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Formulation, Quality Characteristics, and Research Trends of Fish Balls: A Bibliometric Study

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ABSTRACT - Fish balls are a processed fishery product that is gaining increasing attention due to their nutritional value, affordability, and acceptance across various consumer segments. This article presents a synthesis of recent research findings on the formulation, physicochemical properties, texture, sensory testing, and nutritional content of fish balls. The study results indicate that the addition of fish protein isolate (CPI/FPI), transglutaminase enzymes, and natural fillers such as tapioca, konjac, and *porang* can increase water holding capacity, cooking yield, and product elasticity. However, there are trade-offs in color and aroma changes that can affect consumer acceptance. Nutritionally, fish balls have been shown to have a higher protein content and a better amino acid profile than meatballs made from red meat, and have the potential to be a source of omega-3 fatty acids and functional minerals. Bibliometric analysis shows a growing research trend since 2018, although gaps remain in method standardization, the relationship between microstructure and sensory perception, and evaluation at the MSME scale. Thus, further research needs to be directed at an integrated approach that connects instrument analysis, sensory testing, and quality predictive models to support innovation, standardization, and application of research results on an industrial and MSME scale.

Keywords: Fish balls, nutritional content, sensory evaluation.

INTRODUCTION

Fish balls are a popular processed fishery product in Asia, including Indonesia, because they offer a relatively affordable source of animal protein, are easy to process, and are acceptable to various consumer segments. The quality of fish balls is generally determined by three groups of attributes: (i) physical properties—especially firmness/texture and water-binding capacity; (ii) organoleptic acceptability—color, aroma, taste, and texture; and (iii) nutritional composition—specifically protein content and other proximate components (water, fat, and ash). The literature indicates that firmness is a key parameter of fish ball quality and correlates with the gel structure of myofibrillar proteins formed during dough heating (setting and gelation) (Nugroho et al., 2019).

Raw material formulation plays a significant role in final quality. Fish meat source (species, freshwater/marine habitat), proportion of surimi or minced meat, type and level of binding agent (e.g., tapioca), and functional ingredients (e.g., polyphosphate, transglutaminase, or vegetable fiber) have been shown to influence moisture content, firmness, and hedonic scores. Several Indonesian and international studies have shown, for example, that interspecies surimi combinations and starch levels can optimize physical and sensory characteristics; the use of CPI/Asian seabass surimi improves gel properties; and optimizing water content to ±≤65% is necessary to achieve a preferred meatball texture (Canti & Martawidjaja, 2024; Chairita et al., 2010).

Regarding consumer acceptance, various studies reported differences in preference based on fish species (small/large pelagic or freshwater) and formulation design. Field studies and controlled hedonic tests have found that variations in species and formulations influence color, aroma, flavor, and texture scores—which in turn guide the selection of local raw materials (catfish, tilapia, pangasius, tuna, skipjack tuna, etc.) for specific markets (J. Junianto, I. Aufa, et al., 2024; J. Junianto, V. Nurerlindajava, et al., 2024).

From a nutritional perspective, research has shown the influence of fish meat proportion on protein and mineral (e.g., zinc) levels, and that innovations in the addition of functional ingredients (plant-based/enzymatic) need to consider the trade-off between improving nutritional value and sensory acceptance. For example, varying the fish-to-tapioca ratio in snakehead fish meatballs changes the protein content and palatability; the addition of flour or vegetable fiber can increase nutritional value but sometimes lowers sensory scores if levels exceed a certain threshold (Ani et al., 2022; Naiaki et al., 2024).

The processing and handling of raw materials prior to milling also determine the final quality. The length of storage of fish meat at low temperatures and the use of polyphosphates (e.g., STPP $\leq$0.6%) affect water-binding capacity, pH, and gel formation, thus impacting chewiness and acceptability. On the other hand, the use of the transglutaminase enzyme in a fish-chicken meatball combination has been reported to improve texture and palatability, opening up opportunities for diversifying hybrid formulations (Ali et al., 2023; Lukman et al., 2018).

