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A Systematic Review of Fish Protein Hydrolysates in Functional Foods: Balancing Nutritional Fortification with Sensory Acceptance

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ABSTRACT

Fish and fish by-products are rich in high-quality protein and bioactive compounds, but their use in value-added food products is still limited. Fish protein hydrolysate (FPH) has outstanding digestibility and functional properties, making it a potential ingredient for food fortification. However, differences in fish species, hydrolysis methods, and fortification levels can affect nutritional quality and sensory acceptance. This literature review aims to synthesize the latest evidence on the impact of adding various types of fish protein hydrolysates to food products, with a focus on nutritional value, physicochemical properties, and sensory characteristics. The literature review was conducted using the ScienceDirect and PubMed databases following the PRISMA approach. Thirteen eligible studies published between 2015 and 2025 were analyzed using descriptive qualitative analysis. The reviewed studies indicated that FPH derived from salmon, tilapia, seabass, anchovy, tuna, cod, sea bream, and mullet consistently increased protein content, improved amino acid profiles, increased antioxidant activity, and, in some cases, improved mineral content and shelf life. Moderate fortification levels (around 5–10%) provided the best balance between nutritional improvement and sensory acceptance, while higher levels tended to cause darker color changes, texture changes, and unpleasant tastes such as bitterness. Fish protein hydrolysates are promising functional ingredients for nutritionally enriched food products. Optimization of hydrolysis methods and fortification levels is necessary to maximize nutritional benefits while maintaining sensory quality. Further research is needed to evaluate bioavailability and long-term health effects, especially in nutritionally vulnerable populations.

Key Messages:

- Fish protein hydrolysate significantly increases the protein content in food products.
- Different fish species and hydrolysis methods affect the physical and sensory properties of food.
- Moderate fortification levels provide the best balance between nutrition and acceptance.

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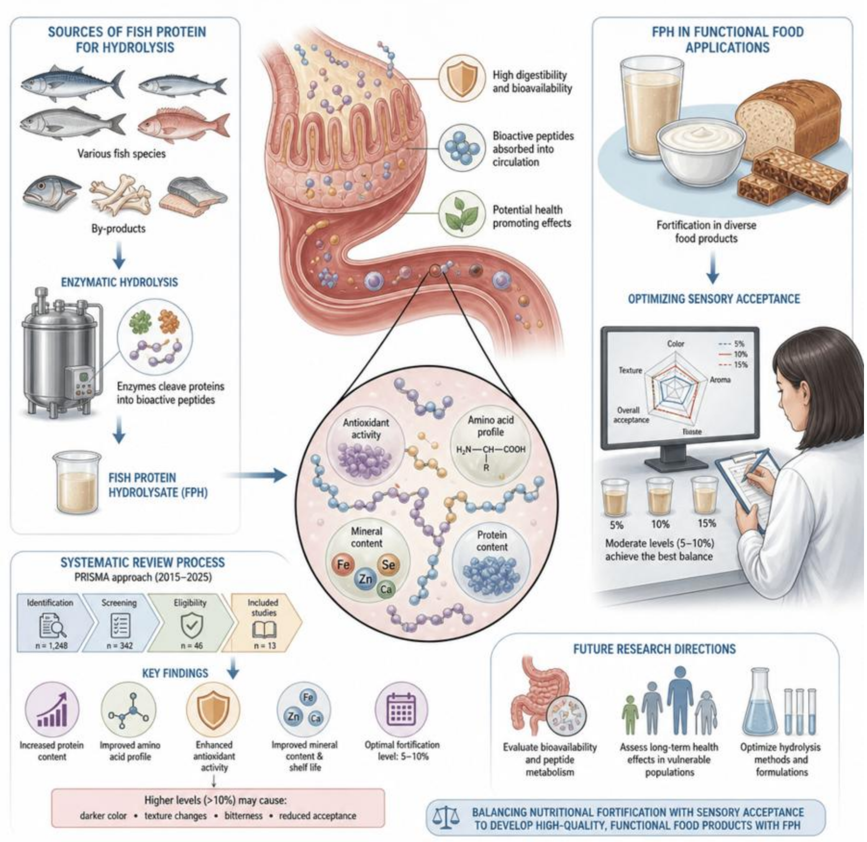
GRAPHICAL ABSTRACT



INTRODUCTION

Fish is a nutrient-rich animal food product, rich in protein and essential amino acids, with good digestibility (1,2). In addition, fish contains essential fatty acids, vitamins, and minerals that play an important role in the body's growth and development processes (1,3). The high nutritional content of fish has enormous potential as a raw material or additive in the development of functional foods. Fish plays a strategic role in meeting the nutritional needs of the community(1). However, the use of fish as a high-value food ingredient is still relatively limited. To date, fish processing has been limited to direct consumption in fresh, canned, and dried forms. On the other hand, the sensory characteristics of fish, especially its distinctive fishy odor, are one of the factors that cause low acceptance of fish among certain groups of people. This condition has led to the large-scale suboptimal utilization of fish's nutritional potential, as well as an increase in waste from the fish processing industry, such as bones and unselected small fish, which have been underutilized and become fishery waste or production waste (4). However, according to research conducted, fishery waste has fairly satisfactory nutritional content, namely 5-80% protein, 1-60% fat, and 1-60% minerals (5).

One of the applications of fish protein currently being developed is fish protein hydrolysate (FPH). Fish protein hydrolysate (FPH) is the result of breaking down protein through an enzymatic process into smaller peptides (4,6). This process produces peptides with smaller chains and sizes, resulting in higher digestibility (4,7). In addition to having better protein content, the hydrolysis process can improve the functional characteristics of proteins, such as stability, foaming, and emulsification, which allows FPH to be easily applied to other products (7). The characteristics of the resulting FPH are greatly influenced by the type of fish, the hydrolysis method, and the enzymes used, resulting in different physical and chemical properties (8). Differences in FPH characteristics will certainly result in differences in the products produced, both in terms of nutritional content and physicochemical properties (color, taste, aroma, texture, and acceptance).

Although there have been many studies related to the use of fish protein hydrolysates in food

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products like biscuit and cookies, most of these studies only focus on one type of fish protein hydrolysate or one particular fish species without conducting a systematic comparison between different types of hydrolysates. For example, adding hydrolyzed albacore tuna (*Thunnus alalunga*) protein to biscuit products can increase the protein content (9). Furthermore, another preliminary study indicated that adding hydrolyzed protein from the Lemuru fish (*Sardinella lemuru*) can increase the protein content of biscuits (10).

Many studies only focus on increasing protein content, while comprehensive evaluations of product characteristics, especially the relationship between changes in nutritional value, physicochemical properties, and sensory acceptance of food products, are still limited. Therefore, a comprehensive literature review is needed to examine the impact of adding various types of fish protein hydrolysates to the characteristics of the resulting food products. This study aims to synthesize research results on the impact of variations in fish protein hydrolysate types on the nutritional value, physicochemical properties, and sensory characteristics of products, in order to identify general patterns and acceptable upper limits for addition. In addition, the results of this study are expected to serve as a reference for the development of fish protein hydrolysate-based functional food formulations that provide optimal nutritional value and widespread acceptance.

