Journal of Halal Science and Research (JHSR)
Vol. 7, No. 2, Month September, Year 2026, Page 125 – 138
doi: 10.12928/jhsr.v7i2.11991

P-ISSN: 2715-6214
E-ISSN: 2964-4909

The potential of fish gelatin as an alternative for developing halal gelatin products: A review

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ABSTRACT
Gelatin is an essential ingredient in the food, pharmaceutical, and cosmetic industries, known for its role as a stabilizer, thickener, and texturizer. Fish gelatin from non-mammalian origins offers a promising alternative that aligns with halal dietary laws without requiring specific slaughtering processes. This review aims to comprehensively evaluate the potential of fish gelatin as a halal substitute, focusing on its physicochemical properties, industrial applications, and suitability for the growing global halal market. The study applied a systematic review method, utilizing Google Scholar and Scopus to collect relevant articles from the last decade. The results indicate that fish gelatin generally has lower gel strength and thermal stability than mammalian gelatin due to its lower proline and hydroxyproline content. Despite these limitations, fish gelatin exhibits sufficient gelling properties for cold applications, such as desserts, and can be enhanced with additives to improve stability and gel strength. Additionally, Indonesia's abundant fish resources provide substantial potential for local production. Fish gelatin has shown promise in food products, especially in items not requiring high thermal stability, as well as in specific pharmaceutical and cosmetic applications.

Article History
Submitted: November 11, 2025
Revised: September 7, 2026
Accepted: September 23, 2026
Published: September 30, 2026

Keywords
Extraction methods, Fish gelatin, Halal alternative, Mammalian gelatin, Physicochemical properties.

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INTRODUCTION

Gelatin is essential as a thickener, stabilizer, and texturizer in various food, pharmaceutical, and cosmetic products. In the food industry, gelatin is often used to form a chewy texture in products such as jelly candy. However, its halal status is often debated because its essential ingredients come from animals, especially pigs and cows, which raises concerns among Muslim consumers (Rismandari et al., 2017). Alternatives to gelatin, such as carrageenan extracted from seaweed, have been widely adopted in the food and cosmetic industries because they have good gel-forming ability and chemical stability, making them potential substitutes for animal gelatin (Zhu et al., 2018). In addition, gelatin from fish sources has been developed to meet halal requirements. It has physical and chemical properties that are close to mammalian gelatin, although it has challenges in weaker rheological strength (Lin et al., 2017).

In Islam, gelatin derived from pigs is considered non-halal and haram for consumption because Islamic law prohibits all products containing pork elements. Pork gelatin is very commonly used in the food and pharmaceutical industries because the production process is cheaper and shorter (Elyasi et al., 2020). Another major problem is the dependence on imported gelatin, including pork gelatin, in Indonesia, where most of the population is Muslim. The need for halal gelatin is a significant challenge because it must be met from sources that comply with Sharia law, for example, from fish or animals that are slaughtered according to Sharia (Nirwandar, 2020). As for beef gelatin, its halal status is highly dependent on the slaughtering process; if the slaughtering does not follow Sharia, the resulting gelatin is considered non-halal, even though it comes from cows. Other obstacles are higher production costs

P-ISSN: 2715-6214
E-ISSN: 2964-4909

and difficult accessibility of raw materials, so the need for halal gelatin is often not fully met (Tukiran et al., 2023). From an economic perspective, this dependence on imports creates a substantial foreign exchange burden, whereas the development of domestic fish gelatin from abundant local fishery by-products offers a strategic opportunity to reduce import costs, generate added value, and strengthen the national halal industry competitiveness in the global market. Fish gelatin is increasingly being considered as a non-mammalian alternative in the halal food industry due to its nature, which is considered halal without requiring slaughter according to Islamic law, as emphasized in several recent studies. The demand for halal products is increasing along with the development of the global market, so the need for halal gelatin from fish is becoming increasingly important (Amalina et al., 2022).

Studies on the potential of halal tourism also support this, showing that halal-based products have an enormous market value for local consumption and attract international tourists (Soleha, 2023). Fish gelatin is an essential alternative to mammalian gelatin in the halal industry because it has comparable chemical and physical properties and is derived from raw materials safe for Muslims to consume. Studies have shown that gelatin from tilapia fish skin and other species can produce gels with suitable strength for industrial applications, without excess fat content and with high protein levels (Reza & Annissa, 2023). The development of fish gelatin sources as a halal substitute supports the diversification of halal products to meet the increasing global market demand.

The abundance of fish in Indonesian waters, such as catfish, provides great potential as a raw material for gelatin, which can be extracted with effective techniques such as ultrasonic assistance, which produces gelatin with high gel strength and suitable viscosity (Asih et al., 2019). In addition, the fish gelatin extraction process is relatively simple. It does not require additional materials that are potentially non-halal, making it a more specific and easy alternative to meet the needs of the halal food industry in Indonesia. This fish gelatin is also more specific in terms of halalness because the extraction process is relatively simple and does not require additional materials that have the potential to contain haram substances (Capriyanda & Mujiburohman, 2021). The abundant availability of fish and easy production processes support fish gelatin as a safe and halal-compliant alternative for Muslim consumers in Indonesia.