Globally, recent research highlighted the link between formulation design, physicochemical characteristics, and consumer acceptability by conducting comprehensive characterization (proximate, amino acids, minerals, pH) of fish meatballs and evaluating stability during cold storage. The results confirmed that fish balls can maintain high protein content and an attractive nutritional profile, but sensory responses are highly sensitive to formulation modifications (Isra et al., 2024).

Many studies focused on a single species or formulation variable with inconsistent testing procedures (e.g., different Texture Profile Analysis protocols, shear tests, or hedonic tests), making quantitative synthesis across studies difficult. Bibliometric mapping is needed to identify topic clusters (species, binders, additives, setting techniques) and dominant and underrepresented measurement standards (Nugroho et al., 2019; Wijayanti et al., 2021). Moreover, many reports focused on proximate metrics and hedonic scores, while microstructural analysis (e.g., SEM, pore/water distribution) and its causal relationship with perceived chewiness have not been consistently reported. It limited the ability to formulate predictive quality models (Wijayanti et al., 2021). Protein content studies are generally proximate-based; evidence regarding the bioavailability of amino acids/functional peptides in fish balls (especially after heating/storage) is still limited in the context of ready-to-eat products (Isra et al., 2024). Fortification/substitution trends (fiber, legumes, transglutaminase, polyphosphate) show mixed results on texture and palatability; comparative studies across usage levels and sensory-shelf-life implications are rarely systematically mapped (Ali et al., 2023; Lukman et al., 2018; Naiaki et al., 2024). Home-industry/MSME-scale studies assessing quality consistency with local raw material variability (farmed vs. pelagic freshwater fish) are still limited, even though the primary market is in this segment (Junianto et al., 2024; J. Junianto, I. Aufa, et al., 2024)

The urgency of bibliometric studies on this topic is supported by at least three reasons. First, the need for affordable animal protein drives the development of fish meatballs from farmed and locally caught species; evidence synthesis is needed to guide optimal formulations for physical quality, palatability, and protein content without increasing the cost of additional ingredients. Second, quality standardization—especially firmness metrics and sensory testing protocols—is crucial for translating research results into consistent production SOPs for MSMEs and industry, thereby reducing costly trial and error. Third, science-based innovations (surimi/CPI, enzymes, plant-based substituents) are evolving rapidly; mapping trends, collaborations, and publication outlets through a bibliometric approach will accelerate the diffusion of best practices and identify priority research gaps (e.g., microstructure-sensory linkages, stability during the cold chain) (Canti & Martawidjaja, 2024; Fadhallah et al., 2024).

METHOD

Below is a structured and detailed summary of common and/or important experimental methods found in recent journal articles and proceedings on surimi-based fish ball formulations. The methods covered include sample preparation, proximate analysis, physicochemical and texture testing, sensory testing, microstructural analysis, microbiological/oxidation examination, and additive treatments (e.g., MTGase, polyphosphate, pectin/carrageenan).

General Design and Sample Preparation

Cited fish ball formulation studies generally use a comparative experimental design (CRD) or factorial design (CRD) to evaluate the effect of one or more factors (e.g., fish species, starch substitution, CPI or MTGase levels, or STPP levels) on physical parameters, sensory characteristics, and protein content. Samples are prepared in replicate sizes (usually 3–5 replicates per treatment) and tested immediately after cooking or after a specified storage period (e.g., frozen or refrigerated storage). For example, Khotimah et al. (2024) used a CRD to compare levels of cassava flour substitution; Canti and Martawidjaja (2024) compared formulations with and without CPI.

