

Flavour Characteristics and Amino Acid Contents of Fish Sauce Produced from Various Raw Materials: Mini Review

Rismayani Miftahul Ilmi¹, Nani Mariati Thamrin¹, and Andi Hasizah^{1,2*}

¹Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University, Makassar, 90425, Indonesia

²Center of Excellence in Science and Technology on Food Product Diversification, Hasanuddin University, 90245, Makassar, Indonesia

Abstract. Fish sauce is a typical seasoning used in various cuisines, especially in several Asian regions such as Japan, Korea, Indonesia, Thailand, Vietnam, and Malaysia. Fish sauce is a thick liquid produced through the fermentation process of raw seafood materials. This product imparts a distinct savoury and salty taste and a unique aroma and flavour to food products. Many types of fish sauce are produced from various seafood products such as fish, shrimp, squid, clams, or a combination of these seafood types. Each type of raw material yields fish sauce with different aromas, tastes, and nutritional contents. This review covers the types of raw materials used in fish sauce production and the taste and aroma characteristics of the resulting fish sauces. The raw materials covered in this article include anchovies, tuna, sardines, mackerel, shrimp, squid, and clams. Furthermore, the fermentation methods used in producing fish sauce from each of these materials will also be presented, along with each fish sauce variety's dominant amino acid content.

1 Introduction

Fish sauce in Figure 1, is one of the traditional spices popular in several regions of Asia, especially East Asia and Southeast Asia [1,2]. Fish sauce is a fermented product of fish or other fishery products in the form of light yellow, purplish red, dark brown, to grey liquids, and has a distinctive aroma and savory taste [3–6] The process of making fish sauce usually uses types of fish that vary depending on the region and method used. In some countries, fish sauce is commonly used as a spice. In addition, this product is rich in nutrients, including all essential amino acids, vitamins, trace minerals, and many bioactive peptides [7,8].

The ancient Romans first developed fish sauce in the 5th century BC under the name Garum [9]. Garum is made from the blood and offal of fresh mackerel or salted mackerel (up to 25% w/w) and fermented for 2-9 months [10]. Nowadays, fish sauce is spreading all over the world, particularly in Asia under different names in each country, such as Mahyaveh dan Suragh in Iran [11,12], Yu-lu in China [13], Myeolchi-Aekjeot in Korea [14], Shottsuru dan

* Corresponding author: andihaszah@gmail.com

Ishiru in Japan [15,16], Kecap Ikan in Indonesia [4], Budu in Malaysia [17], Nam-pla in Thailand [18], Nuoc-Mam in Vietnam [19], Hmyin-ngan-pya-ye in Myanmar [20], and Patis in Philippines [21].

Fish sauce is prepared by spontaneous or non-spontaneous (with the addition of a starter) fermentation of various fish after adding salt and fermented for 1-12 months or more [4,22]. The ratio of fish and salt varies between 1:1 to 6:1 depending on the country [1]. Many types of fish sauce are made from various seafood products such as fish, shrimp, squid, clams, or a combination of these seafood types [23,24]. The type of fish used in the production of fish sauce, which varies from country to country, affects the aroma, taste, and nutritional quality of fish sauce [2,13,25].

This review covers the types of raw materials used in fish sauce production and the taste and aroma characteristics of the resulting fish sauces. The raw materials covered in this article include anchovies, tuna, sardines, mackerel, shrimp, squid, and clams. Furthermore, the fermentation methods used in producing fish sauce from each of these materials will also be presented, along with each fish sauce variety's dominant amino acid content.

2 Fish Sauce Materials and Processing

These types of fish sauce products include different species of fish used as the primary raw material, salt concentrations, adding spices, storage temperatures, storage containers, and processing techniques, resulting in a final product with unique properties in aroma, flavour, and colours. Variety fish sauce production generally has the same concept: salting, enzyme hydrolysis, and bacterial fermentation [5]. The variety of fish sauce raw materials worldwide can be seen in Table 1.

