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Exploring the nutritional value, health benefits and concerns associates in selected fermented fish product in Southeast Asia: A review

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Abstract

Fermented fish is a staple food in Southeast Asian cuisine with a unique flavor and nutritional properties. This paper provides a comprehensive review of fermented fish, its types and methods of fermentation, nutritional value, health benefits, and risks. The paper highlights traditional and modern methods of fermentation using various types of fish and provides examples of popular fermented fish dishes. The nutritional value of fermented fish is emphasized, including their high protein and amino acid content, omega-3 fatty acids, vitamins, and minerals. Moreover, fermented fish has demonstrated promising health benefits such as improved cardiovascular health, gut health, and anti-cancer properties. However, high sodium content and potential risks of histamine poisoning, or other foodborne illnesses require caution in the consumption of these foods. The paper concludes by underscoring the cultural and public health significance of fermented fish and highlighting the potential for further research on the health benefits and risks of this traditional food.

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1. Introduction

Fermented fish is a process of preparing fish by allowing it to ferment, which changes the texture, taste, and aroma of the fish (1). In this process, the fish is traditionally salted and dried out in the open air, allowing microorganisms such as *Bacillus* spp., *Staphylococci* spp., and *Micrococci* spp., which are also prominent to colonize the fish. In fermented fish products, microorganisms catalyze protein degradation by secreting proteases, thereby altering the nutritional values of foods (2). Notably, fermentation can occur spontaneously or be achieved by adding a starter culture (3). Bacteria secrete enzymes that break down the proteins in the fish, resulting in a more tender texture. This preservation technique is commonly found in

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Southeast Asian cuisines, particularly Thailand, Malaysia, Indonesia, and the Philippines. Note that fermented fish is often used as a condiment, seasoning, or flavor enhancer in dishes (4).

In Southeast Asia, fish is a fundamental component of the region's culinary traditions, playing a critical role in local diets and food culture. In these cultures, it holds great cultural and historical importance (5). Fermentation is essentially a preservation technique that allows fish to be stored for extended periods, even without refrigeration technology (6). This was especially crucial in the past when it was a way to ensure food security. Fish tends to spoil quickly and is highly susceptible to microbial contamination if not salted, fried, smoked, or preserved (7). Moreover, fermentation is also used to enhance the flavor of the fish, thereby making it more savory.

Furthermore, fermented fish is used in various dishes and can be enjoyed in various forms (8). For example, in Thailand, it is commonly used in Som Tam. This popular salad combines shredded papaya, fish sauce, and lime juice, as well as in spicy dishes like Nam Khao Tod, a crispy rice salad flavored with fermented fish sauce and chili peppers (9). In Malaysia, fish paste, a by-product of fermented fish, is used extensively in many dishes, such as soups, stews, and fried rice (10). Ultimately, fermented fish has a rich culinary history in Southeast Asia, and today, it continues to be a signature ingredient in many traditional dishes.

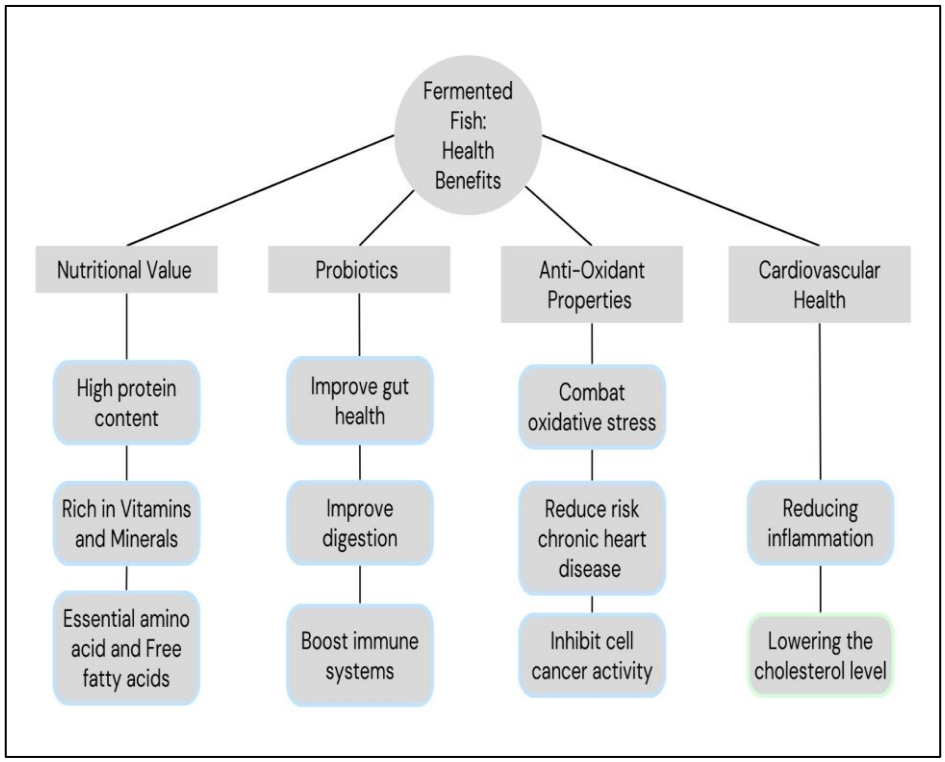

Figure 1. The health benefits of fermented fish products (11–14).