Raw material preparation and dough making

a. Fish selection and handling:
   Fish were cleaned, filleted, cut, and blended/chopped into a mash. For surimi/CPI, several studies have applied pH-shift methods or alkaline/acid protein extraction to isolate the protein (pH-shift extraction: dilution, pH adjustment to ~11 for extraction, followed by neutralization and precipitation). An example of a CPI (catfish protein isolate) application using the pH-shift method was reported by Canti (2024).
b. Formulation
   Fish mash was mixed with fillers (tapioca/tapioca starch, cassava/corn flour), salt, sugar, flavoring, additives (STPP/Na-polyphosphate), and/or functional ingredients (CPI, MTGase, hydrocolloids such as k-carrageenan/konjac). The proportions tested vary; many studies used variations of 0–10% for protein isolate or 0–1% for MTGase enzyme, and 0–0.6% for STPP (these parameters are influenced by regulations and industry practices). Examples of protocols for the use of CPI in fish balls and flour variations were reported by Canti and Martawidjaja (2024) and local meatball studies (Khotimah et al., 2024).

Proximate Analysis (Moisture, Protein, Fat, Ash)

Standard

Almost all studies refer to the AOAC method for proximate analysis (oven-drying moisture, Kjeldahl or Dumas/combustion protein, Soxhlet/solvent fat, ash at 550°C). Results are reported as % wet or % dry as needed. AOAC (Official Methods) is often cited as a methodological reference (Anonymous, 2023; Beshaw et al., 2022).

Operational parameters (common practice examples):

a. Moisture: drying in a 105°C oven to constant weight;
b. Protein: Kjeldahl method (digestion → distillation → titration), N → protein conversion (factor 6.25 or a specific factor if reported);
c. Fat: solvent extraction (Soxhlet) or modern gravimetric methods;
d. Ash: combustion in a muffle furnace at ~550°C to white/stable ash.

Example reference

Isra et al. (2024) and many surimi/fish-ball studies reported proximate with the AOAC method (Molina et al., 2024).

Physicochemical Tests: pH, Water Holding Capacity (WHC), Cooking Yield, Color

a. pH: measured using a pH meter on a homogeneous sample (1:10 w/v in deionized water) — a standard procedure reported in many studies (Canti & Martawidjaja, 2024).
b. Water Holding Capacity (WHC): measured using several methods: (a) centrifugation (weighing before/after centrifugation at a specific speed), (b) the press method, or (c) measuring cooking loss as a proxy for WHC

(percentage of weight lost after steaming/frying). The specific procedure (centrifugation speed/duration or press pressure) is usually reported for each study. References to reviews on the effect of polyphosphates on WHC explain the mechanisms and measurement methods (Q. Chen et al., 2016; Ren et al., 2024).

c. Cooking yield/cooking loss: the weight of the product before and after cooking (steaming or baking) is recorded; yield = (weight after/weight before) × 100%. Many meatball studies report cooking yield as an indicator of water binding and gel stability (Q. Chen et al., 2016).
d. Color (CIE Lab)**: measured with a colorimeter (e.g. Minolta CR-400) on the surface of the cooled product; parameters L, a*, b* are reported to assess visual changes due to formulation/filler addition (Q. Chen et al., 2016).

Texture Analysis — Instrumental (TPA, Shear, Gel Strength)

a. Texture Profile Analysis (TPA): The most frequently used instrumental method for fish balls. The principle is double compression, simulating two bites; the parameters obtained are hardness, springiness, cohesiveness, chewiness, and resilience. Instrument settings (typical examples) include: a cylindrical probe (Ø35–36 mm or P/36), two compressions with a deformation percentage of 30–50%, a pre-test speed of 1–2 mm/s, a test speed of 1–2 mm/s, a post-test speed of 5 mm/s, and an interval between compressions of 3–5 s. The use of the P/36 probe and 50% compression is listed in the study by You et al. (2024) and modern TPA textbooks/chapters (M. S. Rahman et al., 2021).
b. Shear/Warner–Bratzler: Some studies add a shear test to measure cutting strength/toughness (especially for denser products) (Bland et al., 2018).
c. Gel strength: specifically for surimi/surimi-like products (proteins combine to form a gel after heat setting), gel strength measurements (breaking force × deformation) are also common (L. Chen & Opara, 2013).

