Journal of Halal Science and Research (JHSR)
Vol. 4, No. 2, Month September, Year 2023, Page 55 – 67
http://journal2.uad.ac.id/index.php/jhsr/index
P-ISSN: 2715-6214
E-ISSN: 2964-4909

Fish-based gelatin: exploring a sustainable and halal alternative

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ABSTRACT

Gelatin derived from fish has emerged as a promising alternative to traditional gelatin derived from mammals, primarily due to its potential to meet the rising demand for halal-certified products. This article provides a comprehensive overview of the utilization and extraction of gelatin derived from fish as a halal-compliant substitute. This study gathered information regarding the source, extraction method, and contribution to physicochemical properties and applications by reviewing the relevant literature. It discusses the most frequently consumed fish species, such as tilapia, mackerel, and catfish, which are halal and possess outstanding gel-forming properties. Type A gelatine (pre-treated acid) is distinguished from type B gelatine (pre-treated alkaline) based on the solvent used for pre-treatment. Seventy-five percent of the twenty gelatin extraction studies utilized alkaline pre-treatment (i.e., NaOH), where the base solution can eliminate non-collagen from the skin or bone of fish, thereby obtaining pure collagen. All extraction processes are conducted using the hot water extraction method at temperatures ranging from 45 to 70 °C. This method is time-efficient, accelerates collagen decomposition and gelatin solubility, and increases gelatin yield (from 5.33 to 68.75%). The effects of various procedures, including acid and alkaline extraction, on gelatin gel strength, moisture content, ash content, protein content, and fat content are investigated. According to SNI, gelatine has a gel strength between 50 and 300, a moisture content that does not exceed 16%, a lipid content that does not exceed 5%, and an average protein content that does not exceed 87.65%. However, ash concentrations typically persist above 3.25%, presumably due to using bases in pre-treatment processes that do not perfectly dissolve minerals compared to acids. In conclusion, the source and method of extraction will impact the gelatin's characteristics and applications.
Keywords: Gelatin, Fish-based gelatin, Physicochemical properties, Traditional gelatin, SNI

INTRODUCTION

Gelatin is a common constituent in various industries, including food, pharmaceuticals, cosmetics, and photography. Gelatin, traditionally derived from swine and beef (Lin et al., 2017), has been scrutinized due to ethical, religious, and environmental concerns. In recent years, there has been a growing interest in alternative gelatin sources that address these concerns while preserving the ingredient's desirable properties. Gelatin derived from fish is one alternative that has received significant attention (Ma et al., 2021). Fish gelatin is a sustainable and halal alternative to traditional animal-derived gelatin for those seeking a substitute. As the global demand for sustainable and ethical ingredients rises (Furtado et al., 2022), investigating fish gelatin as a viable substitute has become a subject of intensive study.

The primary concern when it comes to Halal gelatin is the origin of the gelatin. Islamic dietary laws prohibit pork consumption and stipulate that animals must be executed according topecific Halal guidelines (Ahmad et al., 2018). Consequently, alternative sources such as bovine, fish, and poultry have attracted considerable interest (Said & Sarbon, 2022). Each source presents its own challenges and considerations, such as accessibility, cost-effectiveness, and the ability to replicate the functional properties of conventional gelatin (Alipal et al., 2021). The extraction procedure is essential to the production of Halal gelatin. Diverse techniques, such as acid extraction, alkaline treatment, and enzymatic hydrolysis, have been explored to access gelatin from Halal sources (Usman et al., 2022). These techniques aim to convert the collagen found in animal connective tissues into gelatinous substances. The choice of extraction method is contingent on variables such as the gelatin source, the gelatin properties desired, and industry requirements (Reddy et al., 2021).

Fish gelatin is extracted from collagen-rich fish tissues, such as scales, skin, and bones. Gelatin is extracted from fish sources using techniques tailored to the characteristics of fish collagen. Gelatin derived from fish possesses unique properties, such as high gel strength, low viscosity, and enhanced solubility, making it appropriate for various applications (Karim & Bhat, 2008). Standard extraction procedures include pre-treatment, acid or alkaline extraction, and purification to obtain high-quality gelatin. Acid extraction involves exposing Halal raw materials to acidic conditions, typically hydrochloric or sulfuric acid. It has been studied how to optimize acid concentration, temperature, and extraction duration for efficient gelatin extraction and desirable gelatin properties (Milovanovic & Hayes, 2018). To solubilize collagen and extract gelatin, alkaline treatment employs alkaline solutions such as sodium hydroxide and potassium hydroxide (Matinong et al., 2022). The effect of alkali concentration, extraction temperature, and time on gelatin yield and properties has been investigated. Gelatine extracted with an acid is designated type A, while gelatine extracted with a base is designatedype B (Sikareepaisan et al., 2007).