Table 1. Summary Raw Materials of Fish Sauce

Commodities	Country	Reference
Anchovy	Iran, China, Italia, Thailand, Indonesia, Korea, Malaysia, Vietnam, Philippines	[3,11,13,14,17,19,26–28]
Sardine	Indonesia, India, Iran	[12,29–31]
Mackerel	Roman, Japan	[10,32,33]
Tunny	Indonesia, Thailand	[6,34,35]
Squid	China, Japan	[15,16,36]
Shrimp	Myanmar, China, Japan	[20,37,38]
Clams	Indonesia, Philippines, Sri Lanka, China	[39–42]

2.1 Anchovy Fish Sauce

Anchovy is widely used as the primary raw material in Asian fish sauces because anchovy is an abundant fish resource living in the Pacific Ocean, Atlantic Ocean, and South America [26,43,44]. Table 2 shows a summary of various anchovy species, processing methods and their parameters of anchovy fish sauce. Various species of anchovies have been used in making fish sauces in each country with various processing methods. In Iran, there are two traditional fish sauces called *Mahyaveh* and *Suragh*. *Mahyaveh* is processed using *Stelophorus sp.* and salt in a ratio of 2:1 (fish: salt) and fermented for 25–30 days at room temperature. The fermentation results are mixed with mustard and other spices, then fermented again for 10-15 days [11,45]. In China, fish sauce (*Yu-lu*) processing uses *Engraulis japonicus* and salt in a ratio of 3-4:1 (fish: salt) fermented for 1-12 months [7,13]. In Thailand, fish sauce processing (*Nampla*) uses *Stolephorus spp.* and salt in a ratio of 2-

3:1 (fish: salt) fermented at 25°C for 12–18 months. The fermentation results are then drained and allowed to stand for 2–12 weeks before packaging [18,46,47]. In Vietnam, fish sauce (*Nuoc-Mam*) is processed using *Stolephorus commersonii* and salt in a ratio of 3:1–2 (Fish: salt) fermented for 9–12 months or more in sealed barrels [5]. In some areas of Vietnam, people also used plant enzymes such as papain or bromelain to speed up fermentation [19]. In Italy, the processing of fish sauce (*Colatura di Alici*) uses *Engraulis encrasicolus*, and salt is layered into wooden barrels in a ratio of 2:1 (Fish: salt). The vat is then tightly closed and fermented for 9-12 months at 18-25°C [3,48]. In Indonesia, fish sauce processing (*Kecap Ikan*) uses *Stolephorus sp.*, or *Coilia dussumieri* [49] and salt in the ratio of 5:1.5-3.5 (Fish: salt) fermented for 1-2 months [50]. In Korea, fish sauce (*Myeolchi-Aekjeot*) is made from fermented *Engraulis japonicus* and salt in a ratio of 4-5:1 (fish:salt) for 12-24 months [51,52]. In particular, *Myeolchi-Aekjeot* is used to strengthen traditional Korean foods' nutrition, flavour, and flavour, including Kimchi [14]. In Malaysia, fish sauce (*Budu*) processing uses *Ilisha melastoma* [17] or *Stolephorus spp.* and salt in a ratio of 3-5:1 (fish: salt) fermented for 3-12 months. Furthermore, the fermentation liquids are added sugar to make the colour of the fish sauce darker and have a thick liquid consistency [5]. In the Philippines, Fish sauce (*Patis*) is manufactured using *Stolephorus commersonii* mixed with salt in ratios ranging from 1-5:1 (fish: salt) and fermented for 3-12 months [27,53].