Several types of fish, such as Tilapia (*Oreochromis niloticus*) and Yellowfin tuna (*Thunnus* sp.), are known to have high potential in gelatin production due to the physical and chemical characteristics of collagen contained in their skin and swim bladder (Hadinoto et al., 2019). Several types of fish, such as tilapia (*Oreochromis niloticus*) and yellowfin tuna (*Thunnus* sp.), have high potential in gelatin production. However, challenges arise in terms of low gel strength and viscosity. Research shows that modifying fish gelatin with substances such as pectin or sodium alginate can increase the melting point and gel strength, making it closer to the characteristics of mammalian gelatin (Sow et al., 2017). The aim of this review is to provide a comprehensive insight into fish gelatin as a halal alternative, covering its potential benefits, limitations, and applications in the halal product industry.

RESEARCH METHOD

Methods

This review used data from two databases, Google Scholar and Scopus. Article searches were conducted by identifying, assessing, and interpreting research results. The search terms (keywords) used in both databases were "fish gelatin", "fish gelatin extraction", "fish gelatin characterization", and "halal fish gelatin". These keywords were combined using Boolean operators, such as "AND" and "OR", to broaden and refine the search results (e.g., "fish gelatin AND extraction", "fish gelatin AND halal", "fish gelatin OR mammalian gelatin"). The selected articles were filtered from the last ten years (2014 – 2024) to ensure the relevance and currency of the information.

Based on the population, intervention, comparison, and outcome (PICO) framework, the research questions were formulated according to the variables studied. The population (P) refers to the types of fish used as raw material for gelatin production, including various fish species such as tilapia, tuna, catfish, and pangasius. The intervention (I) involves the extraction methods applied to produce fish gelatin, which include acid pretreatment, ultrasonic-assisted extraction, and enzymatic extraction. The comparison (C) is made between fish gelatin and mammalian gelatin (bovine or porcine), focusing on their physicochemical properties, such as gel strength, viscosity, melting point, amino acid profile, and

P-ISSN: 2715-6214
E-ISSN: 2964-4909

halal status. The outcome (O) is the resulting characteristics and potential of fish gelatin as a halal alternative, assessed based on gelatin quality, functional properties, and applicability in halal food and pharmaceutical industries. Based on population, intervention, comparison, and outcome (PICO), the research questions focus on:

1. What kinds of fish could be used to produce gelatin?
2. Comparison of fish gelatin extraction methods?
3. What characteristics separate fish gelatin from mammalian gelatin?
4. Identification: Searching for articles in databases using keywords
5. Screening-Sorting articles based on title, keywords, and abstract
6. Eligibility: Sorting articles by reading the contents of the article
7. Inclusion-Determining which articles to use in the review

This review aims to ascertain whether processed marine products, like fish, can serve as a substitute for non-halal gelatin. The parameters used in the article search include fish type, extraction technique, fish gelatin properties, proline and hydroxyproline content, and possible industrial use. Even though not all parameters were present in the articles used, they can still be compared based on the subjects covered in each journal. Articles that satisfy the requirements are found after the manual article screening procedure is completed, removing any uncertainty that may have arisen during the earlier step.

The PRISMA 2020 method for reviews and meta-analyses includes identification and screening (Page et al., 2021). In the identification stage, 1,442 articles were found from Google Scholar and Scopus. The screening stage involved reading the title and abstract of each article, resulting in 70 relevant articles and 1,372 irrelevant articles. Furthermore, further analysis was carried out by reading the complete text, and 30 articles were obtained that met the eligibility criteria. In the inclusion stage, we analyzed the relevant results and identified 18 articles that met the requirements. PRISMA Flowchart: Systematic search results for 2014 – 2024 can be seen in Figure 1.