METHODS

Study Design

This study used a literature review design. This approach was chosen because it was considered to supply a detailed primer on a broad and complex topic and to explore the existing literature. This approach was considered appropriate because it could explain the differences in the effects of adding fish protein hydrolysate to food product characteristics. This literature review was compiled through several stages, namely: (1) Identification of research questions; (2) Selection of relevant literature; (3) Data mapping; (4) Analysis of results; and (5) Report compilation. This process ensures that the literature used is relevant to the study topic.

Search Strategy and Eligibility Criteria

The literature search was conducted using the ScienceDirect (Elsevier, available at https://www.sciencedirect.com/) and PubMed (National Library of Medicine, available at https://pubmed.ncbi.nlm.nih.gov/) as online journal databases. ScienceDirect was chosen because it is a multidisciplinary database with broad and relevant coverage. The keywords used included "fish protein hydrolysate," "food," "food products," "fortification," "substitution," "characteristics," "physicochemical," and "sensory." Boolean operators such as AND, OR, and NOT were used to combine keywords in the search. The search process was conducted since December 20, 2025, using a combination of relevant keywords.

The specific steps of the study selection process, carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, are detailed in Figure 1. Initially, the search strategy identified a total of 9,472 potentially relevant records across the ScienceDirect (8,397) and PubMed (1,075) databases. At this identification and initial screening stage, 4,739 reports were excluded (4,166 from ScienceDirect and 573 from PubMed) based on pre-defined automated database filters and manual review. Specific grounds for exclusion within ScienceDirect (n=4,166) included abstracts from other sources (such as review articles (n=2,148), books (n=1,277), other resources (n= 366), restricted articles (n=397), and articles in other languages (n=5)). Reason for exclusion in PubMed (n=573) were abstracts from other sources (n=407), other sources (n=158), restricted articles (n=7), and other languages (n=1). A subset of 5,227 articles (4,483 from ScienceDirect and 744 from PubMed) met the criteria for the publication date range (2015-2025). The number of reports whose detailed retrieval was sought was narrowed down to 542 (371 from ScienceDirect and 171 from PubMed).

Subsequently, the list was refined by screening the title and abstract, which led to the exclusion of 519 reports (358 from ScienceDirect and 161 from PubMed). A full-text assessment for eligibility was performed on the remaining 23 articles (13 from ScienceDirect and 10 from PubMed). After a thorough review, 10 articles were excluded for being unrelated to the research topic. This systematic process

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ultimately led to the final selection of 13 articles, which are now part of this qualitative descriptive literature review.

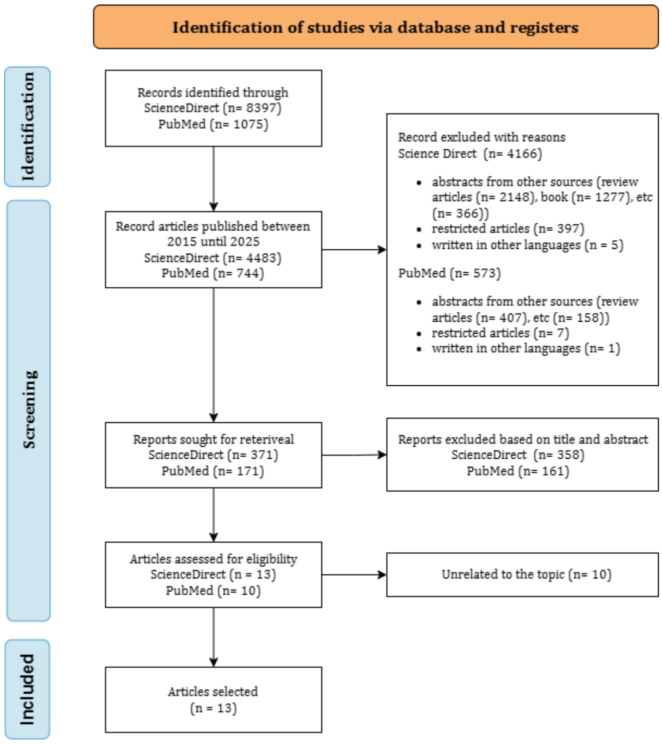

Figure 1 . PRISMA Flow Diagram

Inclusion and Exclusion Criteria

The inclusion criteria established in this study included studies published between 2015 and 2025 to ensure relevance and information needs, written in English, published in open access journals, and providing information related to the addition of fish protein hydrolysate to food products. Exclusion criteria include studies that are not relevant to the topic discussed, articles written in languages other than English, articles that are not available in full text, and articles that discuss the use of fish protein hydrolysate in products apart from food products.

Data Extraction

Data extraction is presented in tabular form to meet the objectives of this review: 1) characteristics of fish protein hydrolysate replacement (author details, type of hydrolysate used, and type of hydrolysis); 2) product formulation and nutritional analysis; 3) product acceptance data (number of panelists and acceptance test tools).

Data Analysis

The extracted data will be analyzed using a qualitative descriptive method with a manual thematic analysis approach. This method was chosen to identify and describe the main themes that emerging in the literature related to the addition of fish protein hydrolysate, which affects food characteristics. The analysis was conducted through systematic stages: researchers familiarized themselves with the data by thoroughly rereading all extracted articles. This was followed by initial coding to highlight specific findings, such as changes in taste, texture, or nutrition. These codes were then grouped to search for broader candidate themes. The candidate themes were reviewed to ensure they did not overlap, before being clearly defined and named (e.g., sensory profiles, physicochemical properties). Finally, the report was produced by synthesizing and comparing findings across the literature into a structured narrative based on these established themes.