Fermented fish, on the other hand, has the highest potential (Figure 1) to promote public health by providing a nutrient-rich food source. Consuming fermented fish can help boost the immune system and reduce the risk of chronic diseases, such as heart disease and cancer. Additionally, promoting the consumption of fermented fish can help reduce the incidence of foodborne illnesses, as the fermentation process kills harmful bacteria and increases the bioavailability of essential nutrients. Furthermore, fermented fish can contribute to a balanced diet and support overall well-being, particularly for individuals with

specific dietary needs or restrictions. Moreover, small-scale fermentation operations can be established in rural communities, providing job opportunities for local residents and supporting local economies while promoting healthy eating habits (4).

However, further research is required to investigate the nutritional quality of fermented fish products in Southeast Asia, particularly with regard to their protein, fat, fatty acid, amino acid contents, and mineral contents. Additionally, the potential health benefits and adverse effects of consuming these products should be examined to fully understand their advantages and limitations. The purpose of the paper is to provide a comprehensive review of fermented fish in Southeast Asian cuisine. The paper highlights the different types of fermented fish products, fermentation methods, their role in traditional dishes, and their nutritional value. In addition, the article will explore the potential health advantages of consuming fermented fish while examining the perceived risks and highlighting necessary precautions to guarantee its safe consumption. Ultimately, the paper seeks to emphasize the importance of fermented fish in Southeast Asian culture and encourage further research into its health effects, potential, and implications for public health policies.

2. Fermented Fish Products

Fermented fish products are commonly found in Southeast Asian countries but can also be found in other regions. The procedures utilized to manufacture these fermented fish differ across different countries since each has its own distinct manner of presenting its culture through food taste and flavor. In addition, fish commonly used in fermentation in Southeast Asia include various types of freshwater and saltwater fish, such as sardines, anchovies, and mackerel, which are locally available and affordable (15). Notably, fish fermentation may be classified into two types: salt-based fermentation and lactic fermentation. Salt-based fermentation is the most commonly used method for producing fermented fish products. The principal basic materials utilized are fish and salt, which initiate the fermentation process by promoting the growth of lactic acid bacteria and other microorganisms in the fish. By controlling moisture and temperature, these bacteria and microorganisms work to break down the carbohydrates and proteins present in the fish, leading to a unique, tangy flavor and texture (16).

Flavoring agents used may include tamarind, palm sugar, monosodium glutamate, and additional flavors that vary depending on the specific producer's preference and target market (17). For instance, producers catering to Asian markets may use a different blend of flavorings compared to those targeting Western markets. Additionally, local preferences and cultural traditions also play a significant role in determining the types of flavorings used. Meanwhile, lactic fermentation involves the use of starter cultures, which are selected strains of beneficial bacteria or fungi that are added to the fermentation mix to achieve consistent and predictable results. The use of starter cultures can help standardize the fermentation process and reduce the risk of contamination while also promoting even fermentation throughout the fish (16). At the same time, the amount of added carbohydrates (such as cooked rice, brine, millet, flour, and even syrup) and salt concentration primarily control the extent of the end products. Fermented fish end products can be divided into three types (Fish sauce, fish paste, and whole fish) depending on their forms. A list of fermented fish products in Southeast Asia is presented in Table 1.

Table 1. The list of selected fermented fish products in Southeast Asia.

Name of Products	Type of Products	Texture	Country	References
Budu	Fish sauce	Liquid	Malaysia	(18)
Nam-pla	Fish sauce	Liquid	Thailand	(19)
Bagoong Alamang	Fish sauce	Liquid	Philippines	(20)
Belacan	Fish paste	Solid	Malaysia	(10)
Kapi	Fish paste	Solid	Thailand	(21)
Terasi	Fish paste	Solid	Indonesia	(22)
Pekasam	Whole fish	Semi-solid	Malaysia	(10)
Peda	Whole fish	Semi-solid	Indonesia	(23)
Burong Isda	Whole fish	Semi-solid	Philippines	(20)

2.1. Fish Sauce

Fish sauce is a liquid condiment made from the fermented and processed flesh of fish, typically small fish such as anchovies or sardines. It has a unique aroma, is dark brown or gray in color, and has a strong salty taste. It is commonly used as food seasoning in cooking and condiments in daily meals. Fish sauce production begins with whole fish being washed, rinsed, and drained before being mixed with salt (11). Generally, an approximate ratio of 3:1 is used in which three parts of fish are mixed with one part of salt. Consequently, it is placed or packed into plastic jars or concrete tanks for large producers with lined layers of salt and left to ferment for a period of time up to 18 months (24). Traditionally, the fermented fish is usually weighed down with a bamboo mat, nylon net, or rocks to prevent the fish from floating, and small holes are made to remove excessive water. After fermentation, the clear aqueous product of prolonged salting fish fermentation, known as fish sauce, will be produced. Subsequently, the fish sauce will be filtered to remove any solid residues and then bottled before being sold in the market in liquid form (17). *Nam-pla* (Thailand), *Patis* (Philippines), *Kecap Ikan* (Indonesia), and *Budu* (Malaysia) are some examples of fish sauce products.