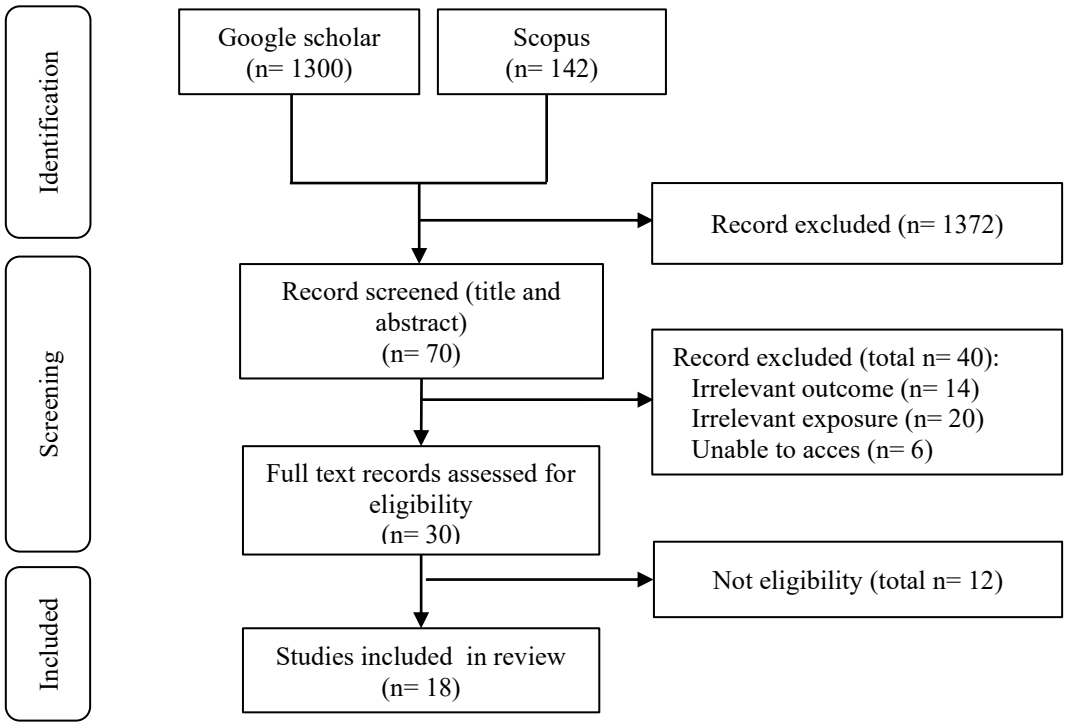


Figure 1. PRISMA flowchart of the results of the systematic search between 2014 – 2024.

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RESULT AND DISCUSSION

Gelatin Perspective in Islamic Law

The concept of halal in Islam is related to the obligation of Muslims to consume products that meet sharia standards, not only in terms of raw materials but also the production process. Haram products, such as those containing pork or alcohol, are strictly avoided and need to be checked for their contents so that people can ensure compliance with Islamic rules (Dewi et al., 2022). Halal not only has an impact on consumer comfort but is also the responsibility of producers to provide safe products according to Sharia principles (Ali, 2016). As stated in the Quran, this guideline emphasizes the principles of justice, cleanliness, and transparency in consumption, which are the essence of halal products for Muslims.

In Islamic law, gelatin derived from pigs or cows that are not slaughtered according to sharia is considered non-halal due to the raw materials being unclean or the slaughtering process not meeting halal requirements (Hakim, 2021). The gelatin production process, such as acid or base extraction, is at risk of contamination with haram materials, which can affect the halal status of the final product. This contamination occurs when the production process is not strictly monitored, especially in products produced in facilities that process non-halal materials (Abdulloh et al., 2020). Therefore, it is essential to ensure that the entire gelatin production chain, from raw materials to the extraction process, follows halal standards to meet the needs of Muslim consumers.

In Islamic law, the safety of consuming animal-based gelatin is highly dependent on its halal status, especially since gelatin is often made from collagen taken from animal bones and skin. Halal Certification Bodies, such as the Indonesian Ulema Council (MUI), play an essential role in ensuring that products in circulation meet halal standards through certification that includes raw materials, production processes, and facilities used (Hatoli, 2020). One of the main requirements for obtaining halal certification is using materials free from haram elements, maintaining cleanliness, and compliance with sharia procedures such as appropriate slaughtering for land animals (Amalina et al., 2022). The implementation of the halal assurance system aims to protect Muslim consumers, provide product safety assurance, and ensure that Muslim consumers can consume products that are guaranteed halal in the market.

From an Islamic legal perspective, fish gelatin is considered halal and does not require slaughter, unlike gelatin from land animals. This makes fish gelatin an alternative that is more certain of its halalness and easier to meet sharia standards (Suryanti et al., 2018). Scholars and fiqh experts support the use of fish gelatin because it is free from ingredients that conflict with sharia. Fish gelatin is also safe for food, pharmaceuticals, and cosmetics requiring halal assurance. This potential makes fish gelatin increasingly in demand in the global halal product market (Suryanti et al., 2017).

International halal standards such as those issued by the Halal Food Authority (HFA) regulate food ingredients to meet halal requirements for Muslims, including fish gelatin, which is recognized as a halal ingredient because it does not require a complicated slaughtering process. In Indonesia, the halal industry development is also significant, with strict standards referring to Islamic guidelines and laws to meet the increasing demand from global Muslim consumers (Nirwandar, 2020). In addition, fish gelatin has excellent potential to replace mammalian gelatin in the food industry because its physical and chemical properties can be adjusted to the needs of various halal products (Reza & Annissa, 2023). This standardization facilitates international trade in safe and quality halal products and provides opportunities for producers to compete in the global halal market.

Gelatin as an Alternative to Mammalian Gelatin/Comparison with Mammalian Gelatin

Gelatin derived from mammals, such as bovine or porcine skin and bones, often poses halal and ethical challenges for Muslim, Hindu, and Jewish consumers, making it essential to find safe and halal alternatives. Fish gelatin has emerged as a potential alternative to meet the demand for halal products, especially since it does not contain religiously controversial ingredients, such as those found in bovine or porcine gelatin (Reza & Annissa, 2023). Research has also shown that fish gelatin, primarily extracted from fish skin and bones, has physicochemical characteristics that support its use as a substitute for mammalian gelatin, although its gel strength is generally lower (Nitsuwat et al., 2021). In

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E-ISSN: 2964-4909

addition, the demand for halal products has driven the development of fish gelatin in Indonesia, which can be an alternative solution to the increasing demand for halal food (Musafira et al., 2023).