Gelatin's physicochemical properties determine its overall quality and suitability for particular applications. Those properties include yield, moisture content, ash content, fat content, protein content, gel strength, pH, viscosity, thermal stability, foaming, and emulsifying properties. Type A gelatin has a lower isoelectric point as a result of the extraction method, which is acidic. It is typically between 7 and 9 pH (Siburian et al., 2020). Due to the alkaline extraction method, Type B gelatin has a higher isoelectric point. Typically, its pH ranges from 4.7 to 5.3 (Liang & Garcia, 2021). Type A gelatin typically possesses greater gel strength than Type B gelatin. It forms sturdier and more rigid gels. Type B gelatin is typically less gel-strength than type A gelatin. The gels formed are more flexible and pliable (Liu et al., 2015). Due to its higher gel strength, Type A gelatin is frequently preferred for applications requiring firm and stable gels, such as the manufacture of gummy chocolates, marshmallows, and hard capsules in the pharmaceutical industry (Bagal-Kestwal et al., 2019). With its gentler and more elastic gels, type B gelatin is utilized in products that require flexibility and a smooth texture. It is frequently used in yogurt dairy delicacies, as a stabilizer in whipped creams, and as an emulsifier and coating in photography (Zhang et al., 2020).

This article intends to provide a comprehensive overview of gelatin derived from fish, concentrating on its production, properties, and applications. It examines the various characteristics that make fish gelatin an appealing alternative, such as its sustainable sourcing, nutritional profile, physicochemical properties, and compatibility with various formulations. The review will delve into the extraction methods used to obtain gelatin from fish, as well as the various fish species and their unique properties that contribute to the gelatin's quality. In addition, the study will cast light on the physicochemical properties of fish gelatin, such as its gel strength, viscosity, solubility, and thermal behavior. Understanding these properties will allow researchers, formulators, and industry professionals to make well-informed decisions regarding the material's use in various applications. Fish gelatin has demonstrated promising application potential in numerous industries. This article examines its applications in the culinary industry, including confections, dairy products, meat processing, and baked goods.

RESEARCH METHOD

This literature review on fish-based gelatin investigates the sustainable and Halal alternative that this ingredient provides. The methodology employed in conducting this literature review has several steps. First, Literature Search: An exhaustive literature search utilizes academic databases, scientific journals, research articles, conference proceedings, books, and pertinent online sources. Second, Inclusion and Exclusion Criteria: Inclusion and exclusion criteria are developed to ensure the selection of pertinent, high-quality literature. The inclusion criteria may emphasize studies published within a certain time frame (2000 - 2020), the source of gelatin, and the provision of substantial information on the production, properties, and applications of fish-based gelatin. Third, Extraction and Analysis of Data: Relevant information is extracted from a comprehensive analysis of the selected literature. Key findings, data, and significant insights about gelatin derived from fish are identified and compiled. The extracted data may consist of information regarding the extraction methods, physicochemical properties, nutritional composition, and potential applications of fish gelatin. The data is systematically

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

organized and analyzed to identify patterns, trends, and knowledge gaps. The extracted data and findings are synthesized and interpreted to provide a comprehensive overview of fish-based gelatin as a sustainable and Halal substitute. The information is organized thematically or logically to address the various facets of fish gelatin, including its benefits, challenges, and potential applications.