Organoleptic/Sensory Testing

a. Scale & Panel: Two common approaches are found: (a) hedonic preference testing (by untrained consumers) using a 9-point or 5-point hedonic scale for overall attributes, taste, aroma, texture, and color; (b) trained descriptive testing for texture/attribute intensity profiles. The number of panels ranges from 30–100 for consumer testing; trained panels are smaller (10–15) but use standardized intensity profiles. For example, many local fishball studies use 30–50 hedonic panelists; some local proceedings/journals use consumer/producer panelists to describe market acceptance (Canti & Martawidjaja, 2024; Khotimah et al., 2024).
b. Procedure: Samples are blindly coded (3-digit random), served in random order to each panelist, serving temperature is consistent; instructions are given, and results are analyzed statistically. Sensory validity is strengthened by the homogeneity of variance (Levene's) test and post-hoc tests (Khotimah et al., 2024).

Microstructural Analysis and Imaging

SEM (Scanning Electron Microscopy) is often used to visualize gel/protein networks, pore distribution, and filler-protein interactions in frozen/cooked products. The general protocol involves critical drying, gold sputter-coating, and observation at specific magnifications. Studies linking microstructure to textural attributes recommend SEM analysis in conjunction with TPA (Ren et al., 2024).

Additive & Enzymatic Treatments (e.g., MTGase, STPP, Hydrocolloids)

a. Microbial transglutaminase (MTGase): Doses tested in studies range from 0–0.8% (w/v) depending on the objective (texture improvement/protein cross-linking). Studies on trout meatballs and fish patties reported increased hardness/springiness at 0.5–0.8% levels without significant changes in proximate composition. MTGase is typically added during the dough mixing stage before setting/cooking, followed by temperature-controlled cooking/ripening (Altan et al., 2024; Kocatepe et al., 2024).
b. Sodium tripolyphosphate/polyphosphate (STPP/PPi): Used at low levels (≤0.5–0.6%) as a water-binding agent/WHC enhancer; operations must take into account regulatory limits and pH effects. Reviews and

experimental studies demonstrated the water-binding mechanism and potential effects on pH and stability (Ren et al., 2024; Wu et al., 2024).

c. Hydrocolloids (k-carrageenan, konjac, carrageenan, carrageenan combinations): used to increase gel strength and improve texture—typical test concentrations are 0.5–5%. Many studies have assessed their effects on texture and palatability. For example, a study of carrageenan in tilapia fish balls (Faridah et al., 2023; Ran et al., 2022).

Safety & Oxidation Parameters: Microbiology, TBARS, TVB-N

a. Microbiology: Total plate count (TPC), coliforms, Salmonella, and Staphylococcus aureus are often examined to assess safety during storage, particularly in studies monitoring shelf-life (e.g., the MTGase study on trout meatballs measured TPC/TC) (Kocatepe et al., 2024).
b. Lipid oxidation (TBARS) and TVB-N: Common parameters for assessing quality degradation during storage. The TBARS method follows a spectrophotometric procedure; TVB-N is measured via Kjeldahl/Conway distillation or automated methods. Studies assessing shelf-stability report TBARS and TVB-N along with texture parameters (Kocatepe et al., 2024; Wu et al., 2024).

Statistical Analysis and Multivariate Data Approaches

a. Univariate analysis: One-way or two-way ANOVA to detect differences between treatments, followed by a post-hoc test (Duncan, Tukey) at a significance level of $p<0.05$—this practice is common in peer-reviewed articles. Many local studies use SPSS, Minitab, or R (Canti & Martawidjaja, 2024; Khotimah et al., 2024).
b. Correlation and regression analysis: used to relate instrumental parameters (TPA) to sensory scores (e.g., correlation of hardness vs. texture preference)(Bland et al., 2018).
c. Multivariate analysis: PCA, cluster analysis, and partial least squares regression (PLSR) are used in more comprehensive studies to group samples based on physicochemical and sensory profiles and to build predictive quality models. Bibliometric studies also report the use of mapping techniques (VOSviewer, Bibliometrix), but these are relevant to the bibliometric methodology section, not laboratory testing (Canti & Martawidjaja, 2024).