Fish gelatin has lower proline and hydroxyproline content than mammalian gelatin, affecting the melting point and gel strength (Table 1). In this case, fish gelatin shows lower melting point characteristics than gelatin from mammals, so fish gelatin is more susceptible to heat and less suitable for specific applications requiring high temperature stability (Hadinoto et al., 2019). In addition, the results of the study showed that the collagen structure of tuna swim bladder, which is rich in glycine and alanine, produces gelatin with high thermal stability, which has the potential to be applied to food and pharmaceutical products that require gelatin with specific stability (Suryanti et al., 2018).

Table 1. Physical and chemical properties of fish and mammalian gelatin for potential applications.

Characteristics	Fish Gelatin	Gelatin Mammals	Source
Contents: Proline and Hydroxyproline	Low, affects gel strength.	Higher, supports greater gel strength big.	Hadinoto et al. (2019)
Point Melt	Lower than gelatin in mammals.	Higher, stable at high temperatures.	Suryanti et al. (2018)
Stability Thermal	Stability thermal tall in several applications.	Stability thermal support various applications.	Suryanti et al. (2018)
Gel Power	Lower, producing a softer gel.	Higher, producing a strong gel.	Rismandari et al. (2017)
Texture Final Product	Texture is softer, less suitable for products that require strength.	Texture is solid, fit for products that require a strong stand.	Oktaviani et al. (2017)
pH resistance	Prone to pH variation.	Resistant to pH variation.	Oktaviani et al. (2017)
Potential Application	Certain food and pharmaceutical products.	Suitable for products that require temperature stability.	Hadinoto et al. (2019)

Fish gelatin has a lower gel strength than mammalian gelatin, making it produce a softer and less firm gel for applications that require a solid structure, such as candy or drug capsules. This deficiency affects the final product's texture, where products using fish gelatin may have a softer texture and are unsuitable for applications that require high strength (Hadinoto et al., 2019). In terms of stability, mammalian gelatin shows better resistance to high temperatures and pH variations, making it more suitable for use in products that require stability under hot or high acidity conditions (Suryanti et al., 2018). Fish gelatin tends to produce a softer gel than mammalian gelatin, which makes it less ideal for applications that require high gel strength such as candy or drug capsules (Rismandari et al., 2017). These characteristics affect the final product's texture, especially in products that require a strong and dense gel for shape retention and consistency. On the other hand, mammalian gelatin shows better stability against temperature and pH variations, making it more suitable for products that require high thermal and pH stability, such as hot or acidic products (Oktaviani et al., 2017).

Fish gelatin is often used in cold food products such as jelly and pudding because it has a lower melting point, making it suitable for products that do not require high temperatures (Table 2). The potential of fish gelatin as a halal alternative makes it an attractive choice for Muslim consumers, considering that mammalian gelatin generally comes from cows or pigs (Sugihartono, 2015). On the other hand, gelatin from mammals such as cows or pigs is more often used in products that require a strong structure, such as gummy candy and marshmallows, because it has a high proline content, which increases gel strength (Abdulloh et al., 2020). In addition to food applications, mammalian gelatin is widely used in pharmaceuticals, such as drug capsules, and cosmetics that require high stability (Nurdiani et al., 2020).

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Table 2. Comparison of applications of fish gelatin and mammalian gelatin.

Aspect	Fish Gelatin	Gelatin Mammals	Source
Main Applications	Cold foods (jelly, pudding).	Products that require strong texture (gummy candy, marshmallow).	Capriyanda & Mujiburohman (2021)
Product Food	Suitable for desserts that do not need a low temperature.	Stable for the application temperature range.	Sugihartono (2015)
Halal/Vegetarian Market Potential	Potential for the halal market because of non-mammalian sources.	Not suitable for the halal/vegetarian market unless halal-certified.	Abdulloh et al. (2020)
Gel Texture and Strength	Lower gel strength compared to gelatin from mammals.	High gel strength because of proline and hydroxyproline content.	Sugihartono (2015)
Pharmaceutical and Cosmetic Applications	Underused in pharmaceutical and cosmetic applications.	Frequently used in capsule medicine and cosmetics.	Nurdiani et al. (2020)

The use of fish gelatin has good prospects in the halal industry in Muslim-majority countries because fish gelatin is acceptable to Muslim consumers as an alternative to mammalian gelatin, which often comes from non-halal sources, such as pig skin (Sugihartono, 2015). However, there are several challenges related to the characteristics of fish gelatin, such as a low melting point and lower gel strength compared to mammalian gelatin, thus requiring technological development to improve its quality (Hadinoto et al., 2019). Further research is needed to overcome these weaknesses, including using enzymatic methods or special processing techniques to improve fish gelatin's stability and gel strength. Collaboration with the food and pharmaceutical industries is also recommended to accelerate the development of fish gelatin formulations and applications to be more competitive in the global market (Suryanti et al., 2018).

