pastes

Fermented shrimp pastes have been reported to possess numerous bioactivities, including antibacterial, antioxidant, anticoagulant, and ACE inhibitory activity (Table 5). The Gram-Positive bacteria isolated from terasi, *Virgibacillus salexigens*, contained bacteriocins that exhibit inhibition against Gram-positive bacteria, including the foodborne bacteria *Listeria monocytogenes*. The antibacterial activity of this substance was stable after heating and pH treatment and might be a desirable antibacterial food additive for controlling this foodborne bacteria [65]. Bacteriocins from LAB isolated from terasi can inhibit pathogenic and spoilage bacteria, including *Eschericia coli*, *Vibrio parahaemoliticus, and Staphylococcus aureus* [66]. The study by Sukmawati et al. [67], also showed that bacteriocins of LAB isolated from the fermentation of rebon shrimp were able to inhibit the growth of pathogenic bacteria, including *Eschericia coli*, *Staphylococcus aureus,* and *Salmonella* Thypimurium*.* These substances were not affected by the addition of NaCl and were stable in a wide temperature and pH range. Thus, they have the potential to be further developed as a natural food preservative [67]. Another study also showed that *Bacillus amyloliquefaciens* isolated from *Kapi* produced a bacteriocin, amycin, that showed a broad range of inhibition, including *L. monocytogenes, Salmonella sp*., and *Shigella sp.* [68].

In addition to their antibacterial properties, fermented shrimp pastes have been reported to possess antioxidant properties [57, 63, 69]. Peralta et al. [70] reported that antioxidative activity in Philippine salt-fermented shrimp paste extracted with 85% ethanol was directed toward 1,1-diphenyl-2-picrylhydrazyl (DPPH) radicals and peroxidation of methyl linoleate. Morever, the extract of a Philippine salt-fermented shrimp paste with 80% ethanol exhibited antioxidative activities against DPPH radicals, hydrogen peroxide, and lipid peroxidation. This antioxidant ability was significantly increased with prolonged fermentation time [63]. Faithong et al. [57] reported antioxidant activity in Thai traditional fermented shrimp and krill products such as Jaloo, KoongSom, and Kapi against DPPH and 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulphonate) (ABTS+) radicals, as well as ferric reducing activity power (FRAP). They discovered that a water-soluble fraction from Kapi exhibited the highest antioxidative activity among all soluble fractions. Another study by Kleekayai et al. [26] also reported that the water extract of two types of Thai fermented shrimp paste, Kapi Ta Dam and Kapi Ta Deang, showed strong antioxidative activities against ABTS+radicals. Furthermore, they found that the water extracts also showed ACE inhibitory activity but did not exhibit antimicrobial activity against *Staphylococcus aureus*, *Bacillus cereus*, *Escherichia coli*, and *Salmonella typhimurium* [26]. Bioactive dipeptides derived from Kapi Ta Dam and Kapi Ta Deang, Ser-Val and Ile-Phe, are also responsible for ACE inhibitory activity. Furthermore, the Trp-Pro peptide was shown to exhibit high radical scavenging activity against ABTS [71]. ACE plays a crucial role in the regulation of peripheral blood pressure, and inhibition of ACE is considered

**Table 5** The bioactivities of fermented shrimp pastes

| Fermented shrimp paste | Bioactivity | Result | References |
|---|---|---|---|
| Terasi | Antibacteria | Bacteriocin from *Virgibacillus salexigens* isolated from terasi inhibit the growth of *Lysteria monocytogenes* | [65] |
| | Antibacteria | Bacteriocin from LAB isolated from terasi inhibit the growth of *Eschericia coli*, *Vibrio parahaemiliticus*, *Staphylococcus aureus* | [66] |
| Kapi | Antibacteria | Bacteriocin from *Bacillus amyloliquefaciens* isolated from Kapi inhibit the growth of *L. monocytogenes, Salmonella* sp., and *Shigella* sp | [68] |
| | Antioxidant | The water extract of Kapi possessed antioxidant activity toward DPPH radical, ABTS, and FRAP | [26, 57, 71] |
| | ACE inhibitory | The water extract of Kapi possessed antihypertensive activity due to the presence of dipeptides Ser-Val and Ile-Phe | [59, 60] |
| Bagoong-alamang | Antioxidant | The ethanol extract of Bagoong-alamang possessed antioxidant activity toward DPPH radical, hydrogen peroxide and lipid peroxidation | [63, 70] |
| Chinese fermented shrimp paste | Fibrinolytic/thrombolytic | *Bacillus sp.* isolated from shrimp paste produce a unique fibrinolytic enzyme | [75, 76] |
| Chinese fermented shrimp paste | Fibrinolytic/thrombolytic | Resistant to pepsin and trypsin digestion and possess anticoagulant activity | [74] |

a useful therapeutic approach in the treatment of hypertension [72].

Seok et al. [73] also revealed that the extract of salted and fermented small shrimp (*Acetes japonicus*) had a cholesterol-lowering effect in high cholesterol-diet-induced hypercholesterolemic animal models. The fibrinolytic enzyme has been found in fermented shrimp paste. Out of 13 Asian fermented foods, shrimp paste was shown to possess the strongest fibrinolytic activity [74]. The study of Anh et al. [75] and Hua et al. [76] also revealed that Vietnamese traditional shrimp paste products possessed fibrinolytic activity, synthesised by bacteria naturally existing in those products, *Bacillus sp.* The fibrinolytic enzyme plays a role in the treatment of cardiovascular diseases. As the blood's clotting ability is enhanced via fibrin fiber synthesis, fibrinolytic enzymes enhance the blood's anticoagulant properties. These data suggest that fermented shrimp pastes have the potential for further development due to their bioactivity characteristics.