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Table 1. Data Extraction

Ref	Source of Fish/By-product	Research Objective	Hydrolysis Method	Product Type	Fortification Level	Primary Nutritional Effects
(11)	Salmon (*Salmo salar*)	Enhancing porridge with bio-calcium and protein hydrolysate for elderly nutrition	Enzymatic hydrolysis (*Protease*)	Porridge	1%, 1.25%, and 1.5%	Increased protein, calcium, and antioxidant activity
(12)	Mullet fish (*Mugil cephalus*) (skin, scales, bones, and leftover meat)	Utilizing fish waste for fish ball production	Fermentation with *Yarrow lipolytica*	Fish balls	1.5%	Extending shelf life; reducing lipid oxidation and histamine formation (good for food safety)
(13)	Tilapia (*Oreochromis niloticus*)	Investigating the effect of THP on nutritional and sensory properties	Enzymatic hydrolysis (*Protease*)	Nutritional bar	5%, 10%, and 15%	Increased protein and ash content; improved amino acid balance, and reduced carbohydrates and fat
(14)	Seabass fish by-products *(Dicentrarchus labrax)* (head and bones)	Strengthening biscuits with fish meal and fish protein hydrolysate	Enzymatic hydrolysis (*Alcalase*)	Biscuits	2.5% and 5%	Increased protein, increased water content, caused by the presence of hydrophilic peptides, potentially affecting cracking and texture
(15)	Salmon (*Salmo salar*)	Enhancing the nutritional value of cookiess through fortification using DSF-PH	Enzymatic hydrolysis and Maillard reaction (glucosamine removal)	Cookies	2%, 4%, and 8%	Increased protein, reduced fat, improved amino acid profile, and enhanced antioxidant activity
(16)	Anchovy (*Stolephorus insularis*)	Evaluating the physicochemical and sensory properties of cookiess enriched with SPI (soy protein isolate) and API (anchovy protein isolate)	Enzymatic hydrolysis	Cookies	F1: 100% SPI, 0% API F2: 75% SPI, 25% API F3: 50% SPI, 50% API F4: 25% SPI, 75% API F5: 0% SPI, 100% API	Increased protein content, improved amino acid profile (especially BCAA)
(17)	Cod (*Gadus morhua*) by-products	Evaluating the nutritional, rheoligical, organoliptic, and textural potential of FPH in the bakery industry	Enzymatic hydrolysis; lyophilized to yellowish-white powder	Bread	P1: 98.5% wheat flour, 1.5% FPH P2: 97% wheat flour, 3% FPH P3: 95.5% wheat flour, 4.5% FPH P4: 94% wheat flour, 6% FPH	Increases protein and antioxidant levels, reduces gluten content in bread, and extends the shelf life of the product.
(18)	Sea bream (*Sparus aurata*) skin waste	Explore potential of gelatin hydrolysate (GH) from skin waste as stabilizer/emulsifier in ice cream	Enzymatic hydrolysis (*Alcalase*)	Ice Cream	D1: sahlep 0.75 g, mono-diglyceride 0.25 g D2: mono-diglyceride 0.25 g, GH 0.75g D3: sahlep 0.75 g, GH 0.25 g D4: GH 1g D5: sahlep 0.33 g, mono-diglyceride 0.33 g, GH 0.33 g	Significant increase in protein content and an improvement in the functional properties of ice cream emulsions

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Ref	Source of Fish/By-product	Research Objective	Hydrolysis Method	Product Type	Fortification Level	Primary Nutritional Effects
(19)	*Blue whiting* (*Micromesistius poutassou*)	Evaluate the feasibility of incorporating blue whiting fish protein isolates (BWFPH) as novel protein bars with whey protein isolate (WPI) and pea protein isolate (PPI), and investigate effects on textural, nutritional, and sensory qualities	Enzymatic hydrolysis	Protein bar	1: 22.25 gram BWFPH 2: 3.76 gram BWFPH 3: 22.25 gram BWFPH 6: 13.10 gram BWFPH 7: 22.07 gram BWFPH 8: 13.82 gram BWFPH 9: 13.10 gram BWFPH 12: 11.43 gram BWFPH 14: 13.82 gram BWFPH 15: 11.43 gram BWFPH 16: 3.76 gram BWFPH	Reduces the hardness of the bar by up to 93%, prevents hardening during storage, and increases the protein, carbohydrate, and mineral content
(20)	*Planizila abu*	Develop functional yogurt with nanoemulsion and microencapsulated FPH to evaluate bioactivity, rheological, physicochemical, and sensory properties during storage	Enzymatic hydrolysis (*Protease)*	Yogurt	Mh10C: $CaCl_2$-microencapsulated-FPH yogurt containing less than 10 kDa protein MhC: $CaCl_2$-microencapsulated-FPH yogurt containing more than 10 kDa protein Neh10a: Alg-Na nanoemulsion-FPH yogurt containing less than 10 kDa protein Neha: Alg-Na nanoemulsion-FPH yogurt containing more than 10 kDa protein	Rich in glutamic acid, aspartic acid, and lysine; enhances acceptable taste and mouth feel, and overall acceptance; In addition, the addition of FPH improves the consistency of the resulting yogurt
(21)	Atlantic salmon (*Salmo salar*) belly loins by-product	Develop chilled texture-modified salmon product for dysphagia patients	Enzymatic hydrolysis	Texture-modified salmon product	1.7%	Enhance protein content and shelf life with health promoting properties
(22)	Common carp roe by-product and silver carp fillets for sausage base	Determining the Effect of Adding FPH on Stabilizing Fish Oil in Silver Carp Sausages (*Silver carp*) during refrigerated storage	Hidrolisis enzimatis (*Alcalase* for 30, 60, and 90 minutes)	Fish Sausage	B: 3 g/100 g FPH 30 min added with 150 g/kg fish oil C: 3 g/100 g FPH 60 min added with 150 g/kg fish oil D: 3 g/100 g FPH 90 min added with 150 g/kg fish oil	Prevents oil oxidation, extends shelf life, preserves omega-3 fatty acids, and increases amino acid content
(23)	Yellowfin tuna (*Thunnus albacares*) red meat by-products	Fortify mayonnaise with FPH by partial egg yolk replacement, evaluate as a fortifying and stabilizing agent	Enzymatic hydrolysis (*Papain*)	Mayonnaise	5%, 7.5%, and 10%	Maintaining emulsion stability without significant loss, increasing protein content, reducing fat content, and increasing antioxidant content

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Table 1. Comparison of Nutritional Content of Fish Protein Hydrolysate Fortified Products

Ref	Best Formulation	Nutritional Analysis		
		Nutrition	**Control (F0)**	**Best Formulation**
(11)	1.5%	Protein (g)		6
		Calcium (mg)	NA	294
		Antioxidants (μmol TE/g DM)		540
(12)	1.5%	Lipid oxidation (meq $_{O_2}$/kg)	13.69	13.83
(13)	10%	Protein (g)	7.04	13.35
		Carbohydrates (g)	80.96	71.18
		Fat (g)	4.24	3.88
		Calcium (mg)	6.62	203.90
		TAA (g/100g)	6.44	16.6
(14)	5%	Protein	6.64	11.35
		Fat	20.89	21.34
		Carbohydrates	67.78	62.63
(15)	4%	Protein (%)	10.65	12.49
		Total MUFA (g/100 lipids)	27.94	26.45
		Total PUFA (g/100 lipids)	1.73	1.86
(16)	F5: 0% SPI, 100% API	Protein (%wb)	4.2	13.29
		TEAA (mg/g protein)	207.41	570.58
		TNEAA (mg/g protein)	356.91	653.31
		TAA (mg/g protein)	564.32	1233.89
(17)	P1: 98.5% wheat flour, 1.5% FPH	Protein (%)	11.37	81.21
		Moisture (%)	43.00	42.06
		Total polyphenols (mg GAE/100g)	126.660	1452.00
		Elasticity (%)	95	97
		Gluten	2	1
(18)	D3: sahlep 0.75 g, GH 0.25 g	Protein (g/100)	3.13	3.32
(19)	16: 3.76 gram BWFPH	Protein (%)	40.14	39.88
		Carbohydrates (%)	30.02	29.08
		Fat (%)	10.07	10.63
(20)	Neh10a: Alg-Na nanoemulsion-FPH yogurt containing less than 10 kDa protein	Antioxidant (IC50 μl/ml)	176.68	127.26
(21)	1.7%	Protein (%)	17.8	18.1
(22)	D: 3 g/100 g FPH 90 min added with 150 g/kg fish oil	Protein (%)	19.26	73.16
		Lipid (%)	3.22	11.37
		Glutamic acid (g/100g protein)	5.66	6.87
(23)	5%	Protein (%)	3.58	6.16
		Fat (%)	50.22	45.29
		Moisture (%)	28.24	24.56
		Carbohydrates (%)	22.95	17.06

*The most preferred products selected by panelists based on organoleptic testing. PUFA: Polyunsaturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; TEAA: Total Essential Amino Acids; TNEAA: Total Non-Essential Amino Acids; TAA: Total Amino Acids.