RESULT AND DISCUSSION

Extraction of Fish-based Gelatin

Several stages are required to obtain gelatin from the skins or bones of fish during the gelatin extraction procedure. Here is an outline of the extraction procedure (Ahmed et al., 2020):

1. Pre-treatment: The fish shells or bones are collected from appropriate fish species, ensuring they are fresh and contaminant-free. Pre-treatment entails a comprehensive cleansing and removal of scales, fats, and other impurities from the fish skins and bones. This procedure is essential for guaranteeing the quality and purity of the extracted gelatin.
2. Acid or Alkaline Treatment: Fish skins or bones are subjected to acid or alkaline treatment to solubilize the collagen protein present in the tissues (Sousa et al., 2017). The choice between acid or alkaline treatment depends on the gelatin's intended properties and characteristics.
    a. In acid treatment, fish skins or bones are immersed in a diluted acid solution, typically hydrochloric or sulfuric acid. The acid aids in degrading connective tissues and releasing collagen from the unprocessed fish material. To facilitate collagen extraction, the mélange is heated at an appropriate temperature for a predetermined time (Dille et al., 2021). Type A gelatin results from acid treatment.
    b. Alkaline Treatment (Type B Gelatin): The alkaline treatment involves immersing fish skins or bones in an alkaline solution, typically lime (calcium hydroxide) or sodium hydroxide. The alkaline solution aids in removing non-collagenous proteins and minerals while preserving the collagen structure. To extract collagen, the mélange is heated under controlled conditions. Type B gelatin is produced through an alkaline process.
3. Extraction and Filtration: After the acid or alkaline treatment, the collagen-rich mixture is extracted using continuous or bulk extraction techniques. Continuous extraction involves passing the mixture through a series of extraction vessels containing new solutions. This procedure maximizes the efficacy of collagen extraction. The treated mélange is agitated or stirred in batch extraction to facilitate collagen extraction. The extracted collagen solution is subsequently filtered to remove impurities and solid particles.
4. Concentration and Purification: The extracted collagen solution is concentrated to increase the collagen content and decrease the water content. Concentration can be accomplished via various methods, including ultrafiltration and vacuum evaporation. The concentrated solution is then subjected to additional purification processes, such as enzymatic treatment or filtration, to eliminate any remaining impurities or coloring agents. These purification processes improve the gelatin's quality and clarity.
5. Drying and Milling: The purified collagen solution is then subjected to dehydrating and milling processes to remove any remaining water and convert it into gelatin. Spray drying, freeze drying, and air drying are methods that can be used to dry substances. After gelatin has been dried, it is milled into a fine powder or granular form for convenience of handling, storage, and subsequent use.

Table 1. describes that it is essential to note that specific parameters, such as temperature, duration, concentration, and the type of acid or alkaline solution used, can alter depending on the gelatin's desired properties and the manufacturer's specifications. Additionally, the extraction procedure may vary slightly between manufacturers or depend on the species of fish utilized.

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

Table 1. Effect of pre-treatment and extraction method on physicochemical properties of fish-based gelatin.

Source	Condition	Yield (%)	Gel strength (Bloom)	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Ref.
Abalistes stellaris skin	Pre-treatment: NaOH 0.05 M, 2 hr Extraction: 4 hr, 55 ℃	10.8	245.0	12.4	1.8	0.7	81.4	Jaziri et al., 2020
Red tilapia skin	Pre-treatment: NaOH 0.2%, 40 min Extraction: 4 hr, 55 ℃	-	150.0	11.1	0.6	-	-	Yusof et al., 2019
Patin bone (*Pangasius hypophthalmus*)	Pre-treatment: HCl 5%, 48 hr Extraction: 7 hr, 70 ℃	5.3	173.9	-	-	-	-	Asih et al., 2019
Pangasius catfish (*Pangasius sp.*) skin	Pre-treatment: Citric acid 1%, 12 hr Extraction: 6 hr, 65 ℃	22.0	59.4	-	-	-	-	Nurilmala et al., 2017
Red tilapia (*Oreochromis niloticus*) skin	Pre-treatment: Citric acid 1%, 12 hr Extraction: 6 hr, 65 ℃	24.7	118.4	-	-	-	-	Nurilmala et al., 2017
Red parrot bone	Pre-treatment: HCl 5%, 26 hr Extraction: 9 hr, 55 ℃	11.7	-	7.3	0.9	-	-	Rahayu & Fithriyah, 2015
Thornback ray skin (Raja clavata)	Pre-treatment: NaOH 0.5 M, 1 hr Extraction: 5 hr, 50 ℃	30.2	140.3	69.3	3.2	0.8	26.8	Lassoued et al., 2014