Optimization of Pre-treatment and Extraction in Fish Gelatin Production

The gelatin production process generally consists of several stages: washing raw materials, pretreatment, extraction, and purification. Pretreatment and extraction are two critical stages in the gelatin production process, so an optimization strategy is needed to produce gelatin with quality that meets standards (Milovanovic & Hayes, 2018). Pretreatment is carried out to change the protein structure in collagen by breaking non-covalent bonds. This can make insoluble collagen into soluble gelatin and facilitate extraction (See et al., 2015). Examples of fish gelatine pretreatment and extraction strategies can be seen in Table 3.

Based on Table 3, there are differences in the pretreatment stages of the same fish raw materials (skin, bones, cartilage, and head). These results indicate that each type of fish has different pretreatment efficiency. Pretreatment methods and extraction conditions can affect the composition and distribution of hydrophobic amino acids in fish gelatin, so that the physical properties of the resulting gelatin are different (Monsur et al., 2014). The pretreatment methods commonly used in fish gelatin production are acid and alkali. Acid pretreatment is widely used for materials with low cross-linked collagen, such as pigskin. Gelatin produced by this method is called type A gelatin, with an isoelectric point at pH 3.8 – 5.5. Alkali pretreatment is used for materials with high cross-linked collagen, such as cowhide. Gelatin produced by this method is known as type B, which has an isoelectric point at pH 5 – 7.5 (Milovanovic & Hayes, 2018).

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Table 3. Examples of fish gelatine pre-treatment and extraction strategies.

Material	Pre-treatment	Extraction	Yield	Source
Lumpfish	NaOH 0.1 N (1:10) at 5°C for 24 h and HCl 0.1 N (1:10) at 5°C for 24 h	CH_3COOH 0.1 N at 1:10 (w/v), 24 ºC for 24 h	35 – 40%	Sasidharan et al. (2024)
Stripped catfish	- NaOH 0.3 M (1:6 (b/v)) for 1 h - CH3COOH 0.05 M (1:4 (b/v) for 3 h	Water, 65ºC for 8 h	23.83%	Putri et al. (2023)
Tilapia	NaOH 0.05 N for 1 h and Citric acid 0.2% (1:4 (b/v)) for 12 h	Water, 65ºC for 7 h	19.64%	Nurilmala et al. (2021)
Shortfin Scad	NaOH 0.2 M for 1 h; H_2SO_4 0.05 M for 1 h; and citric acid 0.1 M for 8 h	Distilled water, 45ºC for 12 h	1.70%	Kuang & Mohtar (2018)
Mackerel	- NaOH (1:20 (b/v)) at various concentrations of 0.1 – 0.3 M and soaking times of 6 – 12 h - CH_3COOH (1:20 (b/v)) at various concentrations of 0.1 – 0.3 M and soaking times of 1 – 3 h	Distilled water, 70 ± 2ºC for 2 h	6.61%	Gunawan et al. (2017)
Yellowfin Tuna	- NaOH 0.1 M (1:10 (b/v)) at room temperature for 2 h - Butanol 10% (1:10 (b/v)) at room temperature for 30 min - CH_3COOH 0.5 M (1:10 (b/v)) at room temperature for 30 min	Distilled water with ratio 1:2 (b/v), 75°C for 6 h	17%	Pratiwi et al. (2017)
Sea bass	CH_3COOH 3% for 12 h	Water with ratio 1:3 (b/v), 70°C for 12 h	31.11%	Agustini et al. (2021)
Starry Triggerfish	Phosphoric acid 3% at ratio 1:3 (w/v) for 12 h	Distilled water with ratio 1:2 (w/v), 70°C for 3 h	11.10%	Nugraheni et al. (2021)
Milkfish	Citric acid 9% (v/v) with ratio 1:3 (b/v) for 48 h	Distilled water with ratio 1:3 (b/v), 60 – 65°C for 6 h	10.48%	Winarti et al. (2021)
Red snapper	Citric acid 1% for 12 h	Water, 90°C until dry	20.04%	Agustini et al. (2019)
Spanish mackerel	Water at ratio 1:4 for 4 h, warm water (60 – 70°C), and CH_3COOH 0.05 M (1:4 (b/v)) at room temperature for 10 h	Distilled water at ratio 1:3 (b/v), 59.7°C for 4.25 h	13.69%	Kusumaningrum et al. (2018)
Catfish	H_2SO_4 0.005 M (1:6 (b/v) for 12 h	Distilled water, 60ºC for 10 h	14.94%	Nasution et al. (2018)
Catfish	Citric acid 1% at a ratio of 1:4 and a time range of 24 – 56 h	Distilled water with ratio 1:4, 45 – 75°C for 5 h	6.14%	Pertiwi et al. (2018)
Cakalang	H_3PO_4 5% (1:8) for 12 h	Distilled water at ratio 1:6 (b/b), 80 – 85°C for 7 h	14.66%	Ridhay et al. (2016)
Tilapia	HCl 5% (v/v) for 24 h and papain enzyme 1.5% (v/v)	Distilled water, 70ºC for 4 h	6.30%	Hidayat et al. (2016)
Baronang	Bromelain enzyme at a concentration of 2% for 4 h	Distilled water at ratio 1:3, 50°C for 4 h	6.56%	Haryati et al. (2019)