2.2. Fish Paste

Fish paste is generally a condiment or flavor additive for rice dishes and is made by reducing the water content of fish to produce puree. It has a pinkish or purplish gray to a dark grayish brown color, depending on the coloring agent added during the making process. The texture of fish paste comes in different forms depending on how long it was exposed to the sun, which ranged from soft and pasty to dry and hard. In addition, it has a strong, pungent smell compared to fish sauce but has a delicious taste. Fish paste is produced by washing, rinsing and draining the raw material, which is small anchovies or plankton krill. Subsequently, the anchovies are mixed with salt in a 5:1 ratio in which five parts of the anchovies are mixed with one part of salt. After that, the salted anchovies are grounded until they become a fine paste before sun-drying to reduce the moisture content. The mixture is stored in jars at ambient temperature for approximately one month or until a typical aroma is developed (25). After the fermentation process is completed, the colour of the mixture will change from pink

to purplish brown with a hard and dry texture. The mixture will be formed according to the desired shape prior to being placed in a plastic or glass jar. *Belacan* (Malaysia), *Bagoong Alamang* (Philippines), *Terasi* (Indonesia), and *Kapi* (Thailand) are some examples of fish paste products.

2.3. Whole Fish

Fermented whole fish products are made by fermenting the fish either whole or with a significant portion of its original form. The principle method to make fermented whole fish is quite similar to other fermented fish products, which includes salting and drying. It consists of two stages of the fermentation process. The first fermentation process of this product begins with washing and cutting the fresh fish into small pieces. Correspondingly, the cleaned fish is arranged in layers by utilizing a dried banana leaf as a divider in the container, and salt is added during this process, known as the maturation phase.

The container is filled with saturated brine solution, and the salting process is allowed for three days. The fish is cleaned with brine solution, placed in a bamboo container, and then dusted with fine salt to eliminate excess salt (26). After the salting process, the fish remains wet and stored in a container. Consequently, it is allowed to dry slowly, and then it naturally undergoes the second fermentation process. During the second fermentation phase, the container is stored at room temperature for one to two weeks, and the process continues for two to three months. Examples of whole fish products include *Peda* (Indonesia), *Pekasam* (Malaysia), *Burong Isda* (Philippines), and *Pla-ra* (Thailand). The fundamental process of fermented fish products is displayed in (Figure 2) (15).

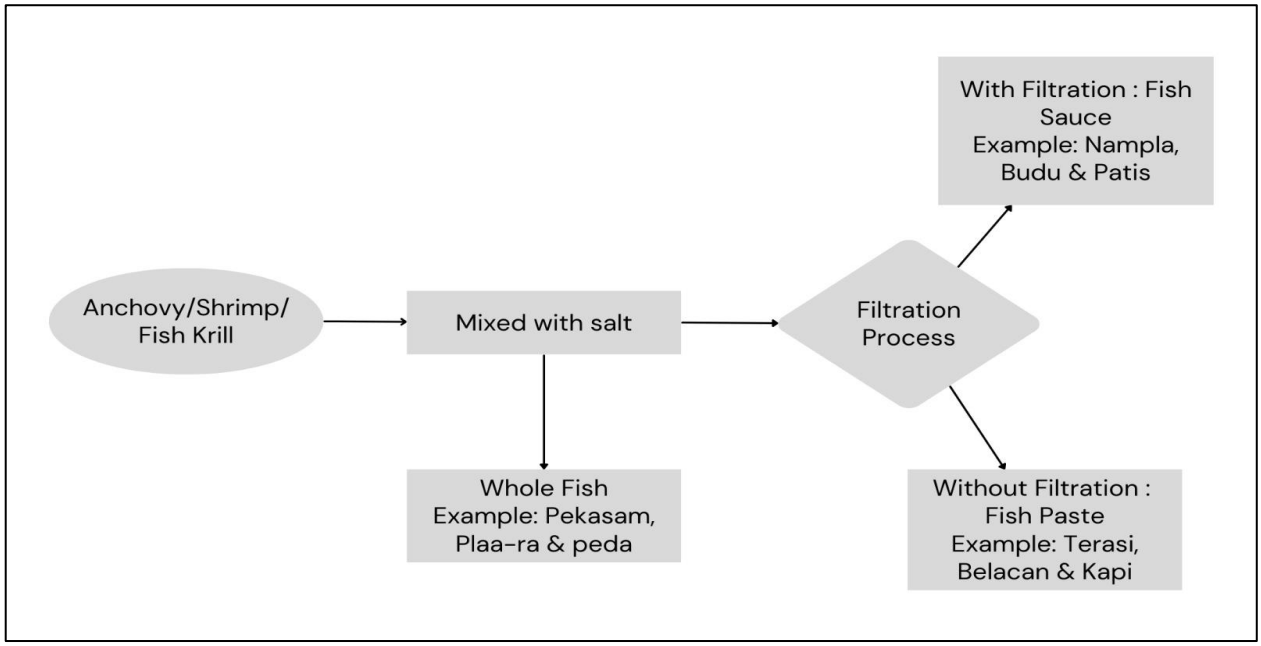

Figure 2. Fundamental process of fermented fish products (5).

The characteristics of Southeast Asia fermented fish products were determined by their pungent smell, which may be off-putting to some individuals (27). As the fermentation process alters the texture of the fish, products often have a soft, chewy, or slimy consistency, depending on how long they have been fermented. Fermented fish products are highly nutritious due to increased protein levels and improved availability of vitamins and minerals

from fermentation (28). These products have the additional benefit of extended shelf life, making them an ideal food source for local communities that live far away from urban areas (29). It is noteworthy that each Southeast Asian country has its unique approach to fermenting fish products, resulting in different flavors and textures. In Southeast Asia, fermented fish products may not be available to everyone. However, lovers of this cuisine relish the distinctive tastes, textures, and nutritional value they bring to their meals.