Example of an Integrated Protocol (Summary of Typical Operational Steps)

a. Take fresh fish meat → clean → grind/chop → add salt, sugar, filler (tapioca), additives (e.g., 0.5% MTGase or 0.4% STPP) → stir until homogeneous (Canti & Martawidjaja, 2024; Khotimah et al., 2024).
b. Shape balls according to standard weight → steam/heat (e.g., steam for 15–30 minutes at 100°C; or cook according to the study protocol) → cool (Canti & Martawidjaja, 2024).
c. Proximate analysis (AOAC), pH, color (Lab*), cooking yield, WHC (centrifuge/press), TPA (probe Ø35–36 mm, 2-cycle, 50% compression, test speed 1–2 mm/s), and gel strength, if relevant. Conduct sensory testing (9-point hedonic) on a randomized consumer panel. For storage studies, measure TBARS, TVB-N, and TPC at specified time intervals (Beshaw et al., 2022; Kocatepe et al., 2024; You et al., 2024).

The methodological summary above demonstrates procedural consistency in meatball/fish ball analysis: (i) AOAC proximate standards for composition, (ii) instrumental texture measurements (TPA ± shear) as the primary indicator of mechanical quality, (iii) hedonic sensory testing for consumer acceptance, (iv) WHC & cooking yield testing as a measure of ingredient and processing function, (v) utilization of MTGase, polyphosphate, and hydrocolloid to improve texture and stability, and (vi) monitoring of quality stability during storage with TBARS/TVB-N and microbiological parameters. The combination of instrumentation (TPA, colorimeter, SEM) and multivariate statistical analysis (PCA/regression) is increasingly common in recent studies to link instrumental attributes with consumer perception and perform data-driven formulation optimization (Bland et al., 2018; Canti & Martawidjaja, 2024; Kocatepe et al., 2024).

This prism flowchart in Figure 1 illustrates the process of study identification, screening, eligibility assessment, and final inclusion. A total of 120 records were initially identified through Google Scholar. After removing duplicates, 105 records were screened based on title and abstract, with 55 excluded for irrelevance. Fifty full-text articles were assessed for eligibility, and 30 were excluded (18 for irrelevance, 12 for incomplete data). Finally, 20 studies were included in the bibliometric synthesis.

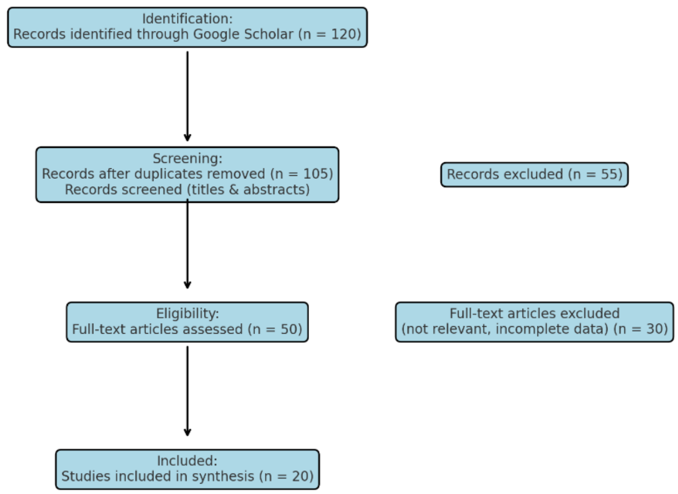

FIGURE 1. Prism flow diagram.