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Source	Condition	Yield (%)	Gel strength (Bloom)	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Ref.
Pangasius catfish (Pangasius sutchi) skin	Pre-treatment: NaOH 0.3 N, 60 min Extraction: 2.4 hr, 64 ℃	23.6	438.3	7.05	1.4	0.2	91.3	Mahmoodani et al., 2014
Mackerel bone	Pre-treatment: NaOH 5%, 24 hr Extraction: 5 hr, 60 ℃	7.9	-	7.9	1.9	-	27.1	Rachmania et al., 2013
Giant catfish skin	Pre-treatment: NaOH 0.2 M, 2 hr Extraction: 12 hr, 45 ℃	19.5	-	3.4	0.2	1.2	85.3	(Rawdkuen et al., 2013)
Tilapia skin	Pre-treatment: NaOH 0.2 M, 2 hr Extraction: 12 hr, 45 ℃	23.3	-	8.5	0.2	0.5	84.3	Rawdkuen et al., 2013
Smooth hound (*mustelus mustelus*) skin	Pre-treatment: NaOH 0.2 M, 2 hr Extraction: 18 hr, 50 ℃	11.8	211.2	4.3	0.05	0.2	92.6	Bougatef et al., 2012
Grey triggerfish (*Balistes capriscus*) skin	Pre-treatment: NaOH 0.2 M, 1.5 hr Extraction: 18 hr, 50 ℃	5.7	168.3	7.4	0.9	0.03	89.9	Jellouli et al., 2011
Cuttlefish (*Sepia officinalis*) skin	Pre-treatment: NaOH 0.05 M, 2 hr Extraction:	-	181.0	6.5	0.05	1.3	91.3	Balti et al., 2011

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E-ISSN: 2964-4909

Source	Condition	Yield (%)	Gel strength (Bloom)	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Ref.
	18 hr, 50 °C							
Chinese herring (*Tenualosa ilisha*) skin	Pre-treatment: $Ca(OH)_2$ 0.2 M, 1 hr Extraction: 3 hr, 50 °C	-	69.3	-	-	-	-	Norziah et al., 2009
Grouper skin	Pre-treatment: NaOH 0.2%, 40 min Extraction: 18 hr, 45 °C	68.5	94.6	-	-	-	-	Irwandi et al., 2009
Damn skin	Pre-treatment: NaOH 0.2%, 40 min Extraction: 18 hr, 45 °C	55.2	143.0	-	-	-	-	Irwandi et al., 2009
Mackerel skin	Pre-treatment: NaOH 0.2%, 40 min Extraction: 18 hr, 45 °C	67.8	46.3	-	-	-	-	Irwandi et al., 2009
Crispy skin	Pre-treatment: NaOH 0.2%, 40 min Extraction: 18 hr, 45 °C	43.6	251.7	-	-	-	-	(Irwandi et al., 2009
Nile perch bone	Pre-treatment: HCl 5%, 12 days Extraction: 5 hr, 65 °C	1.3	160.0	10.0	5.9	0.2	86.1	Muyonga et al., 2004

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

Table 1 demonstrates that 75% of extraction pre-treatments involve alkaline treatment. Pre-treatment with alkali is required to extract gelatin from fish-based source materials. Before the actual gelatin extraction procedure, the basic materials are exposed to an alkaline environment. This pre-treatment procedure has several advantages and contributes to the magnificence of gelatin extraction from fish (Khrunyk et al., 2020). These advantages are the following:

1. Enhanced gelatin yield: Alkaline pre-treatment increases the gelatin extraction yield from fish-derived materials. The alkaline environment aids in the hydrolysis of fish collagen, the primary source of protein for gelatin production. This hydrolysis process breaks down collagen into smaller peptides and amino acids, facilitating the subsequent extraction of gelatin (Pozzolini et al., 2020).
2. Improved solubility: Fish collagen contains cross-links and intermolecular associations that can limit its solubility in water. These associations are disrupted by alkaline pre-treatment, increasing collagen protein solubility. This enhancement in solubility facilitates the extraction of gelatin and the separation of impurities and non-collagenous substances.
3. Reduced impurities: Alkaline pre-treatment aids in the removal of impurities from fish-based source materials. It can break down and dissolve various non-collagenous components of the fish, such as lipids, pigments, and minerals (Bechtel & Smiley, 2010). These impurities can harm the quality and properties of the extracted gelatin, so removing them during pre-treatment is essential for obtaining a purer gelatin product.
4. Reduced odor and flavor: If not adequately addressed, fish-based materials may impart distinct odors and flavors to the extracted gelatin. By neutralizing or reducing the fish's objectionable odorous and flavorful compounds, alkaline pre-treatment can mitigate these issues. This results in a cleaner and more neutral-pasting gelatin, which is desirable for various food and pharmaceutical applications.
5. Improved functional properties: Alkaline pre-treatment improves the functional properties of gelatin derived from fish. During pre-treatment, the hydrolysis of collagen reduces the molecular weight of gelatin peptides. This lower molecular weight enhances the gelatin's gelling ability, emulsification properties, and water-binding capacity, making it more adaptable for various food and non-food applications (Mushtaq et al., 2022).

Table 1 also shows that all research used hot water extraction. Heated water extraction of fish-based gelatin is a technique that uses heated water as the solvent to extract gelatin from fish-based raw materials. This method involves subjecting the raw materials to elevated temperatures, typically between 50 °C and 90 °C in the presence of water, to dissolve the gelatin (Caruso et al., 2020). The temperature may vary based on the specific requirements of the gelatin extraction procedure and the properties of the basic materials employed. Collagen proteins in the raw materials are denatured by the heat applied during hot water extraction. Denaturation involves the unraveling and disrupting collagen helices, resulting in the solubilization of gelatin in water (Xu et al., 2020). Hot water functions as a solvent, allowing gelatin to dissolve and disseminate throughout the liquid.

There are numerous methods for extracting gelatin from fish-based raw materials, including heated, distilled, and mild acid extraction. The approach and conditions under which these procedures are conducted vary. Gelatin yield is relatively high due to hot water extraction's relatively high extraction efficiency. The heat denatures collagen and promotes its solubilization in water, enabling efficient gelatin extraction from unprocessed materials (Chen et al., 2022). In addition, heated water extraction typically requires shorter extraction times than other methods. The heat accelerates the extraction process by facilitating collagen decomposition and gelatin dissolutio resulting in a quicker extraction and increased throughput (Jafari et al., 2020).

Extraction with distilled water is a benign process that preserves the molecular integrity of gelatin. It reduces the likelihood that gelatin will denature or degrade during extractionresulting in a greater yield of intact gelatin (Senadheera et al., 2020). Since distilled water is readily available and relatively inexpensive, gelatin extraction using distilled water is a cost-effective option. It eliminates the need for additional compounds or solvents, thereby reducing the cost of extraction. Mild acid extraction facilitates collagen hydrolysis, breaking collagen into smaller peptides and amino acids (Noor et al., 2021). This hydrolysis process increases gelatin's solubility and facilitates its extraction, resulting in a greater gelatin yield than non-hydrolyzed techniques. The hydrolysis of collagen during moderate acid

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

extraction can improve the functional qualities of extracted gelatin. The resultant gelatin peptides have reduced molecular weights, which can enhance their solubility, gelling ability, and water-binding capacity, resulting in a gelatin product of higher quality (Ranasinghe et al., 2022).

Physicochemical Properties of Fish-based Gelatin

The specific physicochemical properties of gelatin can vary depending on the collagen source, extraction method, processing conditions, and any subsequent modifications or treatments applied to the gelatin. These properties can be optimized and tailored to satisfy the specific needs of various industry applications, including food, pharmaceuticals, cosmetics, and photography. The optimization process can be done by controlling the condition of pre-treatment and method of extraction. Besides that, the gelatin source also determines its physicochemical properties' quality. When it comes to fish-based gelatin, the part of fish chosen for gelatin extraction is the key point of the physicochemical properties of gelatin. Here are some important physicochemical properties of gelatin derived from fish (Himashree et al., 2022).