The production of fermented fish products is categorized into traditional and modern methods. Traditional and modern fermentation methods differ in many ways. Traditional methods employ simple techniques and rely on natural environmental factors such as temperature, humidity, and airborne microorganisms to initiate fermentation. At the same time, modern methods utilize technology, chemicals, and controlled environmental conditions to speed up the fermentation process (15). In traditional methods, the fermentation vessel is usually made of clay or wood and placed in a natural environment like a stable or a cave. Ingredients like yeast, salt, or lactic acid are added to the mix, and the mixture is left to ferment at an ambient temperature for a specific duration. The fermented food is then preserved in traditional ways like smoking, salting, or drying, depending on the local tradition. This method is often slow, but it allows for the preservation of traditional flavors and can produce unique and complex flavor profiles.

In contrast, modern fermentation methods use advanced technology like high-pressure fermenters, temperature control, and artificial inoculation of microbial cultures (30). Chemicals like antibiotics and preservatives may also be added to speed up and control the fermentation process. This results in more consistent and predictable results, which is essential in commercial production settings (6). However, there is still a significant demand for traditional fermented foods due to their unique textures and flavors. Moreover, traditional methods are deemed sustainable, environmentally friendly, and safe, as the natural fermentation process inhibits the growth of harmful microorganisms. Summing it up, while modern fermentation methods provide more controlled and predictable results, they tend to produce uniform and less complex flavors. At the same time, traditional fermentation methods employ natural variables that can result in varied and complex flavors that are much loved by many cultures worldwide.

3. Nutritional Quality of Fermented Fish Products

Nutritional quality refers to the amount and variety of essential nutrients in a particular food item or product. It includes the presence of macronutrients such as carbohydrates, proteins, and fats, as well as micronutrients such as vitamins and minerals necessary for proper growth, development, and overall health (12). When considering the nutritional quality of fermented fish products, examining the concentration of essential nutrients and any potential risks associated with consuming these products is crucial. Overall, fermented fish products can be a good source of essential nutrients. Hence, it is vital to include them as part of a balanced diet that incorporates various other nutrient-rich foods.

3.1. Proximate Analysis of Fermented Fish Products

Proximate analysis of fermented fish (Table 2) separated into its basic components, such as moisture, protein, fat, ash, pH, and carbohydrates (25,31,32). The moisture content of fish sauce ranges from 62.86% to 71.87%. *Kecap Ikan* has the highest moisture content, while *Nam-pla* has the lowest. In contrast, the moisture content of fish pastes ranges from 32.16%

to 67.44%. The moisture content of fish sauce was expected to be high since it was a liquid product. Fish paste was classified as an intermediate moisture food since it lost most water content during sun-drying. Note that several studies stated that the moisture contents varied based on the type of fish used and the treatment of samples or the processing method used in order to get the final products (4,33).

Table 2. The proximate analysis data of fermented fish products.

Parameter/Sample	Moisture	Ash	Protein	Fat	Carbohydrate	pH
Fish Sauce						
Nam-pla	62.86	-	1.60	-	-	5.30
Budu	68.50	16.68	12.21	0.41	0.07	5.17
Kecap Ikan	71.87	23.50	1.60	0.50	1.50	5.42
Patis	66.20	22.50	5.35	0.31	3.60	5.10
Fish Paste						
Kapi	33.93	32.94	26.20	3.91	2.57	7.16
Belacan	32.16	56.15	31.83	1.01	11.01	7.31
Terasi	40.64	29.12	30.47	3.52	1.94	7.53
B. Alamang	61.67	22.82	21.89	5.13	1.33	5.21
Whole Fish						
Pla-ra	62.39	-	18.94	2.17	-	5.20
Pekasam	67.44	43.97	34.22	2.38	19.43	4.96
Peda	46.85	16.90	28.12	1.37	17.46	6.00
Burong Isda	54.29	-	25.10	1.78	14.92	5.78

Several studies have discovered that fermentation typically leads to an increase in the moisture content of fermented fish over time. This rise in moisture is attributed to the absorption of water from the surroundings and the emission of volatile substances resulting from fermentation reactions within the fish (4). Thus, the moisture content of the products is usually high. However, the differences among them might be due to their water activity (Aw) (34). Conversely, certain research also highlighted the reduction in moisture content in fish following fermentation, which occurs due to the osmotic movement of salt and water. As salt and water are drawn out of the fish during fermentation, moisture levels decrease (4,25). A study by Sripokar et al. (25) has reported that the water activity of fermented fish products is correlated with its moisture content, in which this water activity is reduced by salt migration and equilibration of soluble components. Notably, the high salt concentration in fermented food reduces water activity and provides an advantage as a bacteriostatic for spoilage microorganisms, creating unfavorable conditions for microbial activity (34–36). Protein hydrolysis also may impact the moisture content since it may increase the solid matter in semi-liquid products such as *Budu* (37).