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RESULTS

The results of the literature review offer an in-depth examination of the impact of adding different fish protein hydrolysates to each food product. Researchers identified that all of the selected literature had similar objectives, namely to improve the nutritional content, characteristics, and sensory properties of the food products produced. Table 1 presents data in the form of a summary of all selected literature, including: 1) Author identity; 2) FPH source used; 3) Research objectives; 4) Hydrolysis method used in FPH production; 5) Products produced; 6) All formulations used in the research; and 7) Significant impacts of FPH addition on the resulting food products.

Studies and characteristics

Fish protein hydrolysate (FPH) can be obtained from various types of fish and fish by-products, such as scales, fins, heads, offal, and bones (4). The hydrolysates used in the literature studied include salmon hydrolysate (*Salmo salar*), mullet hydrolysate (*Mugil cephalus*) by-products, tilapia hydrolysate (*Oreochromis niloticus*), seabass hydrolysate *(Dicentrarchus labrax)* by-products, anchovy hydrolysate (*Stolephorus insularis*), Cod (*Gadus morhua*) by-products, Sea bream (*Sparus aurata*) skin waste, *Blue whiting* (*Micromesistius poutassou*), *Planizila abu,* Atlantic salmon (*Salmo salar*) belly loins by-product, Common carp roe by-product, and Yellowfin tuna (*Thunnus albacares*) red meat by-products. In addition, the hydrolysis method can also be carried out in various ways, including conventional enzymatic hydrolysis, a combination of hydrolysis and the Maillard reaction, and fermentation (Table 1). These variations in method result in different peptide compositions, functional properties, and sensory impacts on the resulting hydrolysate (4,8). The utilization of FPH and its potential has been widely studied and described in the literature. The high protein and amino acid content of FPH is the main reason for adding FPH to food products, especially to address protein deficiency in infants, pregnant women, and lactating mothers. This is because insufficient protein intake can lead to health issues related to child growth and development, pregnancy complications, malnutrition, stunting, and wasting (24). In addition, FPH has bioactive components such as antioxidants, fat homeostasis, anti-inflammatory, anticancer, neuroprotective, and antihypertensive properties (25). The development of fish protein hydrolysates can also be used for elderly and patients with dysphagia as a means of modifying the texture of the food produced (21).

Our study indicates that FPH has been used as an additive or substitute in various types of food products, including cookies, biscuits, porridge, fish balls, nutrition/protein bars, bread, ice cream, yogurt, textured-modified salmon product, fish sausage, and mayonnaise (Table 1). The purpose of adding FPH to each of these food products is similar, namely to increase specific nutrients, such as protein, amino acids, antioxidant activity, and minerals. In addition, adding FPH to food products also tends to improve their texture and taste. Furthermore, research conducted on the existing literature indicates that the nutritional content increases with the addition of fish protein hydrolysate, particularly in terms of protein and amino acids. An increase in other nutrients such as calcium was reported in the first study (11).

Preferred product formulation and nutritional analysis

All studies examined tested the nutritional content of each formulation produced. Laboratory tests related to nutritional content were conducted to determine whether there was an increase in specific nutritional content with the addition of FPH in the product through statistical analysis. According to all studies examined, formulations with FPH addition were compared to control formulations or formulations without FPH addition in the products produced. Based on the studies used, the formulations most preferred by the panelists used ratios varying between 1.5% and 34%. Table 2 shows that overall, the addition of fish protein hydrolysate increases the nutritional content, especially protein and amino acids. The increase in protein in the resulting product is in line with previous research which states that the more fish protein hydrolysate is added, the higher the protein content in the resulting product (26). Overall, the addition of fish protein hydrolysate showed an increase in nutritional content, especially protein and amino acids (Table 2).

Protein plays a role in the synthesis of body tissues during growth and produces enzymes and hormones that regulate various physiological functions in the body (27,28). The use of fish protein

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hydrolysate can increase protein content by 11.37% to 81.21% (17). The highest increase in protein content was observed in the product made with 98.5% wheat flour and 1.5% FPH derived from cod fish waste as a nutritional supplement (17). The increase in protein content is closely related to the increase in amino acids. This is because amino acids are the result of breaking down proteins into smaller peptides. Thus, an increase in protein will increase the amino acid content in a product.

Additionally, food products use FPH as a fortification ingredient to enhance the protein's digestibility. This is due to the increase in protein and amino acid content in a product, which in turn will increase the digestibility of the resulting protein. The higher the protein digestibility value contained in a product, the better the quality of the product, and the more protein can be absorbed and utilized by the body (29).

Other studies indicate that adding FPH to food products can increase their calcium and antioxidant content (11,17,20). A study found that adding 1.5% FPH to porridge can make it more nutritious for older people by giving it more protein, calcium, and antioxidants (11). Increasing the antioxidant content in products can provide additional health benefits, such as helping to manage blood glucose levels, neutralizing free radicals, acting as an anti-inflammatory, and reducing oxidative stress in the body (30).

Improving the nutritional content of all products not only enhances nutritional quality but also contributes to product quality and the resulting health benefits. Nutritional differences in food products fortified with FPH depend on the composition of the ingredients used in the formulation, the hydrolysate manufacturing technique, and the cooking process.

Panelist Acceptance of Fish Protein Hydrolysate Fortified Foods

Table 3 shows the results of the comparison of panelists' acceptance of fish protein hydrolysate fortified products. Panelist acceptance analysis of the food products was conducted using different numbers of panelists, ranging from 6 to 60, to determine their acceptance in terms of taste, color, aroma, texture, and overall impression. The analysis was conducted using different assessment instruments, including 5-point hedonic scale, 9-point hedonic scale, a Fuzzy logic-based sensory scorecard, and the ISO 13299:21 method. The results obtained from the entire literature show that the addition of FPH to food products can improve the taste, texture, and overall acceptance of the products produced.

Flavor is one of the determining factors that influence consumers in their acceptance of a product. A study states that adding 1.5% fish protein hydrolysate can increase consumer acceptance of the product (11). Fish protein hydrolysate can function as a flavor enhancer in the product because FPH contains amino acids in the form of glutamate compounds that can impart the product an umami (savory) taste (31–33). This is also in line with research which shows that adding 4% fat-free salmon protein hydrolysate fortification to cookies can improve the nutritional profile and sensory attributes of the resulting cookies because it provides an optimal balance between texture, color, better fatty acid composition, maintaining cookies integrity, denser and softer texture, reducing cracking, water retention, and increasing protein content (15).