The main factor determining the selection of the pretreatment method is the level of collagen cross-linking in the raw material used. Each raw material has different characteristics caused by various factors such as fish species, tissue, collagen type, and age. In fish skin, pretreatment using acid is often considered adequate because it can facilitate gelatin extraction by removing some acid-soluble proteins, lipids, and other unwanted components, disrupting some collagen molecular cross-links, and causing

P-ISSN: 2715-6214
E-ISSN: 2964-4909

skin swelling (Niu et al., 2013). The acid pretreatment method is also widely chosen by researchers as the only pretreatment method. Acid treatment helps remove impurities. Research conducted by Agustini et al. (2021) showed that gelatin made from red snapper skin with a 3% citric acid pretreatment method for 12 hours can yield 31.1%. According to Nugraheni et al. (2021), several types of acids have been studied for their effects on the characteristics of starry triggerfish (*Abalistes stellaris*) skin gelatin in the pretreatment process. The study results concluded that pretreatment with acetic acid can produce gelatin with the best viscosity and gel strength. On the other hand, the most significant yield, protein content, and water content are obtained from phosphoric acid treatment.

The combination of alkali and acid pretreatment is one of the pretreatment methods that positively affects the resulting fish gelatin. Pretreatment with alkali helps remove non-collagen proteins and fats, while pretreatment with acid provides a slightly acidic medium pH for good gelatin extraction results (Shyni et al., 2014). Research by Sasidharan et al. (2024) revealed that the use of a combination of pretreatment with 0.1 N NaOH and 0.1 N HCl at a temperature of 5°C for 24 hours on gelatin from Atlantic lumpfish (*Cyclopterus lumpus*) skin can produce a yield ranging from 7.3 – 41.1%, gel strength 2869 – 3801 pascals, and viscosity at a shear rate of 0.1 – 1 s ranging from 15 – 37 Pa s.

Pretreatment with proteolytic enzymes is one of the preferred methods that can be used to improve the extraction results and quality of gelatin. Proteolytic enzymes are one type of enzyme that functions to break down proteins into smaller molecules. Proteolytic enzymes can be used in gelatin pretreatment because they can hydrolyze covalent cross-links in the terminal region of the protein and facilitate the transformation of collagen into gelatin, resulting in less waste than chemical treatment (Zhang et al., 2011). The pretreatment process with enzymes can be used alone or in combination with chemical pretreatment (acid or alkali). (Hidayat et al., 2016) have optimized pretreatment with a combination of 5% HCl and 1.5% papain enzyme in the gelatin production process from tilapia fish bones (*Oreochromis niloticus*). The results showed that the gelatin obtained had a yield of 6.30% with better viscosity and gel strength characteristics compared to control and acid treatments. According to Haryati et al. (2019), baronang skin was extracted into gelatin using a 2% bromelain enzyme, yielding 6.56%, 0.35% ash, and 92% protein.

After pretreatment of the raw materials, gelatin extraction with water at various temperatures and times is the standard extraction method to obtain fish gelatin products (Table 1). The most frequently used extraction temperature in various research articles is 45 – 50°C, while the extraction time commonly used varies from 2 hours to 24 hours. Nurilmala et al. (2021) have optimized the gelatin extraction process from yellowfin tuna skin at various temperatures. They concluded that the higher the gelatin extraction temperature, the higher the yield. According to Sompie et al. (2015), high temperatures will help break hydrogen bonds in the gelatin hydrolysis process. The more hydrogen bonds are broken, the higher the collagen solubility level will be, so more gelatin yield will be obtained. However, increasing the temperature and the length of gelatin extraction time also affect the properties of the resulting gelatin gel. Research by Kittiphattanabawon et al. (2016) showed that gelatin extracted from clown featherback fish skin at high temperatures and longer times produced poor gel strength. Increasing temperature and extraction time can degrade protein molecular bonds into shorter bonds.

Gelatin Characteristics of Different Fish Sources

Fish gelatin is an alternative to mammalian gelatin. However, there are some limitations in the widespread use of fish gelatin. This is due to the differences in physical and chemical properties between fish gelatin and mammalian gelatin. Several characteristics, including gel strength, viscosity, and pH, assess gelatin quality. A comparative analysis of gelatin characteristics from various sources is presented in Table 4.

Based on Table 4, fish gelatin has different characteristics in various types of fish. However, in general, the characteristics of the fish gelatin produced have met the standards set by the Gelatin Manufacturers Institute of America, with gel strength in the range of 50 – 300 bloom, viscosity 1.5 – 7.5 cP, and pH 3.8 – 7.5 (GMIA, 2018). Differences in the characteristics of fish gelatin can be caused by two factors: raw materials and extraction methods. Raw material variables that can cause differences in the characteristics of fish gelatin are fish species, fish habitat, fish age, collagen type, and amino acid concentration. Meanwhile, extraction method variables that can affect the characteristics of gelatin are

P-ISSN: 2715-6214
E-ISSN: 2964-4909

pretreatment methods (acid, alkali, enzyme), extraction temperature, and extraction time (Pratiwi et al., 2017).

Table 4. Comparing gelatin's characteristics from various sources.