1. Gel strength refers to gelatin's ability to solidify when chilled. Fish-based gelatin typically demonstrates moderate to high gel strength depending on the specific fish species and extraction conditions(Siburian et al., 2020). Gel strength is an essential property for applications requiring gelling, such as confections, desserts, and gummy chocolates.
2. Viscosity: Viscosity is a measure of a substance's resistance to flow. Variables such as the molecular weight and concentration of the gelatin can affect the viscosity of fish-based gelatin (Jafari et al., 2020). The viscosity of gelatin solutions is crucial for controlling flow characteristics in applications such as coating and encapsulation.
3. Water-binding capacity (Moisture content): Gelatin has a high water-binding capacity, which indicates that it can absorb and retain water. Gelatin derived from fish is renowned for its exceptional water-binding properties, which enable it to retain moisture and enhance the texture and juiciness of food products. This property is especially advantageous in meat products, as it enhances moisture retention and tenderness.
4. pH Sensitivity: The pH sensitivity of gelatin derived from fish affects its behavior in various environments. Gelatin has an isoelectric point corresponding to the pH at which it is most insoluble. Above or below this pH, the solubility of gelatin increases. The pH of gelatin derived from fish can be altered to optimize its functionality for specific applications.
5. Ash content: As a protein-based component derived from collagen, gelatin typically contains a trace quantity of ash. Ash content refers to the inorganic residue remaining after completely combustion of organic matter. It represents the minerals and other inorganic compounds present in the sample. The ash content of gelatin can vary based on variables such as the collagen source and additional processing processes.
6. Protein content: Gelatin is a protein-rich ingredient; gelatin derived from fish is no different. Typically, between 85% and 95% of its weight is protein. Gelatin's protein is derived from the collagen found in fish tissues, which is hydrolyzed during extraction to produce gelatin.
7. Fat content: Gelatin derived from fish is typically very minimal in fat. As the extraction procedure aims to remove fats and lipids from the raw materials, the fat content may be negligible or in trace amounts. The fat content is typically less than 1% of the total weight.

Fish species, extraction method, collagen concentration, chilling rate, pH, processing, and modification can all affect the gel strength of fish-based gelatin. The gel strength is a measurement of the gel's firmness or rigidity when it has chilled. Variations in collagen composition between fish species directly impact the gel strength of extracted gelatin (Lueyot et al., 2021). Certain fish species may have higher or lesser gel strength collagen than others. The unique amino acid composition and molecular structure of collagen in various fish species contribute to these differences. The technique used to extract gelatin from fish can affect its gel strength. Temperature, time, and pH can impact the denaturation and solubilization of collagen, which in turn influences the gel strength of extracted gelatin (Yang et al., 2022). By optimizing the extraction parameters, the desired polymer strength can be achieved. Additional processing processes or alterations, such as enzymatic treatments or hydrolysis, can affect the gel strength of gelatin derived from fish. Enzymatic interventions can affect the gel strength of gelatin by altering its structure and properties. Hydrolyzed gelatin, which has undergone partial collagen hydrolysis, can manifest different gel strengths than non-hydrolyzed gelatin (Coppola et al., 2020).

Several variables, including fish species, gelatin extraction method, dehydration technique, and storage conditions, can influence the moisture content of fish-based gelatin. Due to variations in composition and water retention properties, the hydration content of various fish species differs. For instance, fatty fish such as salmon may have a higher natural moisture content than slender fish such as cod (Felician et al., 2018). The extraction method, such as alkaline or acid treatment, can affect the gelatin's ability to retain moisture. In addition, the extraction conditions and parameters, such as temperature and duration, can influence the final moisture content. After gelatin has been extracted, the drying method can substantially affect its moisture content. Various drying processes, including air, freeze, and spray drying, can result in varying moisture content. The drying process's duration and temperature also contribute to determining the ultimate moisture content. After gelatin is manufactured, its moisture content can be affected by storage conditions. High humidity during improper storage can contribute to moisture absorption and increased moisture content (Zhao et al., 2018). However, preserving gelatin in a dry environment can lead to moisture loss and a lower moisture content.

The ash content of gelatin derived from fish can be affected by some factors. The ash content of different fish species and body sections used to produce gelatin can vary. Diet, habitat, and metabolic rate all impact the ash content of fish. Certain species or body parts may contain inherently higher minerals and trace elements, resulting in a gelatin with a higher ash content (Sousa et al., 2017). By modifying the solubility of mineral compounds, acidic or alkaline extraction processes can also influence the ash content. The presence of contaminants or additives can affect the amount of ash in gelatin derived from fish. Heavy metals and environmental pollutants can contribute to the ash concentration. In addition, additives or processing aides, such as pH adjusters or preservatives, can introduce ash into the final product during gelatin production (Alfaro et al., 2015).