The determination of ash content is to identify the level of mineral contents present in a product that is not destroyed by high temperature (38). A previous study of fish sauce demonstrated *patis* with 22.50%, *Kecap Ikan* with 23.50%, and *Budu* with 16.68% of ash content value. No recent studies have reported the ash content value for *Nam-pla*, and it was expected to have low ash content since its raw material is anchovies. According to Herlina and Setiarto, (2024) (22), fermented food that uses shrimp as raw material will have high ash content due to the presence of inorganic substances in the shrimp shell. Thus, fermented fish products such as *Belacan* and *Cincalok* have higher ash content since shrimp itself is abundant in mineral content. Both *Belacan*, with 56.15%, and *Cincalok*, with 43.97% ash value, do not comply with the Malaysian Food Act 1983 (Act 1981) and Regulations (1985) since they

exceed the value suggested by the law. In contrast, the ash value for *Belacan* and *Cincalok* should not be more than 30% and 15%, respectively. It was proposed that other fish paste and fermented fish products provided in (Table 2) above have lower mineral content since their ash content value is low.

Proteolytic enzymes produced during fermentation may decrease the protein content in fermented food. As Sharma et al. (35) suggested, fermented food has low protein content compared to fresh material due to the microorganism activity during the fermentation process. Fish paste has a higher protein content, ranging from 21.89% to 31.83%, compared to fish sauce (1.60%-12.21%) and fermented fish products (18.94%-34.22%). The reported protein content varied for different products, which may be due to the concentration of salt added and the period of fermentation (39). This explains the low protein content value of *Nam-pla* and *Kecap Ikan*, which extend their fermentation up to 18 months and cause rigorous degradation of proteins. Note that the fat content of fermented fish products varies depending on the raw material and the processing method used.

This previous study explains the high amount of fat content in fermented shrimp and shrimp paste products compared to fish sauce and fermented fish products, as stated in (Table 2) above. According to Sripokar et al. (25), the polyunsaturated fatty acid content in the shrimp contributed to high-fat content. Despite shrimp being used as raw material, some products, such as *Belacan*, have the lowest fat content compared to *Bagoong Alamang*, *Kapi*, *Terasi*, and *Cincalok*. This condition was explained by the processing method used by those products, whereas *Bagoong Alamang* roasted the shrimp, and *Kapi* and *Terasi* dried the shrimp in the oven before fermenting, which extracts the shrimp oil with a huge amount of fatty acid. *Pla-ra* has the highest amount of fat content compared to other products that use fish as raw material.

On the other hand, Yuvaraj et al. (37) have reported that the difference in the fat content of the product might be due to certain factors such as the quality of the fish species, season, and collection sites that reflect its fat value. Carbohydrates have several key functions in the human body, such as providing daily energy and being the primary fuel source for the brain. The carbohydrate content in fermented fish products is higher than in fish sauce and fish paste due to the addition of cooked rice rich in carbohydrates. Furthermore, these ingredients provide various carbon sources that are deliberately added to increase yield and reduce unit cost due to the optimization of hydrolytic enzymes (40). As stated in Table 2 above, Cincalok has a higher carbohydrate content with a 19.43% carbohydrate value, and *Budu* has the lowest carbohydrate content with 0.07%.

Even though the carbohydrate content in *Budu* was small, it was still useful in providing great flavors and aroma for the product. Theoretically, fermented fish is acidic, indicating its pH value is low, and the fermentation process might produce inorganic compounds such as lactic acid, acetic acid, and propionic acid (35). Moreover, the fermentation process generates ammonia, which could also lower the pH value (25). From Table 3, we can observe that the fermented fish products have a lower pH value, ranging from 4.96 to 6.00, attributed to adding rice. This stimulates microbial activity, and the production of this product itself uses lactic acid fermentation in its manufacturing process. Fish sauce products are less acidic than fermented fish products, ranging from 5.10 to 5.42. Fish paste is considered higher in pH value since it ranges from 5.21 to 7.53. According to Ilyanie et al. (41), the high pH of fish paste products is due to its main ingredient, shrimp and salts. However, pH changes may have

occurred due to the methods used to manufacture fermented products. Moreover, common microorganisms such as yeast and mold were usually isolated during the fermentation process and were considered as factors of the pH change.

3.2. Amino Acid Profile Analysis of Fermented Fish Products

The amino acid composition of different fermented fish products has been provided in (Table 3). Amino acids are organic compounds composed of nitrogen, carbon, hydrogen, and oxygen, with a variable side chain group. Based on previous studies, fewer researchers have studied the amino acid composition of fermented fish products except for *Nam-pla*, *Kecap Ikan*, *Budu*, *Terasi*, and *Kapi*. According to data from previous studies, *Nam-pla* has the highest total amount of amino acid, at 16960.60 mg/g, while *Kapi* has the lowest, at 24.39 mg/g. The amount of its essential amino acid was 3799.80 mg/g for *Nam-pla* and 9.71 mg/g for *Kapi*. The amount of essential amino acids (His, Arg, Thr, Lys, Met, Val, Iso, Leu, Phe, Try) is relatively higher than non-essential amino acids (Ser, Gly, Val, Leu, Asp, Glu, Ala, Pro, Cys, Tyr, Asp, Cys, Glu) both in the *Nam-pla* and *Terasi*. Meanwhile, for *Budu*, *Kecap Ikan*, and *Kapi*, the non-essential amino acid is higher than its essential amino acid.