Source	Gel Strength (bloom)	Viscosity (cP)	pH	References
Fish Gelatin				
Stripped catfish skin	229.38	7.20	6.44	Putri et al. (2023)
Mackerel skin	70,81	5.51	5.47	Gunawan et al. (2017)
Catfish Skin	204.01	6.17	5.56	Nurilmala et al. (2021)
Sea bass skin	138.98	3.40	-	Agustini et al. (2019)
Starry Triggerfish skin	219.02	2.20	4,66	Nugraheni et al. (2021)
Milkfish bone	283.10	4.35	-	Winarti et al. (2021)
Red snapper skin	211.90	7.30	5.69	Agustini et al. (2021)
Spanish mackerel skin	291.00	8.07	-	Kusumaningrum et al. (2018)
Catfish bone	364.19	3.83	4.46	Pertiwi et al. (2018)
Tilapia bone	376.21	7.57	5.11	Hidayat et al. (2016)
Stingray cartilage	103.03	4.74	5.79	Santoso et al. (2015)
Gelatin standard				
GMIA	50 − 300	1.5 − 7.5	3.8 − 7.5	GMIA (2018)

Gel strength is an essential physical property of gelatin because it is related to the ability of gelatin to change the form of a sol into a reversible gel. Gel strength in gelatin is measured using the bloom value. The higher the bloom value, the stronger the gel. Bloom values are divided into three groups, namely high (220 to 300 blooms), medium (150 to 220 blooms), and low (< 150 blooms). Fish gelatin with high gel strength is from tilapia fish bones (376.21 blooms), while the low gel strength is gelatin from mackerel skin (70 blooms). The difference in gelatin gel strength is caused by the number of α-chain components, β-chains, and γ-chains, and amino acid composition (Kumar et al., 2017). According to Nurilmala et al. (2021), the living environment of fish affects the variation in the gel strength of fish gelatin. Fish from tropical waters produce gelatin with higher gel strength than fish from cold waters.

The viscosity of gelatin is an essential physical property for process control. Viscosity is used to determine the ability of gelatin to form a gel at a specific concentration and temperature. Viscosity is one of the quality parameters in gelatin products because it determines the application of gelatin in food products. Gelatin with high viscosity is more in demand in the commercial market and is priced higher (Joy et al., 2024). Gelatin with the highest viscosity comes from Spanish mackerel skin at 8.07 cP, while the lowest viscosity is shown in gelatin from sea bass skin at 3.40 cP. According to Gunawan et al. (2017), gelatin viscosity is influenced by the relationship between gelatin molecular weight and amino acid chain length. The higher the amino acid chain, the higher the viscosity of gelatin.

The pH value is one of the physical parameters that determine the quality of gelatin. The pH value can affect other physical properties of gelatin, such as viscosity and gel strength. Gelatin with a neutral pH value will be more stable and easier to apply to food products (Nurilmala et al., 2021). The difference in pH value in each gelatin source is caused by the pretreatment method. The acid pretreatment method will produce type A gelatin with a pH of 3.8 to 5.5. The alkali pretreatment method will produce type B gelatin with a pH range of 5 to 7.5. Combining acid and base during the pretreatment stage can produce gelatin with a pH value that deviates from types A and B (Kumar et al., 2017).

Fish Gelatin: Glycine, Proline, and Hydroxyproline Content

Gelatin is a protein derivative product of collagen found in skin, bones, and cartilage. Gelatin contains 9 of the ten essential amino acids, with the main components being glycine, proline, and hydroxyproline (Sasidharan et al., 2024). The diverse amino acid composition makes gelatin one of the multipurpose polymers for application in various industrial fields. In general, gelatin has many

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functions: emulsifiers, binders, precipitants, elasticity regulators, digestibility regulators, preservatives, stabilizers, and humectants (Pratiwi et al., 2017).

Gelatin is composed of repeating amino acid units, namely glycine-proline and glycine-hydroxyproline. The gelatin structure consists of 2/3 of the amino acid glycine, while the remaining 1/3 is proline and hydroxyproline. Glycine and proline are two amino acids included in gelatin products, which are very important in determining the physical properties of gelatin (Pranoto et al., 2011). Variations in amino acids, particularly proline and hydroxyproline, will impact gelatin's melting point and gel strength. According to Joy et al. (2024), gelatin containing high levels of proline and hydroxyproline amino acids will have a higher melting point and gel formation.

Fish gelatin has a lower proline and hydroxyproline amino acid content than mammalian gelatin. The content of proline and hydroxyproline in mammalian gelatin is around 30%, warm-water fish gelatin ranges from 22 – 25%, and cold-water fish gelatin is 17%. The low proline and hydroxyproline amino acid content in fish gelatin causes poor gel formation. In addition, gelatin from cold-water fish has the characteristic of being a thick liquid at room temperature, which limits its use in the food industry (Milovanovic & Hayes, 2018). Cold-water fish live in waters with low temperatures < 15°C, while warm-water fish live in waters with temperatures around 25°C. Types of cold-water fish are salmon, cod, herring, and trout. Types of warm-water fish are tilapia, yellowfin tuna, catfish, and patin (Zheng et al., 2024).