Table 2. Summary of Anchovy Fish Sauce Processing

Country	Species	Fish:salt (w/w)	Fermentation Duration	References
Iran	<i>Stolephorus sp.</i>	2:1	25-30 days + 10-15 days after adding spices	[11,45]
China	<i>Engraulis japonicus</i>	3-4:1	1-12 months	[7,13]
Thailand	<i>Stolephorus spp.</i>	2-3:1	12–18 months	[18,46,47]
Vietnam	<i>Stolephorus commersonii</i>	3:1–2	9–12 months	[5,19]
Italy	<i>Engraulis encrasicolus</i>	2:1	9–12 months	[3,48]
Indonesia	<i>Stolephorus sp.</i> <i>Coilia dussumieri</i>	5:1.5-3.5	1-2 months	[4,49,50]
Korea	<i>Engraulis japonicus</i>	4-5:1	12-24 months	[14,51,52,54]
Malaysia	<i>Ilisha melastoma</i> <i>Stolephorus spp.</i>	3-5:1	3-12 months	[5,17,55]
Philippines	<i>Stolephorus commersonii</i>	1-5:1	3-12 months	[27,53]

2.2 Sardines Fish Sauce

Sardine, a pelagic fish with high omega-3 fatty acids, is primarily consumed as a dietary source [56]. In addition to anchovies, Sardine is most frequently used for fish sauce production [1]. Various species of sardines have been used in making fish sauces in several countries with various processing methods. In Indonesia, in addition to using anchovies, fish sauce also uses *Sardinella spp.* or *Sardinella lemuru* [30] and salt in the ratio of 5:1.5-5:3.5 (Fish:salt) fermented for 1-2 months [5]. In Southern India, fish sauce (Colombo cured) is processed using *Sardinella spp.* and salt in a ratio of 3:1 (fish: salt) fermented for 2–4 months. Improvements in the quality are obtained if 5% acetic acid is added in place of tamarind [57]. In Iran, fish sauce (Suragh) uses *Sardinella spp.* or *Dussumieria acuta* and salt in a ratio of 5-3:1 (fish: salt), as well as the addition of red soil or ocher that is only available in Hormuz Island, Iran. The mixture is left for spontaneous fermentation for six months at room temperature [12].

2.3 Mackerel Fish Sauce

Mackerel is a pelagic fish widely used in making fish sauce in various Asian countries [13]. The world's first fish sauce, Garum, came from Romans and was made from *Rastrelliger* spp., or *Scomber scombrus* fresh and salt (up to 25 w/w%) and fermented for 2-9 months [32,58]. In Japan, one of the fish sauce processing (Shottsuru) uses horse mackerel (*Trachurus japonicus*) or pacific mackerel (*Scomber japonicus*) and salt in a ratio of 3:1 or 7:2 (fish: salt). Shottsuru is allowed to disintegrate in earthenware jars and in wooden and cement tanks for 12–18 months [33,59].

2.4 Tunny Fish Sauce

Fish sauce is mainly produced from anchovies, Sardines, and mackerel [1]. However, several countries use tuna as raw material for fish sauce. In Indonesia, in addition to anchovies and sardines, fish sauce processing is also found using *Thunnus albacores* loin and salt with a ratio of 2:1 (fish:salt) fermented at 50oC for 1-1.5 months. The enzyme papain is also used to manufacture tuna sauce to speed up fermentation [6,34]. In Thailand, fish sauce processing is also found using Skipjack tuna (*Kastuwonus pelamis*) viscera and salt with a ratio of 3:1 (fish:salt) fermented at a temperature of 27-35oC for 1-12 months [35].

2.5 Squid Sauce

Squid is one of the world's most important commercial seafood products and is mainly utilized or produced as sliced raw fish, and dried, seasoned, smoked, and fermented products [60]. There have been few reports that utilized squid as a material for fermented sauce. In China, squid sauce was made from *Symplectoteuthis oualaniensis* mixed with salt, water and koji (*Aspergillus oryzae*) with a ratio of 5:0,5:4:1 (squid:salt:water:koji) fermented at 48°C for one month [36]. In Japan, squid sauce (*Ishiru*) is prepared with squid and salt with a ratio of 5:1 (squid: salt) and left to ferment for 12-24 months [15,16]. After fermentation, this liquid is then deproteinized by boiling and filtered. Finally, the resulting liquid is taken as a finished product [5].