Color plays an important role in product acceptance. This is because before tasting the flavor, smelling the aroma, and feeling the texture of the food product, panelists will first look at the color of the product. The more attractive the color of the product, the greater its influence on panelist acceptance (13,15) The color of the product is influenced by the type and intensity of the fish protein hydrolysate added. The addition of fish protein hydrolysate to the product results in a darker color as the amount of fish protein hydrolysate increases (34). This is due to the Maillard reaction between the free amino acid groups in the protein hydrolysate and the sugar content in the ingredients. In addition, the non-enzymatic darkening reaction, namely sugar caramelization, also enhances the darkness of the product (13). This Maillard reaction can also impart the product a bitter taste because the heating of sugar (caramelization) often burns and gives the product a bitter taste. In general, the Maillard reaction can affect the aroma and texture of the product because it produces a sweet aroma and a harder texture from the caramelization process (13).

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Table2 . Comparison of Acceptance of Fish Protein Hydrolysate Fortified Products

Ref	Panel (n)	Instrument	Average acceptance score of the most preferred product					Impact on Sensory Characteristics and Acceptance
			Taste	Color	Odor	Texture	Overall	
(11)	50 elderly consumers (≥60 years old)	9-point hedonic scale	7	7.00	7.0	6.8	7.00	Viscosity decreases and causes the color to become darker with the addition of high hydrolysate
(12)	6 trained panelists	Descriptive sensory analysis (color, aroma, texture, overall preference)	NA	7.17	6.83	6.50	7.67	Shelf life extended to 12 days; improved microbiological stability; and better pH control; however, no significant changes in sensory acceptance.
(13)	30 partially trained panelists	Fuzzy logic-based sensory scorecard	0.94	0.78	0.79	0.93	0.90	Improvement in texture and water content with moderate TPH addition; hardness increases with 15% addition
(14)	10 trained panelists	Comparison with reference method (ISO 13299:2016)	NA	NA	NA	NA	NA	The color becomes darker and the texture becomes more brittle with high levels of addition
(15)	25 untrained panelists	9-point hedonic scale	8	7.80	7.4	7.53	8.0	Softer texture with 4% DSF-PH; the score is due to; darker color and increased moisture retention with higher DSF-PH addition
(16)	60 untrained panelists	9-point hedonic scale	6.28	6.17	6.25	7.42	6.53	Improved texture and sensory attributes, reduced density, and darker color with increasing API dosage
(17)	20 trained panelists, aged between 21-55 years (15 female and 5 males)	5-point-based hedonic test and a total acceptability hedonic scale method	2.60	2.80	3.30	3.60	6.20	Improve crust color; pore uniformity; crumb softness; and reduce bitterness as FPH increases; reduce firmness; and extend shelf life by reducing microbial activity and moisture content
(18)	25 panelists (15 females and 10 males)	5-point-based hedonic test	5	5	4	5	5	Adding fish skin gelatin hydrolysate could be successfully used in ice cream production without negatively affecting appearance, odor, flavor, and melting quality
(19)	15 semi-trained panelists between 18-55 years (9 females and 6 males)	9-point hedonic scale	5.29	8.26	5	NA	6	As the amount of BWFPH increases, the color becomes brighter and the product's texture becomes softer
(20)	14 highly trained panelists	5-point-based hedonic test	4	4	3.35	NA	4	Nanoemulsions containing proteins smaller than 10 kDa improve sensory quality, gel structure, and appropriate consistency
(21)	9 trained panelists	Comparison with reference method ISO 13299:2016	NA	NA	NA	NA	NA	Significantly softer texture; lower firmness; darker color; and enhanced taste
(22)	28 untrained panelists (25-35 years)	9-point hedonic scale	4.50	5	5	NA	5	Improves sensory properties and texture, making it firmer and chewier
(23)	10 trained panelists	9-point hedonic scale	NA	NA	NA	NA	7.60	There was an increase in viscosity and oxidative stability during storage

NA: data presented in scale form

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Meanwhile, nearly all products containing added FPH showed that as the amount of FPH increased, the level of acceptability decreased, because FPH has a fishy odor that causes a decline in the level of acceptability among panelists and consumers (34). This is also consistent with research previously which states that when fish meal is added to a food product, the result is a strong fishy odor, as the fishy odor is dominated by the fish meal (35).

The addition of FPH to food products results in a variety of textural characteristics. In the bread products produced, it was noted that adding 1.5% FPH can uniform the pores, soften the crumb, and reduce the hardness of bread (17). Meanwhile, adding FPH to ice cream, yogurt, and mayonnaise can improve texture, increase viscosity, enhance consistency, and stabilize the products (18,20,23). In addition, fish sausages and fish balls made with FPH will result in products that are firmer and chewier. (12,22). This is because the addition of FPH can improve the microscopic texture of food products, resulting in a better texture.

Overall, the panelists' ratings ranged from 4 to 8 (slightly dislike until like very much), indicating that, on the whole, the food products containing FPH were well-received by consumers. Meanwhile, based on the Fuzzy logic-based sensory scorecard, the products received an overall score of 0.90, indicating that they were highly liked. Sensory testing is conducted to determine consumer perceptions of the product. The higher the score, the better the consumer acceptance of the product's taste, aroma, color, texture, and overall quality (34). This sensory evaluation can be used as a basis for determining the optimal formulation and identifying which characteristics require adjustment or reformulation to produce a product with good nutritional content and high consumer acceptance. Based on the sensory analysis of the 13 selected articles, it can be concluded that the addition of FPH improves the resulting sensory quality, particularly in terms of texture; however, if the FPH content is too high, it can result in a strong fishy odor, a darker color, and a bitter taste.

DISCUSSION

The results of this study indicate that the addition of fish protein hydrolysate (FPH) in food production needs to be carefully adjusted to the characteristics of the main ingredients and food matrix used. The interaction between hydrolyzed peptides and other food components, such as starch, vegetable protein, and fat, can affect the physicochemical and sensory properties of the final product(11). Therefore, selecting the appropriate fortification level is a key factor in maintaining a balance between increased nutritional value and consumer acceptance. In addition, other studies have also mentioned that fish protein hydrolysate can improve the sensory and textural characteristics of food products (17,36).

Several reviewed studies report that the use of FPH at high fortification levels has the potential to cause undesirable sensory changes, such as the emergence of a bitter or sour aftertaste, as well as a stronger fishy odor which is quite disturbing when consumed (35,37,38). This phenomenon is related to the presence of hydrophobic peptides and volatile compounds formed during the hydrolysis process (39). Hydrophobic peptides are amino acid chains that are water-repellent (nonpolar) and tend to be insoluble in water, this contributes significantly to the bitter taste in FPH because amino acids such as proline, leucine, phenylalanine, and valine play a key role in determining the bitter taste (40). In addition, hydrophobic peptides have low molecular weights (ranging from 0.5 to 3.0 kDa), which are often associated with a higher intensity of bitterness (41). The bitterness of FPH is also influenced by the enzymes used in the hydrolysis process. The use of alkalase results in a generally more bitter taste in FPH because the resulting peptides have high hydrophilicity and low molecular weight (0.5-1 kDa) (42). Meanwhile, the use of papain results in a generally less bitter taste compared to the use of alkalase because of the larger peptide size and lower degree of hydrolysis (43).