Essential amino acids are beneficial in various processes, such as building muscle and regulating the immune function of the human body. Meanwhile, non-essential amino acids are considered essential only under specific circumstances, such as illness or stress. The essential amino acid profile of fermented fish products was dominated by Lys, while non-essential amino acids were dominated by Glu. Note that alanine and glutamic acid contributed to the unique characteristic of umami and savory taste. Amino acids are produced from the enzyme reaction and the action of halotolerant microorganisms, which hydrolyze fish protein into amino acids, peptides, and ammonia (42). The differences in amino acid composition among fermented fish products might be due to the raw material used. Products that use the same raw material may be affected by the fish species and the source of the fish itself.

The chemical score, amino acid score, and essential amino acid index were calculated and presented in (Table 3) below. A complete amino acid composition was required in order to calculate the chemical-based measures of the protein quality and nutritional value of fermented fish products. The chemical score is limiting amino acid in the samples, which has the lowest value compared to the average of other essential amino acids. The result reveals that the limiting chemical score in fermented fish products, which are *Nam-pla*, *Budu*, and *Kecap Ikan*, is the amino acid Trp. The value of the amino acid score determines the adequacy of essential amino acids in food products consumed daily. Amino acid Trp exhibits the lowest amino acid score; hence, Trp from fermented fish products (*Nam-pla*, *Budu*, and *Kecap Ikan*) is insufficient for the human body. It must be obtained by consuming other protein-rich foods, such as protein from cereal and milk, or combining two or more protein sources in the diet, which is often used as an effective way to fulfill human diet requirements.

However, fermented fish products can be eaten with other sources of food that have higher Trp to sum up their lackness (42,43). Protein digestibility and PDCAAS were determined to predict the digestibility amount of protein. The high value of protein digestibility indicates that more protein could be digested in the human intestines. The fermentation process has improved the digestibility of food due to the partial degradation of complex protein into more simple and soluble products. Furthermore, the increase of proteolytic enzymes during

fermentation has consequently promoted protein breakdown into smaller peptides easily digested by enzymes (44). *Nam-pla*, *Budu*, and *Kecap Ikan* have lower protein digestibility values, possibly due to stroma protein in fish meat that reduces their percentage of protein digestibility.

Table 3. The amino acid composition of fermented fish products.

Amino acid (mg/g)	*Nam-pla*	*Budu*	*Kecap Ikan*	*Kapi*	*Terasi*
Alanine	644.70	5.70	60.00	2.57	16.30
Arginine	157.70	1.70	26.00	1.69	19.87
Aspartic acid	932.30	8.20	40.70	2.99	32.27
Cysteine	47.50	0.60	0.00	0.06	3.17
Glutamic acid	1449.70	17.4	128.50	0.25	40.14
Glycine	558.20	5.10	20.00	0.00	12.97
Histidine	392.20	3.10	10.20	0.46	21.33
Isoleucine	310.80	4.60	61.00	1.45	15.61
Leucine	388.30	7.10	92.70	2.58	22.55
Lysine	943.20	7.50	48.50	2.23	29.49
Methionine	209.70	3.00	4.50	0.55	9.17
Phenylalanine	904.70	3.80	42.00	1.49	11.03
Proline	395.70	3.50	51.30	3.45	10.30
Serine	407.20	3.20	8.70	0.60	12.50
Threonine	606.70	4.60	9.00	0.00	13.09
Tryptophan	77.20	1.00	0.00	0.00	4.46
Tyrosine	87.50	3.20	26.50	1.19	14.95
Valine	567.00	5.50	78.20	1.41	28.56
∑ Essential	3799.80	40.80	346.10	9.71	175.16
∑ Non-essential	13160.80	48.00	361.70	14.68	147.42
∑ Amino acid	16960.60	88.80	707.80	24.39	322.58
Chemical score	4.22	5.88	0.00	-	-
AA Score	5.88	9.09	0.00	-	-
EAA Index	732	8.56	0.56	-	-
Protein Digestibility (%)	66.26	67.29	66.51	-	-
PDCAAS (%)	100	9.80	10.70	-	-

3.3. Fatty Acid Profile of Fermented Fish Products

Fatty acids are a fat or lipid main component comprising hydrocarbon chains terminating with carboxylic acid groups. The amount of fatty acid in food is correlated with its fat content, but it comes with more specific information. Essential fatty acids are needed by the human body. However, they cannot be produced naturally in sufficient amounts to meet physiological needs due to the absence of the required enzymes. Therefore, they must be obtained by proper diet intake. An omega-3 and omega-6 fatty acids are essential fatty acids that can be obtained by eating fish and its products, such as fish oil (45). As mentioned previously, fish is a main food source rich in omega-3 fatty acids. Consumption of omega-3 fatty acids may reduce inflammation throughout the body.

Inflammation in the body can damage the blood vessels and lead to heart disease and strokes. Fermented fish, as one of the fish products, may also be a good source of omega-3 fatty acids (45). However, studies investigating fatty acid compositions in fermented fish products worldwide are limited. Each of those studies produced different results without any common consistency. Despite the fact that minimal research has been conducted regarding fatty acids content in fermented fish, the presence of omega-3 fatty acids in fermented fish products cannot be denied. As a naturally hydrolyzed product, the omega-3 content is high in

fish sauce. This is especially true for anchovies in fish sauce, which abound in omega-3 fatty acids (45). However, the presence of omega-3 fatty acids cannot explain the different values in unsaturated and saturated fatty acids. Therefore, thorough investigations are required to obtain more information about the contradictions of fatty acid composition.