2.6 Shrimp Sauce

Like fish sauce, shrimp sauce is a customary condiment in East and Southeast Asia, especially from Myanmar, China, and Japan, that is fermented at a high salt concentration [37]. The genus *Acetes* is the most common raw material to produce shrimp sauce [61]. In Myanmar, the shrimp sauce Hmyin-ngan-pya-ye is used as an essential condiment or seasoning in daily cuisine [61]. Processing Hmyin-ngan-pya-ye shrimp sauce using fresh shrimps from various genera, such as *Acetes* and *Mysid*, mixed with salt and fermented for 3-12 months [20]. In China, shrimp sauce processing using *Acetes chinensis* shrimp and salt in a ratio of 3:1 (fish:salt) fermented for 12-24 months or more in closed barrels [37]. Di Jepang, another type of Japanese fish sauce (Shottsuru) is made from small shrimp (*Mysid*) mixed with fish meat before salting. The fish-to-salt ratio could be within 3:1, and the mixture is left to ferment for 12-18 months at room temperature [5,59].

2.7 Clam Sauce

At present, there are limited accounts of the way fermented clam sauce is being processed. However, just like making fish sauce, clam meat can be fermented at high salt concentrations to make clam sauce [62,63]. Table 3 shows a summary of various clam species, processing

methode and their parameters of clam sauce. In Indonesia, the process of processing clam sauce uses freshwater clam (*Batissa violacea*), salt, and gelatin with a ratio of 2:1:0.3 (clam:salt:gelatin), and added enzymes and fermented for 1-2 weeks at room temperature [42]. In Philippines, Clam sauce uses freshwater clam (*Batissa violacea*), sugar, and soy sauce with a ratio of 4:1:1. Cook the clam meats slowly in water until the pulp caramelizes into a thick, brown, intense, and flavorful sauce. After these steps, the sauce is left cool, stored in bottles, and sealed [39]. In Sri Lanka, the process of processing clam sauce used mud clam (*Geloina coaxans*) with salt and papaya crude extract with a ratio of 5:2:3 (clam:salt:papaya crude extract), fermented at 60oC for 10 days [40]. In China, clam sauce processing used Manila clam (*Ruditapes philippinarum*), salt, and soybean koji with ratio 5:3:1, and fermented at 35oC for 12-18 days [41].

Table 3. Summary of Clam Sauce Processing

Country	Species	Clam:salt (w/w)	Fermentation Duration	References
Indonesia	<i>Batissa violacea</i>	2:1:0.3 (add gelatin)	1-2 weeks	[42]
Philippines	<i>Batissa violacea</i>	4:1:1 (clam:sugar:soy sauce)		[39]
Sri Lanka	<i>Geloina coaxans</i>	5:2:3 (add papaya extract)	10 days	[40]
China	<i>Ruditapes philippinarum</i>	5:3:1 (add koji)	12–18 days	[41]

3 Free Amino Acid and Taste of Fish Sauce

The amino acid composition of fish sauce may be nutritionally essential, especially in regions where fish sauce is a significant source of dietary protein [36]. Amino acids have a close relationship with flavor because they are the main components in the formation of proteins, which in turn affect the taste and aroma of food [64,65]. Some amino acids, particularly glutamate and aspartate, are known to elicit the taste sensation of umami, which is described as a savory or meaty taste [66]. This perception is mediated by specific taste receptors on the taste buds, particularly the T1R1/T1R3 receptor, which responds to glutamate and aspartic acid [67]. Amino acids can undergo chemical reactions, such as the Maillard reaction, during food processing or cooking. This reaction involves the reaction of amino acids with reducing sugars, leading to the formation of a complex mixture of volatile compounds that contribute to the aroma and flavor of foods [1,29,48]. Certain amino acids, such as phenylalanine and tryptophan, can impart a bitter taste when present in high concentrations [65,66]. Bitter taste perception is mediated by specific taste receptors, such as TAS2R receptors, on the taste buds [68]. The presence of bitter-tasting amino acids can affect the overall flavor balance of foods, particularly when present in excess. Amino acids may interact synergistically with other taste compounds, so that can leading to a more balanced and palatable flavor profile [68].