In the context of food production, technological approaches such as the application of debittering techniques, the selection of more selective enzymes, and the addition of food additives that function as flavor and aroma enhancers can be mitigation strategies to improve product acceptance (17). Other studies have indicated that the Maillard reaction can reduce bitterness in FPH but may alter its structure and result in peptide loss during the process (44). Consequently, the Maillard reaction is often combined with enzymatic hydrolysis using exopeptidases to break down hydrophobic peptides, which are the primary

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contributors to bitterness (45,46). Combining FPH with 4% glucosamine at 120 °C for 60 minutes significantly reduced the bitterness score from 9.37 to 1.44 while enhancing antioxidant activity (15). In addition, encapsulation methods can mask the bitter taste of FPH and enhance the bioactivity of the resulting product because during the encapsulation process, FPH is protected, allowing it to act as a barrier between oxidative compounds and FPH, which delays the reaction (20,47).

However, adding FPH to food products can improve several aspects of sensory acceptance, such as: making bread more soft; improving the texture of mayonnaise, ice cream, and yogurt to make them more uniform and stable; and softening the texture of cookies (15,17,18,20,23). The amino acids such as glutamic acid and aspartic acid found in FPH make it a natural flavoring agent that imparts a savory or umami taste to products (11). Other studies have also shown that FPH has potential as a natural emulsifier rich in nutrients and as a natural preservative to extend product shelf life (12,21).

Additionally, the products studied in this research can serve as examples in designing practical solutions for utilizing local food ingredients and food processing by-products (waste) to improve nutritional intake and address existing nutritional problems in the community, which can then lead to other related nutritional and health problems, such as malnutrition, wasting, stunting, and dysphagia (21,48).

Implications for future research

The development of products based on fish protein hydrolysate (FPH) offers significant opportunities in addressing nutritional problems, particularly protein deficiency in vulnerable groups such as toddlers and children (48). Fortified food products based on FPH can serve as a source of high-quality protein with adequate digestibility, thereby supporting optimal growth and development. The use of FPH in food products can also serve as an innovation to improve food texture, making it more palatable and suitable for patients with specific conditions, such as dysphagia and elderly (11,21).

Furthermore, the utilization of FPH from fishery by-products is also in line with the principles of sustainability and circular economy, as it can reduce industrial waste and increase the added value of local food ingredients. Thus, the results of this study have practical implications for the food industry, particularly in the development of fish-based functional food products that are not only highly nutritious but also have sensory characteristics that are acceptable to consumers. The integration of food technology, nutrition, and consumer preferences is key to the successful implementation of FPH on an industrial scale.

Hydrolysates have various potentials as nutrient-rich food ingredients and can help overcome various existing nutritional problems. Although various benefits of fish protein hydrolysates have been reported, future research is still needed to optimize the application of FPH in a more comprehensive and sustainable manner. One important research direction is the development of integration between the optimization of hydrolysis methods, the characteristics of the resulting peptides, the control of lipid oxidation, and the simultaneous improvement of sensory characteristics (39). This integrated approach is necessary to produce hydrolysates with more uniform and consistent quality, while minimizing the formation of bitter or off-flavors in food products.

In addition, further research needs to pay attention to in-depth evaluation of product stability during storage, especially in products containing fat, considering that fish protein hydrolysate can interact with lipid components and affect the rate of oxidation. The development of encapsulation technology or combination with natural antioxidants could also be a potential research topic to improve the stability and quality of fortified products. Another aspect that requires further attention is research on specific target groups, particularly toddlers, children, and other nutritionally vulnerable groups. Intervention studies involving protein bioavailability testing, metabolic responses, and the impact of long-term consumption are urgently needed to provide stronger scientific evidence regarding the health benefits of consuming food products fortified with fish protein hydrolysate. This approach is expected to bridge the gap between laboratory research results and their application in the context of public health.

CONCLUSION

The results of the study show that the addition of fish protein hydrolysate from various fish sources can consistently improve the nutritional value of food products, particularly in terms of protein content and

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quality. In addition, the addition of fish protein hydrolysate can extend the shelf life and antioxidant levels in products. The recommended fortification level is in the moderate range, or around 5–10%, to achieve the most optimal results in balancing nutritional improvement with sensory acceptance of the food products produced. FPH fortification in food products has the potential to address protein malnutrition issues, especially in developing countries. FPH-based products can also be developed to modify food textures in order to address other nutritional issues, such as those faced by patients with dysphagia and the elderly, ensuring they continue to receive adequate nutrition.

However, there are still several challenges that pose problems in the use of fish protein hydrolysate in food products, including color changes, fishy or distinctive fish aroma, bitter aftertaste, and lipid stability. Despite these challenges, FPH fortification offers a profound industry impact by driving commercial sustainability. Because FPH is predominantly derived from fish processing by-products, such as frames, heads, and viscera, its utilization directly supports a circular economy. By transforming industrial waste into high-value functional ingredients, the food industry can significantly reduce environmental footprints and maximize resource efficiency. Consequently, FPH development aligns with global trends toward sustainable food systems and responsible production practices. Therefore, technological development in advanced processes and formulations is essential to maximize the potential use of fish protein hydrolysate as a nutritious, sustainable, and consumer-acceptable fortification ingredient for food products. Future research should also explore broader applications of FPH across diverse food matrices to fully maximize its functional, nutritional, and sustainable potential.

DECLARATION OF THE USE OF AI

The authors declare that no artificial intelligence (AI), AI-assisted technologies, or large language models (LLMs) were used in the conception of the study, data analysis, or the drafting, writing, and editing of this manuscript. The only exception is the graphical abstract, which was created using the design platform Illustrae (https://illustrae.co/). The authors take full responsibility for the content and accuracy of the graphical abstract and the entire manuscript.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Noreen S, Hashmi B, Aja PM, Atoki AV. Health benefits of fish and fish by-products—a nutritional and functional perspective. Front Nutr. 2025;12:1564315. doi:10.3389/fnut.2025.1564315 PubMed PMID: 40416371.
2. Dawson BR, Mantzioris E, Connell SD, Nagelkerken I, Hall T, Mellin C. Fish by-products as reliable proxies to evaluate nutritional fatty acid contents in commercial fish fillets. Food Chem. 2025 Feb 28;466(1):142223. doi:10.1016/j.foodchem.2024.142223 PubMed PMID: 39616699.
3. Silalahi Y, Masfria M, Sinaga SM, Siburian R. The Nutritional Lipid Profiles of Marine Fish from Medan, Indonesia. Open Access Maced J Med Sci. 2023 Jan 22;11(E):104–9. doi:10.3889/oamjms.2023.11376
4. Chalamaiah M, Dinesh Kumar B, Hemalatha R, Jyothirmayi T. Fish protein hydrolysates: Proximate composition, amino acid composition, antioxidant activities and applications: A review. Food Chem. 2012 Dec 15;135(4):3020–38. doi:10.1016/j.foodchem.2012.06.100 PubMed PMID: 22980905.