3.4. Mineral Composition of Fermented Fish Products

Minerals are one of the nutrients needed in the human body, also known as essential minerals that help bones, muscles, heart, and brain work properly. Minerals are also crucial for making enzymes and hormones. Essential minerals can be divided into major minerals (macrominerals) and trace minerals (microminerals). These two groups of minerals are equally essential in maintaining a healthy body. However, micro minerals are only required in smaller amounts than macro minerals. The mineral composition of fermented fish has been stated in (Table 4) based on several studies by previous researchers. The information about fermented fish has been summarized into three categories: fish sauce, fish paste, and whole fish since the information or current study about each mineral composition of fermented fish products is low. Moreover, a study made by Narzary et al. (2021) (5) has proved that fermented fish increases the nutritional value of fresh fish, including its mineral composition compared to fresh fish.

Fish paste has high Calcium (Ca) and Phosphorus (P) content, with 115.7 mg and 18.8 mg. Fish sauce and whole fish with 7.7 mg, 1.3 mg and 28.9 mg, 26.4 mg, respectively. The amount of Ca and P was attributed to the decomposition of fish bone and other structures by bacteria lactic acid in the fermented process (46). Ca is vital in nerve functioning, blood pressure regulation, and immune system health. Both Ca and P are essential for healthy bones and teeth. Magnesium (Mg) is discovered naturally in many different foods, including fermented fish products. Notably, fish paste has a high Mg value of 470.8 mg, followed by fish sauce at 31.5 mg and whole fish at 15.9 mg. In addition, Mg helps maintain the proper level of other minerals such as Ca, P, and Zinc to ensure they are well-functioning.

Table 4. Mineral composition of fermented fish products (45,47,48)

Mineral	Fish sauce	Fish paste	Whole fish
Macro Mineral			
Ca (mg)	7.7	115.7	28.9
P (mg)	1.3	18.8	26.4
Mg (mg)	31.5	470.8	15.9
Na (mg)	1389.6	2766.8	855.9
K (mg)	51.8	774.7	163.9
Micro Mineral			
Fe (mg)	8.7	2.1	0.6
Cu (mg)	0.1	0.1	0.1
I (mg)	0.0	0.0	0.0
Zn (mg)	0.4	0.5	0.5
Selenium (mg)	1.6	24.5	18.3

All fermented fish products have the highest amount of Sodium (Na) compared to other minerals since salt is mixed in their manufacturing process (48). The main source of Na is salt, which is used as a condiment and inhibits microbial activity in the fermentation process. Na is needed for proper fluid balance, nerve transmission, and muscle contraction (49). However, high Na consumption and low potassium intake will contribute to high blood pressure and heart disease. A small amount of micromineral is recorded for fermented fish products, and

no presence of hazardous minerals and heavy metals was detected. Note that heavy metals such as Aluminium, Arsenic, and Cadmium are very dangerous to the human body. Even in tiny amounts, these minerals would lead to nerve dysfunction and memory loss, a weakened immune system, and even kidney damage.

4. Health Benefits of Fermented Fish

In addition to preventing food contamination, fermented fish products are essential in human nutrition and cannot be produced in the human body (5). To stay fit and healthy, humans must consume several foods high in peptides, vital amino acids, and other nitrogenous chemicals, like fermented fish products. Fish products improve their nutritional value through their activity during fermentation, and microorganisms and enzymes are responsible for creating these beneficial chemicals that help maintain good health.

Furthermore, these products contain a variety of vitamins and minerals. Aqueous soluble present in fish sauce include vitamin A, vitamin B1 (thiamine), vitamin B2 (riboflavin), vitamin B6 (pyridoxine), and niacin. Fish products are also enriched with minerals such as Manganese (Mn), Ca, Mg, P, Na, and Iron (Fe). Peptides and amino acids, which arise naturally during the fermentation of salted fisheries products, are recognized as antioxidants and play a significant function as flavor and aroma enhancers. According to Nikoo et al. (2023) (50), fermented fish flesh protein hydrolyses include hydrophobic amino acids with significant free radical-scavenging activity. They can protect against oxidation by giving protons to free radicals.

The antioxidant properties of fermented fish are beneficial in reducing certain cancers by preventing or reducing oxidative damage. The activation of apoptosis in a human lymphoma cell line by peptide fractions extracted from the anchovy sauce of *Budu* and *Nam-pla* had an anticarcinogenic effect. It demonstrated potential in preventing cancer (11). Many fermented fish products have antioxidant properties, such as fermented blue mussels, fish sauces, and fermented fish shrimp. At the same time, biogenic amines are abundant in fish products and are mostly produced through microbial decarboxylation of amino acids (35). Since biogenic amines are nitrogen sources and can create hormones, nucleic acids, alkaloids, and proteins, they are critical to human health. Furthermore, they can govern activities in the human system, such as body temperature regulation, blood pressure increases or decreases, and nutrition intake (12). Thus, fermented fish is considered one of the protein sources for the human body that provides many health benefits to stay healthy by following individual nutritional needs.

Overall, research has proven that consuming fermented fish products may have various health benefits. For example, the high omega-3 fatty acid content of fermented fish products has been linked to improved cardiovascular health, including reducing the risk of heart disease and stroke (13). Fermented fish products also contain beneficial microorganisms that can improve gut health, aid digestion, and boost the immune system (14). Additionally, research has proven that fermented fish products contain bioactive compounds that have anti-cancer properties (51).