## Potential hazard in fermented shrimp pastes

Although fermented shrimp pastes have many health advantages due to their high nutritional value and bioactivities, their beneficial aspects could be limited due to the presence of several compounds that pose health risks, including sodium chloride, biogenic amines, and N-nitroso compounds [46, 77]. Despite the fact that consumers do not consume these fermented shrimp pastes in large quantities, it is important to remove or reduce the undesirable compounds in order to eliminate health risks. For instance, excessive consumption of sodium chloride can lead to health problems. Consequently, it is necessary to implement low-salt production techniques [78].

Biogenic amines (e.g., histamine, tyramine, cadaverine, and putrescine) are typically generated by the decarboxylation of unbound amino acids that are released from proteins by microbial enzymes. Their toxicity in excess poses a hazard to human health. Unfortunately, fermented shrimp pastes typically contain considerable amounts of biogenic amines [79, 80]. For example, an average histamine content in fermented shrimp paste from Taiwan was 32 mg/kg, and an average putrecine and tyramine content in shrimp sauces from Malaysia were 331 mg/kg and 499 mg/kg, respectively [81, 82].

Comparing these amounts, the biogenic amines in terasi from Indonesia are considerably higher. Tryptamine reached up to 4170 mg/kg, putrescine reached up to 25,420 mg/kg, cadaverine reached up to 17,960 mg/kg, histamine reached up to 1830 mg/kg, and tyramine reached up to 13,290 mg/kg [83]. According to this study, putrescine, cadaverine, and tyramine were the dominant biogenic amines found in terasi. High amounts of putrescine, histamine, and tyramine were also found in shrimp and fish sauces [81]. Prester [79] noted that putrescine and cadaverine are generally formed in several shrimp products, while histamine formation is generally low in shellfish products.

Particularly, various biogenic amines at different concentrations in foods may elicit slight responses, such as 5 mg of phenylethylamine, 5–10 mg of tyramine, 25 mg of tryptamine, or 10–40 mg of histamine. Toxic responses are required at concentrations of 80–100 mg of histamine or 25–250 mg of tyramine [84]. Histamine and tyramine are the two biogenic amines that pose the greatest hazard to human health, whereas cadaverine and putrescine have less significant toxicological effects. Compared to histamine, cadaverine and putrescine are highly sensitive spoilage indicators [79, 80]. Consequently, it is possible to hypothesize that exceptionally high levels of putrescine and cadaverine indicate poor product quality.

## Future, challenge, and prospect of terasi

Terasi, an Indonesian fermented shrimp paste, is a product that generally has a high content of ash or minerals, especially sodium salt. The high sodium content in terasi products poses a high health risk if consumed in large quantities. Excessive sodium consumption is also associated with high blood pressure, which is a major risk factor for heart disease and stroke [85]. Moreover, as consumers become more aware of the negative effects of excessive sodium consumption, the use of low-salt products in the food industry is also growing in popularity. Therefore, terasi development with a lower salt concentration can be advantageous to tackle the risk issues.

In addition, the production process of terasi still occurs on a small-enterprise scale and involves spontaneous fermentation by utilizing endogenous bacteria from raw materials, thus leading to the non-uniform quality of terasi products. The use of starter cultures, both individually and in combination, of *Lactobacillus plantarum* SB7 and *Bacillus amyloliquefaciens* BC9 in terasi production has been reported previously and showed better nutritional quality as well as consumer preference than those of the non-innoculated terasi [54]. Therefore, there is a need for further development of novel processes using various other types of LAB and enzyme-producing hydrolytic bacteria as starter inocula to produce terasi with superior quality. LAB may not only produce nutritional compounds but also preserve and improve the flavor of terasi products. Starter cultures may accelerate fermentation and prevent the growth of spoilage microorganisms. However, commercial starter cultures are not used very often because they cannot adapt well to the fermentation environment and cannot be changed to make the desired end products. This means that researchers need to look into new microbes as starter cultures for terasi fermentation. Furthermore, appropriate measures for tackling undesired compounds related to health risks should be carefully designed to maximize the health benefits of the consumption of terasi.

Fermented marine food products have been identified as rich sources of bioactive compounds, including amino acids and peptides. Bioactive peptides with antioxidant and ACE inhibitory activity have been identified as the first report derived from Kapi [71], and there have been no reports regarding bioactive peptides in terasi, even though these compounds have promising applications as natural functional food ingredients or nutraceuticals. Issues such as problems with large-scale production, compatibility with different food matrices, gastrointestinal stability, bioavailability, and long-term stability are the main concerns for the exploration of bioactive peptides isolated from terasi.

## Conclusion

This paper examined various aspects of terasi and other fermented shrimp pastes, including their history, microbiology, fermentation process, nutritional properties, bioactivities, potential dangers, as well as their future, challenges, and prospects. The microbial profiles and nutrient composition indicate the presence of a diverse microbial population and rich sources of amino acids, particularly umami amino acids. The technology process of terasi and other fermented shrimp pastes is typically still carried out in a traditional manner, involving salting, dehydrating, and natural fermentation. These products also exhibited biological activity, particularly antibacterial and antioxidant activity. However, high salt content and the occurrence of undesirable compounds such as biogenic amines limit their nutritional value and biological activities. Therefore, further advancement of innovative techniques, such as the addition of novel starter cultures and low-salt fermentation, is necessary to tackle the risks and enhance the production of high-quality terasi. Starter cultures may accelerate fermentation and inhibit spoilage microorganisms, as well as help to degrade biogenic amines. Furthermore, appropriate measures in tackling the undesirable compounds associated with health risks should be carefully designed to maximize the health benefits. This study will be beneficial for future research into fermented shrimp products to highlight their long-term food value.

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## Declarations

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