https://doi.org/10.56303/jhnresearch.v5i2.1272

5. Waqar M, Sajjad N, Ullah Q, Vasanthkumar SS, Ahmed F, Panpipat W, et al. Fish By-Products Utilization in Food and Health: Extraction Technologies, Bioactive, and Sustainability Challenges. Food Sci Nutr. 2025 Nov 1;13(11):e71184. doi:10.1002/fsn3.71184
6. Wisuthiphaet N, Kongruang S, Chamcheun C. Production of Fish Protein Hydrolysates by Acid and Enzymatic Hydrolysis. J Med Bioeng. 2015;4(6):466–70. doi:10.12720/jomb.4.6.466-470
7. Dinakarkumar Y, Krishnamoorthy S, Margavelu G, Ramakrishnan G, Chandran M. Production and characterization of fish protein hydrolysate: Effective utilization of trawl by-catch. Food Chemistry Advances. 2022;1:100138. doi:10.1016/j.focha.2022.100138
8. Cassol GZ, Almeida FLC, de Castro RJS, Sato HH. Unlocking the potential of fish protein hydrolysates: Bioactive and technofunctional properties, applications, challenges, and future perspectives. Food Research International. 2025 Aug 1;213:116609. doi:10.1016/j.foodres.2025.116609 PubMed PMID: 40436582.
9. Honrado A, Ardila P, Leciñena P, Beltrán JA, Calanche JB. Transforming 'Bonito del Norte' Tuna By-Products into Functional Ingredients for Nutritional Enhancement of Cereal-Based Foods. Foods. 2023 Dec 1;12(24). doi:10.3390/foods12244437
10. Asare SN, Gruber Ijong F, Rieuwpassa J, Setiawati NP. Penambahan Hidrolisat Protein Ikan Lemuru (Sardinella lemuru) pada Pembuatan Biskuit. Jurnal Ilmiah Tindalung. 2018;4(1).
11. Charoensri P, Kijroongrojana K, Sukkwai S, Nilsuwan K, Benjakul S. Physical, sensory, antioxidant and nutritional properties on Riceberry rice porridge fortified with bio-calcium and protein hydrolysate from salmon (Salmo salar) frame for elderly. J Agric Food Res. 2025 Mar 1;19:101679. doi:10.1016/J.JAFR.2025.101679
12. Pinheiro ACDAS, Schouten MA, Tappi S, Gottardi D, Barbieri F, Ciccone M, et al. Strategies for the valorization of fish by-products: Fish balls formulated with mechanically separated amberjack flesh and mullet hydrolysate. LWT. 2024 Oct 1;209. doi:10.1016/j.lwt.2024.116724
13. Asharaf F, Blossom KL, Safeena MP, Martin Xavier KA, Abdullah S. Debittered tilapia protein hydrolysate incorporated functionalized nutrition bar: Application of fuzzy modeling for sensory analysis. Food and Humanity. 2025 May 1;4. doi:10.1016/j.foohum.2025.100568
14. Honrado A, Ardila P, Leciñena P, Beltrán JA, Calanche J. Nutritional enrichment of cereal foods: feasibility study and characterisation of biscuits fortified with seabass by-products. Int J Food Sci Technol. 2024 Aug 1;59(8):5376–88. doi:10.1111/ijfs.17230
15. Sharma K, Chanchi Prashanthkumar M, Patil U, Ma L, Benjakul S. Characteristics and nutritional value of cookies fortified with debittered salmon (Salmo salar) frame protein hydrolysate. J Agric Food Res. 2025 Mar;19:101732. doi:10.1016/j.jafr.2025.101732
16. Canti M, Putra MF, Hutagalung RA, Hartanti AT, Della F. Physicochemical and sensory properties of novel cookies enriched with soy and anchovy protein isolate (Stolephorus insularis). Applied Food Research. 2025 Jun 1;5(1). doi:10.1016/j.afres.2025.100946
17. Oprea OB, Sannan S, Tolstorebrov I, Claussen IC, Gaceu L. Effects of Fish Protein Hydrolysate on the Nutritional, Rheological, Sensorial, and Textural Characteristics of Bread. Foods. 2024 Feb 25;13(5):698. doi:10.3390/FOODS13050698
18. Tekle S, Goktas H, Agan C, Develioglu-Arslan A, Tekin-Cakmak ZH. Using Fish Skin Gelatin Hydrolysate as Stabilizer and/or Emulsifier Agent in Ice Cream Production and Melting, Textural, Rheological, and Sensory Characteristics. Gels. 2025 Aug 1;11(8). doi:10.3390/gels11080643
19. Khodaei D, Noci F, Ryan L. Optimizing Protein Bars With Whey Protein Isolate, Pea Protein Isolate, and Blue Whiting (Micromesistius poutassou) Fish Protein Hydrolysate: A Simplex-Centroid Mixture Design Study. Food Sci Nutr. 2025 Jan 1;13(1). doi:10.1002/fsn3.4701
20. Vakili N, Ataee M, Kakoolaki S, Ahari H, Ghorbanzade A. Effect of nanoemulsified and encapsulated Planiliza abu protein on fortified yogurt. Food Sci Nutr. 2024 Dec 1;12(12):10433–47. doi:10.1002/fsn3.4150
21. Prabhu L, Skuland AV, Varela P, Rosnes JT. Fish Protein Hydrolysate as Protein Enrichment in Texture-Modified Salmon Products. Foods. 2025;14(2). doi:10.3390/foods14020162