5. Risk and Precautions

Fermentation is a natural process that increases the shelf life and enhances the flavor of these products. However, it is crucial to understand the potential risks associated with consuming fermented fish products and take necessary precautions to avoid foodborne

illnesses. One risk associated with fermented fish products is the presence of histamine. Note that histamine is a biogenic amine produced during fermentation and can accumulate in high levels in some products (52). Histamine production in fish fermentation occurs when bacteria from the Enterobacteriaceae family, such as Klebsiella, Enterobacter, and Citrobacter, convert free histidine (an amino acid found naturally in fish) into histamine (53). This can occur during fish storage, especially when the temperature is not adequately controlled. In traditional fish fermentation processes, fish is often stored at ambient temperatures, which can allow bacterial growth and histamine production.

The bacterial growth is mainly due to the salt present in the fermentation process, which inhibits other microorganisms while encouraging the growth of histamine-producing bacteria (54). Consumption of fish products with high levels of histamine (more than 100 mg/day) can cause scombroid poisoning, which can lead to symptoms such as headache, nausea, vomiting, and skin irritation. Note that histamine production can be reduced by controlling the fermentation process, specifically the temperature, time of fermentation, and the addition of bacterial growth inhibitors (53). One effective method is hygienically handling high-quality raw fish, preventing bacterial contamination. To decrease the risk of scombroid poisoning, individuals must consume fermented fish products that have been properly stored and refrigerated below 4°C (55).

Another potential risk is the presence of *Clostridium botulinum*, a bacterium that grows in anaerobic conditions and can produce toxins that can lead to botulism. The fermentation process of fish products can create an environment for *C. botulinum* to grow. To reduce the risk of botulism, individuals must ensure that fermented fish products are made using fresh ingredients, properly cooked, and stored at an appropriate temperature (56). In addition, precautions must also be taken to prevent cross-contamination between raw and fermented fish products. Fish, especially raw fish, can contain harmful bacteria such as *Vibrio parahaemolyticus* and Salmonella. Moreover, individuals must ensure that raw fish products are thoroughly cleaned and cooked before being used in fermented fish products. Individuals must also use separate utensils and cutting boards for raw and fermented fish products to avoid cross-contamination (57).

Another precaution to consider is avoiding homemade fermented fish products unless following a reliable and safe recipe. Homemade products may not undergo the necessary quality control and safety measures as commercial products, increasing the risk of contamination (55). In accordance with the Malaysian Food Regulations 1985, which falls under the Food Act 1983, and standard food safety practices, to ensure the safety of a fermented fish product, the manufacturer must adhere to public health control measures, utilize permissible food additives, label clearly, maintain microbiological standards, utilize appropriate packaging material, and undergo routine inspections and audits by the health authorities. In conclusion, fermented fish products can provide a unique taste experience and nutritional value. However, it is crucial to take precautions to avoid potential risks. These precautions include consuming properly stored and refrigerated products, using fresh ingredients, avoiding cross-contamination, and avoiding homemade products unless following reliable and safe recipes. Accordingly, by practicing these precautions, individuals can safely enjoy the many benefits of fermented fish products while minimizing the risk of foodborne illnesses.

6. Conclusions

Fermented fish are produced in different ways around the Southeast Asian region, mostly influenced by culture and followed by their ancestors who passed to them. The same country may also have different processing methods that produce the authentic flavor and savory taste of their own fermented product, representing their region. Fermented fish can be produced by lactic acid fermentation, the final product of which is much better than spontaneous fermentation. Lactic acid fermentation products can be prepared in a shorter time. Hence, a lower cost is required than fermented fish products, which depend primarily on autolytic processes. The salt concentration, species of raw material, and methods used to manufacture fermented fish impact their nutritional quality. In addition, the fermentation period also is one of the factors. Note that longer fermentation could create tastier products and enhance their nutritional value through microbial activity during fermentation. At the same time, microorganisms play an essential role in producing high-quality fermented fish due to their particular metabolic features that help make healthier and safer fermented fish products. Fermented fish has high nutritional quality and is rich in protein, minerals, amino acids, and omega-3 and omega-6 fatty acids, which is good for human health. Despite the fact that fermented fish are always issued with high concentrations of salt, we cannot deny that fermented fish are also good at preventing hypertension and heart disease. The fermented fish and fish products have great potential in developing novel fish products with improved food safety, nutritional value, and health benefits.

7. Future Prospects and Challenges

The demand for fermented fish is increasing worldwide. Hence, new technology needs to be introduced in order to fulfil the market needs while maintaining the quality of the products produced. Therefore, additional studies are required to get more information about fermented fish in Southeast Asia, especially in the Philippines, where there are few scientific studies about their fermented fish products. Explanations about amino and fatty acids need to be more detailed and precise to ensure the next researcher can understand their features. Thus, future research studies should focus on elucidating the mechanisms by which microorganisms influence the quality of fermented fish. This is crucial for ensuring the high demand for these products domestically and internationally.

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Author Contributions

M.B.A; Formal analysis, writing original draft preparation. N.B.J., N.H, J.B.R and A.H.B.M.S.; Conceptualization, methodology, funding acquisition, writing review and editing. F.C.N and Y.; Writing review and editing.

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Conflicts of Interest

The author claimed no conflict of interest.

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