Fish sauce's flavor taste is heavily influenced by amino acids, which are classified into umami (aspartic acid and glutamic acid), sweetness (glycine, alanine, serine, proline and lysine), bitterness (arginine, tryptophan, leucine, isoleucine, methionine, phenylalanine, histidine, tyrosine and valine) and tasteless amino acids (cysteine) [13,66]. Table 4 shows fish sauce's free amino acids and dominant taste properties. The study found glutamic acid, aspartic, alanine, valine, lysine, leucine, histidine, arginine, and glycine were the amino acids to have dominant taste characteristics in fish sauce. Glutamic acid and aspartic are the most dominant in all fish sauce variants. Glutamic and aspartic acids are the most abundant free amino acids in fermented fish, especially for fish sauce, and their concentrations often exceed

the taste threshold [64,65]. Glutamic and aspartic acids represent umami taste qualities [68]. Alanine, followed by glutamic and aspartic acid, is the most dominant in the fish sauce and represents sweetness [38,68]. The following most dominant amino acids are leucine and lysine. Leucine was found in anchovy, Sardine, mackerel, tunny fish sauce, and clam sauce. At the same time, lysine was found in anchovy and sardine fish sauce, squid sauce, and shrimp sauce. Leucine is an amino acid that is associated with bitterness, while lysine is an amino acid that is associated with sweetness [65]. Valine, arginine, and histidine, found in anchovy fish sauce, mackerel fish sauce, squid sauce, and clam sauce, are amino acids that represent bitterness [68,69]. However, under certain conditions, valine, arginine, histidine, and other bitter amino acids can enhance the mellow feel of fermented products and bring out unique flavours, but can also enhance umami [70]. Histidine in fish sauce also contributes to the umami and “fish sauce-like” taste, especially for tunny fish sauce [5]. The last amino acid is glycine, found in shrimp sauce. Like alanine, Glycine is an amino acid representing sweetness, especially in shrimp sauce [37,68].

Table 4. Free amino Acid with Dominant Taste Properties of Fish Sauce

Fish Sauce	Amino Acid	Association Taste Properties	References
Anchovy Fish Sauce	Glutamic acid Leucine Lysine Aspartic acid Valine	Umami Bitterness Sweetness Umami Bitterness	[1,10,13,17,26]
Sardine Fish Sauce	Aspartic acid Glutamic acid Lysine Alanine Leucine	Umami Umami Sweetness Sweetness Bitterness	[10,12,31]
Mackerel Fish Sauce	Aspartic acid Alanine Leucine Glutamic acid Arginine	Umami Sweetness Bitterness Umami Bitterness	[10,32]
Tunny Fish Sauce	Glutamic acid Histidine Aspartic acid Alanine Leucine	Umami Bitterness Umami Sweetness Bitterness	[6,34,35]
Squid Sauce	Glutamic acid Alanine Lysine Valine Aspartic acid	Umami Sweetness Sweetness Bitterness Umami	[15,36]
Shrimp Sauce	Glutamic acid Lysine Aspartic acid Alanine Glycine	Umami Sweetness Umami Sweetness Sweetness	[20,37,38]
Clam Sauce	Alanine Glutamic acid Aspartic acid Valine Leucine	Sweetness Umami Umami Bitterness Bitterness	[41]

4 Conclusion

Previous research has categorized variations in raw materials for processing fish sauce in various countries, such as anchovies, sardines, mackerel, tuna, squid, shrimp, and clams. Variation raw materials of fish sauces have variant formulations with processing flow. However, the fundamental for the fermentation process remains the same, which involves the application of salts onto the fish. Previous studies have shown the presence of free amino acids like glutamic acid, aspartic, alanine, valine, lysine, leucine, histidine, arginine, and glycine, contributing to its flavor taste in multiple varieties of fish sauces.

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