As a result of the processing procedures involved, fish gelatin typically contains minimal amounts of protein and fat. Protein and lipid compositions of different fish species vary. Some species are inherently leaner and contain less fat, while others may contain more. Consequently, the selection of fish species for gelatin production can impact the protein and lipid content of the final product. Protein and fat content can be affected by the procedures used to prepare the fish before gelatin extraction. The processing conditions and duration can affect the level of protein and lipid extraction (Ghaly et al., 2013). The extraction method, such as acid or alkaline treatment, can influence the solubility and separation of protein and lipids from fish tissue. Several stages are required to eliminate impurities and non-gelatinous components during gelatin production. These procedures, such as degreasing and deashing, can help reduce the gelatin's lipid and protein content. The efficacy of these depletion and removal techniques can affect the gelatin's ultimate protein and fat content.

Industrial Application of Fish-based Gelatin as Halal Alternative

Gelatin derived from fish is a promising halal alternative for numerous industrial applications. The following are notable industrial applications of fish-based gelatin as a halal alternative (Alipal et al., 2021; Wasswa et al., 2020):

1. Food Industry: Fish-based gelatin is used in the food industry as a halal alternative to gelatin derived from mammals. It can be used as a gelling agent, stabilizer, and texturizer in various culinary products, including candies, marshmallows, and jelly desserts. Gelatin derived from fish has comparable functional properties and complies with halal requirements.
2. Pharmaceutical Industry: Gelatin capsules are widely used to encapsulate medications and supplements in the pharmaceutical industry. Gelatin capsules derived from fish provide a halal option for Muslim consumers. They possess similar properties to gelatin capsules derived from mammals and ensure the integrity and safety of the pharmaceutical ingredients.
3. Cosmetics and Personal Care Industry: Halal-compliant gelatin derived from fish is utilized in the cosmetics and personal care industries. It is used to produce cosmetic lotions, skin care products, and hair care formulations. Halal-compliant gelatin derived from fish provides suitable functionality as a film-forming agent, binder, and stabilizer.
4. Nutraceuticals and Functional Foods: In producing nutraceuticals and functional foods, fish-based gelatin is a halal alternative. Following halal standards, it can be incorporated into collagen

supplements, protein bars, and fortified foods, providing essential amino acids and promoting overall health and wellness.

5. Biomedical and Biotechnological Applications: Fish-based gelatin is acquiring popularity as a halal alternative in biomedical and biotechnological applications. It can be used as a scaffold for tissue engineering, a dressing for wound recovery, and a vehicle for drug delivery systems. In these applications, gelatin derived from fish is halal-compliant, ensuring its suitability for diverse consumer preferences.

Industrial Coatings and Adhesives: Gelatin derived from fish can be a halal substitute. It is a binder in paints, varnishes, textile coatings, bookbinding, and packaging adhesives. Industries can meet halal requirements without sacrificing functionality by substituting gelatin derived from mammals with gelatin derived from fish.

CONCLUSION

The investigation of gelatin derived from fish as a sustainable and halal alternative has yielded promising results. This article aimed to cast light on the viability of fish-derived gelatin as an alternative to traditional gelatin sources, addressing both environmental and religious concerns. Utilizing fish byproducts that would otherwise go to waste, using fish-based gelatin provides a sustainable solution. This reduces environmental impact and encourages a more responsible and efficient use of marine resources. In addition, the procurement of fish-based gelatin conforms to halal requirements, making it a viable option for Muslim consumers looking for gelatin products that adhere to their dietary and religious requirements. The article examines in depth the physicochemical properties of gelatin derived from fish. Diverse parameters, including gel strength, viscosity, moisture content, ash content, protein, and lipid content, were examined to evaluate the functionality and applicability of fish-derived gelatin in various food and non-food applications. These properties were comparable to or even preferable to conventional gelatins, indicating that fish-based gelatin could serve as a suitable substitute. This article's findings indicate that fish-based gelatin can be a sustainable and halal alternative to conventional gelatins.

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