RESULT AND DISCUSSION

Result

Below is a synthesis of key empirical findings from recent journal research and proceedings (2022–2025) regarding the effects of fish meat, fish protein isolate (CPI/FPI), enzymes (MTGase), binders/fillers (tapioca, konjac, porang), and additives (STPP, hydrocolloid) on (A) product physicochemical/technical properties (WHC, cooking yield, pH, color), (B) instrumental textural properties (TPA, gel strength, shear strength), (C) sensory acceptability/appetite, and (D) protein content and quality stability during storage. Each item refers to a searchable publication.

Physicochemical and Functional Properties (WHC, Cooking Yield, pH, Color)

a. Catfish Protein Isolate (CPI) / Fish Protein Isolate (FPI) improves WHC and cooking yield.
   Several studies have found that the addition of CPI or FPI to fish ball or fish ball formulations significantly increases water-holding capacity and cooking yield compared to controls without isolates, due to the increased protein content, which plays a role in forming a gel network and retaining water. It was reported that increased WHC and cooking yield in mackerel fish balls formulated with CPI (pH-shift extraction). Similar results were reported for MCM:CPI formulations (varying ratios) that maintained proximate post-freezing quality (Alkuraieef et al., 2020; Canti & Martawidjaja, 2024).
b. The use of surimi or the addition of gel-quality meat (e.g., abalone or high-quality surimi) increases gel strength and WHC, but can decrease whiteness depending on the source.
   Experimental studies have shown that substitution with surimi components or the addition of meat with high gel capacity increases gel strength and WHC values, but some ingredients (e.g., abalone, certain types of FPI) alter color parameters (decreasing L*/whiteness). A trade-off between improved functional properties and color changes was noted (You et al., 2024).
c. Fillers (tapioca, cassava/porang starch, konjac) affect the final water content and protein content.
   The addition of starch-based fillers (tapioca, cassava, porang) generally reduces the final product's wet protein percentage (with a thinning effect) but can improve texture (compact/chewy) and reduce raw material costs. Several Indonesian studies report that filler combinations—in the right proportions—enable products to meet SNI standards while maintaining acceptable sensory scores. Konjac (glucomannan) and porang have demonstrated the

ability to act as natural thickeners/binders, reducing the need for synthetic additives (Khotimah et al., 2024; Wijayanti et al., 2021).

d. STPP/polyphosphate increases WHC but regulatory and pH effects must be considered.

Literature reviews and laboratory studies suggest that STPP improves protein water-binding capacity and cooking yield, but parameter levels (≥0.5–0.6%) are regulatory sensitive and can affect pH and sensory aspects if excessive. The mechanism of polyphosphate on WHC was previously discussed (You et al., 2024).

Instrumental Texture Properties (TPA, Gel Strength, Shear Strength)

a. TPA (hardness, springiness, cohesiveness, chewiness) is consistently the primary indicator of formulation changes.

Generally, the addition of CPI/FPI, MTGase, and hydrocolloids increases hardness and springiness—indicating stronger gels and chewier textures. Many studies use a P/36 probe and a compression setting of ~50% (TPA) so results can be compared between studies. For example, Canti (2024) found an increase in hardness and gel strength when CPI was added; You (2024) reported a strong relationship between increased gel strength and TPA parameters.

b. MTGase consistently increases firmness/gel strength and cooking yield.

Studies on trout/rainbow trout and similar products have shown that MTGase (typical dosages of 0.5–0.8% w/w) results in increased gel strength, hardness, and cooking yield and often reduces cooking loss. This effect is seen in both fresh and frozen products during long-term storage. An empirical report from Kocatepe et al. (2023) and several studies from 2023–2024 support this.

c. The interaction of ingredients (filler × isolate × enzyme) produces a non-linear pattern.

When protein isolates (CPI/FPI) are combined with vegetable fillers or MTGase, the effects on TPA parameters are not always additive: in some combinations, hardness increases, but cohesiveness or springiness do not increase proportionally, indicating a complex interaction between protein fractions, starch, and enzymatic cross-linking. This necessitates multifactorial studies and multivariate analysis (PCA/PLSR) to map the relative influence of these factors (Canti & Martawidjaja, 2024; Kamani et al., 2024).