https://doi.org/10.56303/jhnresearch.v5i2.1272

22. Hajfathalian M, Jorjani S, Ghelichi S. Characterization of fish sausage manufactured with combination of sunflower oil and fish oil stabilized with fish roe protein hydrolysates. J Food Sci Technol. 2020 Apr 1;57(4):1439–48. doi:10.1007/s13197-019-04179-6
23. Unnikrishnan P, Puthenveetil Kizhakkethil B, Anant Jadhav M, Sivam V, Ashraf PM, Ninan G, et al. Protein hydrolysate from yellowfin tuna red meat as fortifying and stabilizing agent in mayonnaise. J Food Sci Technol. 2020 Feb 1;57(2):413–25. doi:10.1007/s13197-019-04069-x
24. Ratnawati R, Satriani S. The Effect of Giving Biscuits Made from Haruan Fish Flour and Yellow Pumpkin on the Nutritional Status of Toddlers. Journal of Health and Nutrition Research. 2024 Aug 21;3(2):144–8. doi:10.56303/jhnresearch.v3i2.261
25. Gao R, Yu Q, Shen Y, Chu Q, Chen G, Fen S, et al. Production, bioactive properties, and potential applications of fish protein hydrolysates: Developments and challenges. Trends Food Sci Technol. 2021 Apr 1;110:687–99. doi:10.1016/j.tifs.2021.02.031
26. Maulani A, Poernomo A, Lisyana H, Sumandiarsa IK. Karakteristik Gluten Free Cookies Fortifikasi Hidrolisat Protein Ikan Lele. Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan. 2024 Jun 30;19(1):73. doi:10.15578/jpbkp.v19i1.991
27. Faroj MN. Pengaruh Substitusi Tepung Ikan Teri (Stolephorus commersonii) Dan Tepung Kacang Merah (Vigna angularis) Terhadap Daya Terima Dan Kandungan Protein Pie Mini. Media Gizi Indonesia. 2019 Jan 31;14(1):56–65. doi:10.20473/MGI.V14I1.56-65
28. Rofidah K, Putriana N, Roqimah AGC, Arini LDD. Membangun Kesehatan Dari Dalam Dengan Menu Sehat Berprotein Tinggi. 2. 2024;(3). doi:https://doi.org/10.55606/jig.v2i3
29. Mentari AD, Setiawan B, Palupi E. Pengembangan Rutf (Ready To Use Therapeutic Food) Berbahan Serealia Dan Kedelai Bagi Balita Malnutrisi Akut Berat. Media Gizi Indonesia (National Nutrition Journal) 2022. 2022;17(1):11–20. doi:10.204736/mgi.v17i1.11-20
30. Putriana AE, Damayanthi E, Palupi E, Nasution Z, Handharyani E. Evaluation of Dietary Fiber, Antioxidant Capacity, Physicochemical Properties, and Consumer Acceptability of a Green Okra (Abelmoschus esculentus L.) Pudding. Journal of Health and Nutrition Research. 2025 Aug 1;4(2):718–26. doi:10.56303/jhnresearch.v4i2.461
31. Mardiyah U, Jasila I, Arianty D. Pembuatan Hidrolisat Ikan Rucah Sebagai Penyedap Rasa Alami dengan Memanfaatkan Enzim Bromelin pada Buah Nanas (Ananas comosus). Samakia : Jurnal Ilmu Perikanan. 2024 May 2;15(1):69–75. doi:10.35316/JSAPI.V15I1.4781
32. Peinado I, Koutsidis G, Ames J. Production of seafood flavour formulations from enzymatic hydrolysates of fish by-products. LWT - Food Science and Technology. 2016 Mar 1;66:444–52. doi:10.1016/j.lwt.2015.09.025
33. Tejpal CS, Vijayagopal P, Elavarasan K, Linga Prabu D, Lekshmi RGK, Asha KK, et al. Antioxidant, functional properties and amino acid composition of pepsin-derived protein hydrolysates from whole tilapia waste as influenced by pre-processing ice storage. Journal of Food Science and Technology 2017 54:13. 2017 Oct 17;54(13):4257–67. doi:10.1007/s13197-017-2897-9
34. Septiyanti S, Patimah S, Bur N. Penja Fish Flour Cookies: Nutritional Composition and Sensory Acceptability as a Local Food-Based Intervention for Child Undernutrition. Journal of Health and Nutrition Research. 2025 Dec 1;4(3):950–9. doi:10.56303/jhnresearch.v4i3.512
35. Hassan T, Buy I, Mata M. Effect of Sorghum Flour and Anchovy Meal Substitution on Organoleptic Properties of Biscuits. Journal of Health and Nutrition Research. 2024 Dec 11;3(3):185–91. doi:10.56303/jhnresearch.v3i3.284
36. Laishram M, Desai AS, Bhave SG, Pathan DI, Pawase AS, Wasave SM, et al. Valorisation of Fish Side Stream Through Development of Fish Protein Hydrolysate to Enhance Physiochemical and Sensory Characteristics of Pasta. Journal of Aquatic Food Product Technology. 2025 Jul 3;34(6):414–27. doi:10.1080/10498850.2025.2534101
37. Kaushik N, Falch E, Slizyte R, Kumari A, Khushboo, Hjellnes V, et al. Valorization of fish processing by-products for protein hydrolysate recovery: Opportunities, challenges and regulatory issues. Food Chem. 2024 Nov 30;459. doi:10.1016/j.foodchem.2024.140244 PubMed PMID: 38991448.

https://doi.org/10.56303/jhnresearch.v5i2.1272

38. Nemati M, Shahosseini SR, Ariaii P. Review of fish protein hydrolysates: production methods, antioxidant and antimicrobial activity and nanoencapsulation. Food Sci Biotechnol. 2024 Jun 1;33(8):1789. doi:10.1007/S10068-024-01554-8 PubMed PMID: 38752116.
39. Zhang X, Dai Z, Zhang Y, Dong Y, Hu X. Structural characteristics and stability of salmon skin protein hydrolysates obtained with different proteases. LWT. 2022 Jan 1;153:112460. doi:10.1016/j.lwt.2021.112460
40. Rusydan AM, Zulfaidah NT. Bioactive Peptides: Exploring Potentials and Overcoming Challenges for Future Foods. Jurnal Farmasi Syifa. 2024;2.
41. Xiang Q, Xia Y, Fang S, Zhong F. Enzymatic debittering of cheese flavoring and bitterness characterization of peptide mixture using sensory and peptidomics approach. Food Chem. 2024 May 15;440. doi:10.1016/j.foodchem.2023.138229 PubMed PMID: 38159315.
42. Yolandani, Liu D, Raynaldo FA, Dabbour M, Zhang X, Chen Z, et al. Comparison of prediction models for soy protein isolate hydrolysates bitterness built using sensory, spectrofluorometric and chromatographic data from varying enzymes and degree of hydrolysis. Food Chem. 2024 Jun 1;442. doi:10.1016/j.foodchem.2024.138428 PubMed PMID: 38241997.
43. Yarnpakdee S, Benjakul S, Kristinsson HG, Kishimura H. Antioxidant and sensory properties of protein hydrolysate derived from Nile tilapia (Oreochromis niloticus) by one- and two-step hydrolysis. J Food Sci Technol. 2015 Jun 29;52(6):3336–49. doi:10.1007/s13197-014-1394-7
44. Idowu AT, Benjakul S. Bitterness of fish protein hydrolysate and its debittering prospects. J Food Biochem. 2019 Sep 1;43(9). doi:10.1111/jfbc.12978 PubMed PMID: 31489658.
45. Fu Y, Chen J, Bak KH, Lametsch R. Valorisation of protein hydrolysates from animal by-products: perspectives on bitter taste and debittering methods: a review. Int J Food Sci Technol. 2019 Apr 1;54(4):978–86. doi:10.1111/ijfs.14037
46. Zulkipli AS, Salleh RM. Flavour Improvement of Protein Hydrolysates Derived from Cephalopods Byproducts Using Maillard Reaction: A Short Review. ASM Science Journal. 2021;15:1–13. doi:10.32802/ASMSCJ.2021.694
47. Chen J, Wei C, Hou J, Wang J, Ruan Q. Debittering and antioxidant improvement of soy protein hydrolysates using curcumin as hydrophobic core. J Sci Food Agric. 2025 Mar 15;105(4):2506–14. doi:10.1002/jsfa.14023 PubMed PMID: 39535324.
48. Nesse KO, Nagalakshmi AP, Marimuthu P, Singh M. Efficacy of a Fish Protein Hydrolysate in Malnourished Children. Indian Journal of Clinical Biochemistry. 2011 Oct 15;26(4):360–5. doi:10.1007/s12291-011-0145-z

https://doi.org/10.56303/jhnresearch.v5i2.1272