Opportunities and Applications for Fish Gelatin

The demand for halal gelatin is increasing along with the growing Muslim population in the global and domestic markets, requiring a safe and halal source of gelatin. Fish gelatin offers a more suitable alternative because it is free from the potential for pork contamination commonly found in commercial gelatins based on pork or other mammals (Sugihartono, 2015). In addition, fish gelatin has physicochemical properties that are suitable for the food and pharmaceutical industries, although it has a lower melting point, making it more flexible in specific product applications (Hadinoto et al., 2019). In Indonesia, a maritime country, the availability of fish gelatin raw materials is relatively abundant, so it has the potential to be developed as a local and environmentally friendly halal gelatin material.

The demand for halal products in the global market continues to increase, in line with the growth of the Muslim population, which has reached 1.8 billion people, and the increasing public awareness of the importance of halal consumption. Data from the Global Islamic Economy Report notes that global spending on halal products is predicted to reach USD 1.97 trillion in 2024, up from USD 1.37 trillion in 2018, with an average growth rate of 6.3% per year (Nirwandar, 2020). This creates a massive opportunity for fish gelatin, which is acceptable as halal in various Muslim countries, especially Indonesia, one with the largest Muslim population. In addition, fish gelatin offers a competitive advantage in halal because its raw materials do not come from land animals that require a unique slaughtering process (Tukiran et al., 2023). In addition, the abundant availability of fish in maritime countries such as Indonesia has the potential to lower production costs, making it a sustainable and more affordable option in the global market.

Fish gelatin has excellent potential as a thickener and stabilizer in the food industry, especially for candy, jelly, marshmallow, and meat-based products. Due to its lower melting point, fish gelatin can produce a soft texture and easily dissolve at low temperatures. It suits product applications with cold storage temperatures or direct consumption (Sugihartono, 2015). In addition, fish gelatin can be used in halal products, making it a suitable ingredient for markets with halal preferences at home and abroad, such as halal candy and gelatin-based desserts (Adiningsih & Purwanti, 2016).

Fish gelatin shows excellent potential in the manufacture of hard and soft capsules in the pharmaceutical industry as an alternative that is more in accordance with halal principles. Research shows that gelatin produced from tilapia fish bones (*Oreochromis niloticus*) can meet commercial gelatin quality standards with viscosity and ash content properties suitable for pharmaceutical needs (Capriyanda & Mujiburohman, 2021). In its application, capsules made from fish gelatin can meet the needs of the halal pharmaceutical product market, providing more comprehensive access for Muslim consumers who prioritize the halalness of the medicinal products they consume. In addition, fish gelatin can be applied in wound dressings and other health products, utilizing its biocompatible properties.

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Research on the characteristics of gelatin from tilapia fish skin shows that this gelatin can form an emulsion with high stability, which is helpful in various health care applications (Suryanti et al., 2017).

Fish gelatin is now widely used in cosmetic products because of its ability to form a film layer on the skin that maintains moisture and improves skin texture. Research by Suryanti et al. (2018) found that the gelatin fraction from tilapia fish skin has good emulsion characteristics, which can be applied in skin care products such as face masks and moisturizers. In addition, fish gelatin is also suitable for halal cosmetics, considering Muslim consumers are increasingly prioritizing halal ingredients in their cosmetic products (Sugihartono, 2015). Examples of applications include sheet masks and peel-off masks made from fish gelatin, which are not only halal but can also provide optimal moisture to the skin.

The use of fish gelatin, although potentially an environmentally friendly alternative, still faces challenges related to stability and gel strength under varying temperature conditions, mainly because its melting point and gel strength tend to be lower than mammalian gelatin. Modification of the properties of fish gelatin, such as using certain acids in the extraction process, has been shown to improve fish gelatin's physical and chemical quality. For example, research on tilapia skin gelatin showed that gelatin fractionation can improve emulsion stability, making it more suitable for food applications (Suryanti et al., 2017). In addition, the selection of fish species used in gelatin production also significantly affects the quality of the final product, because each species has varying protein and amino acid content, which can affect the gel strength and viscosity of the product (Sugihartono, 2015). Further research is needed to identify the correct modification method and determine fish species that produce high-quality gelatin to meet the food industry's needs more optimally.

CONCLUSION

Fish gelatin holds significant potential as a halal-compliant alternative to mammalian gelatin for use in food, pharmaceutical, and cosmetic products. Its non-mammalian origin satisfies Islamic dietary laws without requiring specific slaughtering processes, making it particularly attractive to Muslim-majority markets. While fish gelatin generally shows lower gel strength and thermal stability due to its reduced proline and hydroxyproline content, recent studies have demonstrated that its properties can be enhanced through modifications, rendering it suitable for various applications. Additionally, Indonesia’s abundant fish resources offer a sustainable and accessible raw material base for local and global halal markets. Fish gelatin’s functionality has proven effective for products that do not require high-temperature stability, such as cold desserts, halal confectioneries, and certain pharmaceuticals. Challenges remain, particularly in matching the physicochemical properties of mammalian gelatin, but advances in extraction and modification techniques continue to improve fish gelatin’s quality and usability. Ultimately, fish gelatin represents a viable solution for the halal industry, meeting both consumer demand for religious compliance and increasing global interest in sustainable and ethically sourced ingredients.

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