Sensory Acceptance/Likeability

a. A strong but imperfect correlation exists between instrumental parameters (especially hardness/springiness) and texture preference scores from consumer panels.

Many studies report a positive correlation between hardness (TPA) and perceived preferred chewiness, but this correlation is not linear. Too high a hardness value decreases liking, indicating an optimum window for consumer-preferred texture. You et al. (2024) and local studies report this correlation and the importance of consumer hedonic testing (30–100 panels).

b. The addition of protein isolate (CPI/FPI) tends to maintain or improve overall scores as long as it does not negatively impact color/flavor.

Canti's (2024) study and the mackerel-CPI storage report indicate that consumer panels give similar or higher liking scores to formulations with CPI compared to the control, primarily due to a more compact and chewy texture. However, if the isolate or meat source produces a “strong” fishy odor or discoloration, flavor/color scores may decrease.

c. Plant-based fillers (porang, konjac, yam) can be sensorially acceptable if proportions are adjusted—improving texture but reducing relative protein content.

Local studies report that the use of porang/konjac flour increases the panel's preferred chewiness/compactness but tends to reduce the percentage of moist protein; this compromise is important when the goal is a “high-protein” product. SNI studies/national research indicate that optimal filler proportions are necessary to maintain sensory-nutritional balance.

d. Differences in regional preferences/market segmentation are important—hedonic test results vary across local studies.

Several field studies in Indonesia have shown variability in preferences (e.g., softer textures are preferred in one region, chewier in another), indicating that formulation recommendations should be tailored to the target market. Local consumer preference studies emphasize the importance of large-scale consumer surveys for MSME product design.

Protein Content, Nutritional Value, and Storage Stability

a. The addition of CPI/FPI increases the protein content per wet weight and improves the amino acid profile of the final product.

Several proximate composition studies have shown an increase in protein percentage when CPI/FPI is added (CPI contains up to 90% db of isolate protein), allowing the final product to meet the standard for a "protein source" claim. Comparative data from MCM:CPI show an increase in protein content with increasing isolate fraction (Alkuraieef et al., 2020; Canti & Martawidjaja, 2024).

b. The effect of chilling/freezing on protein is relatively small, but lipid oxidation (TBARS) and TVB-N increase over time—MTGase can slow some physical degradation but does not necessarily suppress lipid oxidation without additional antioxidants.

Frozen/cold chain storage tests have shown that microbiological parameters and TBARS/TVB-N increase over long intervals; MTGase improves structural stability and can reduce cooking loss during storage, but does not completely suppress lipid oxidation unless antioxidant treatment or vacuum packaging is applied. A 210-day report on trout meatballs (Kocatepe et al., 2024) and Altan et al. (2024) study highlighted this issue.

c. Post-heating amino acid bioavailability and proteolytic changes during storage are rarely studied.

Among the studies analyzed, the majority reported proximate (total protein) levels, but only a few measured amino acid bioavailability or changes in functional peptide composition after heating/during storage. It confirmed the research gap in the area of functional nutrition claims for fish meatball products (Alkuraieef et al., 2020; Shaviklo, 2007).

Additional Findings—Added Value from Non-conventional Ingredients & Waste Utilization

a. Valorization of by-products/local ingredients enhances nutritional value without compromising sensory properties when controlled:

The use of bio-calcium from fish bones, oyster mushroom flour, or marine residues for fortification has shown potential to increase mineral (Ca, Zn) or fiber content, and in some formulations, provides texture/nutritional enhancement without compromising consumer acceptability (e.g., the addition of fishbone bio-calcium to tilapia fish balls increases Ca content and gel strength) (Rahmadina, 2024; Trisnawati et al., 2024).

b. Application of plant proteins (soy protein isolate, whey, fava bean protein) as substitutes/modifiers

Research testing ISP/WPI/FPI for texture improvement reports that plant proteins can improve cohesiveness/chewyness but often degrade the flavor profile/authenticity of fish products at high doses—referring to the need for hybrid formulations that consider sensory profiles. Studies in 2024–2025 are beginning to explore fava bean protein and whey as alternatives in the context of low-grade surimi (Kamani et al., 2024; P. Rahman et al., 2024).

Discussion

A bibliometric analysis of publications discussing the effect of fish meat in meatball products shows that research trends largely focus on three main aspects: product physical properties, consumer preference, and nutritional content, particularly protein.

Physical Properties of Meatballs

Most studies report that the addition of fish meat to meatballs significantly affects texture, chewiness, and water-holding capacity. For example, research by Hafid et al. (2023) found that the use of catfish meat produced meatballs with a softer texture while maintaining good elasticity, unlike pure beef meatballs. Furthermore, Zhang et al. (2023) in Food Proceedings showed that the myofibrillar protein composition of fish plays a crucial role in forming a gel network, which supports the chewiness of meatballs.

Consumer Preference

Sensory analysis in various publications confirms that the substitution of fish meat in meatballs is acceptable to consumers at certain proportions. Pratama and Ustadi (2023) reported that panelists gave high preference scores to snakehead fish meatballs up to a 50% substitution level, after which acceptance declined due to a more dominant fishy aroma. Similarly, Yusuf et al. (2023)found in an international proceeding that the use of excipients such as ginger or lime can improve sensory acceptance of fish-based meatballs.

Protein Content and Nutritional Value

Protein content is one of the advantages of fish meatballs. Wibowo (2024) noted that substituting catfish meat can increase protein content by 12–15% compared to pure beef meatballs. Similar results were reported by Rahman & Fitria (2022) in a food research proceeding, stating that local freshwater fish can enrich the essential amino acid profile of meatballs. Furthermore, the presence of omega-3 fatty acids in some types of marine fish makes fish-based meatballs more functionally valuable than red meat meatballs (Nendissa et al., 2024).

Research Trends and Publication Patterns

Bibliometric studies also show that the number of publications related to fish-based meatballs has consistently increased since 2018. This is related to the push for healthy food research and diversification of protein sources. The largest research centers are from Indonesia, given that meatballs are a popular food, with significant publication contributions in national and international proceedings (Gürbüz et al., 2025).

Overall, previous research results confirm that the use of fish in meatballs can improve nutritional quality while maintaining sensory characteristics, although innovative strategies are needed to overcome the fishy odor, which remains a barrier to consumer acceptance.

CONCLUSION

The synthesis of various studies indicated that fish balls have significant potential as a nutritious, affordable, and consumer-acceptable source of animal protein. The addition of fish protein isolate (CPI/FPI), enzymatic treatments (e.g., MTGase), and natural fillers (tapioca, konjac, porang) have been shown to improve water-holding capacity, cooking yield, and textural properties, although there are still trade-offs in color and flavor. Sensory testing consistently confirmed that consumer acceptance was strongly influenced by textural balance—especially the level of chewiness—while excessive modification can actually decrease acceptability.

From a nutritional perspective, the use of fish meat or protein isolate can increase protein content and amino acid profiles, adding to the benefits of omega-3 fatty acids and functional minerals. However, research gaps remain regarding amino acid bioavailability, the relationship between microstructure and sensory perception, and quality stability during long-term storage.

Bibliometric analysis showed that publications on fish balls have continued to increase in recent years, but methodological variations and the limited scope of studies at the household/MSME scale still hinder the standardization and widespread application of research findings. Therefore, further research needs to focus on an integrated approach that combines instrumental analysis, sensory testing, and microstructural characterization to develop predictive quality models. Collaboration between academics, MSMEs, and industry is also crucial to ensure consistent implementation of innovations that contribute to food security and consumer health.

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