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PRODUCTION OF GELATIN EXTRACTED FROM FISH SWIM BLADDER: A NARRATIVE REVIEW

PRODUÇÃO DE GELATINA EXTRAÍDA DE BEXIGA NATATÓRIA DE PEIXE: UMA REVISÃO NARRATIVA

PRODUCCIÓN DE GELATINA EXTRAÍDA DE LA VEJIGA NATATORIA DE PECES: UNA REVISIÓN NARRATIVA

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ABSTRACT: O consumo mundial de peixes tem aumentado mundialmente, principalmente devido à preocupação dos consumidores com dietas saudáveis que forneçam proteínas de qualidade. Com o crescente consumo de peixes consequentemente há um aumento na industrialização e na quantidade de resíduos gerados durante o processamento como: peles, escamas, espinhas, cabeças e bexigas. Estes resíduos se descartados de forma inadequada podem causar impactos ambientais, por este motivo nos últimos anos a comunidade cientifica tem realizado estudos utilizando estes resíduos para a extração de gelatina e tem comprovado que estas fontes se mostram promissoras para serem utilizadas em diversos setores como indústria alimentícia, farmacêutica e biomédica. Assim, o presente artigo buscou realizar uma revisão narrativa de artigos sobre a produção de gelatina a partir da bexiga natatória de peixes entre os anos de 2015 e 2024. Foram selecionados 8 artigos nas plataformas de busca SCOPUS, PubMed e Web of Science. A caracterização da gelatina obtida e as técnicas utilizadas nos artigos estão aqui apresentadas.

Keywords: Swim bladder. Gelatin. Fish by-product. Sustainability.

RESUMO: Global fish consumption has increased worldwide, primarily driven by consumers' growing concern for healthy diets that provide high-quality protein. With the rising demand for fish, there has consequently been an expansion in industrial processing and in the volume of by-products generated, including skins, scales, bones, heads, and swim bladders. When improperly discarded, these residues may cause significant environmental impacts. For this reason, in recent years the scientific community has undertaken studies exploring the use of such by-products for gelatin extraction, demonstrating that these alternative sources are promising for application across multiple sectors, including the food, pharmaceutical, and biomedical industries.Accordingly, the present study aimed to conduct a narrative review of articles published between 2015 and 2024 addressing gelatin production from fish swim bladders. A total of eight articles were selected from the SCOPUS, PubMed, and Web of Science databases. The characterization of the extracted gelatin and the methodologies employed in the selected studies are presented herein.

Palavras-chave: Bexiga natatória. Gelatina. Resíduo de peixe. Sustentabilidade.

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RESUMEN: El consumo mundial de pescado ha aumentado de manera significativa, impulsado principalmente por la creciente preocupación de los consumidores por dietas saludables que aporten proteínas de alta calidad. Con el incremento del consumo de pescado, se ha producido consecuentemente una expansión en la industrialización y en la cantidad de subproductos generados durante el procesamiento, tales como pieles, escamas, espinas, cabezas y vejigas natatorias. Cuando estos residuos se eliminan de forma inadecuada, pueden generar impactos ambientales significativos. Por esta razón, en los últimos años la comunidad científica ha llevado a cabo estudios orientados al aprovechamiento de dichos subproductos para la extracción de gelatina, demostrando que estas fuentes alternativas son prometedoras para su aplicación en diversos sectores, como la industria alimentaria, farmacéutica y biomédica. En este contexto, el presente estudio tuvo como objetivo realizar una revisión narrativa de artículos publicados entre 2015 y 2024 sobre la producción de gelatina a partir de la vejiga natatoria de peces. Se seleccionaron ocho artículos en las bases de datos SCOPUS, PubMed y Web of Science. La caracterización de la gelatina obtenida y las metodologías empleadas en los estudios seleccionados se presentan en este trabajo.

Palabras clave: Vejiga natatória. Gelatina. Subproducto de pescado. Sostenibilidad.

INTRODUCTION

The fishing industry generates millions of dollars annually, driven by the increasing consumption of fish, which is directly associated with growing consumer concern for healthy diets and high-quality protein sources. This rise in fish consumption has, in turn, led to greater industrialization within the sector and to an increase in the volume of by-products generated during processing, including skins, scales, bones, heads, and swim bladders.

When improperly discarded, these residues may cause significant environmental impacts. For this reason, in recent years the scientific community has conducted studies exploring the use of such by-products for gelatin extraction, demonstrating that these alternative sources are promising due to their gelling, thickening, and stabilizing properties, and may be applied across various sectors, including the food, pharmaceutical, and biomedical industries (HUANG et al., 2019; ALIPAL et al., 2021).

Research indicates that fish skin (SILVA et al., 2017; DE OLIVEIRA et al., 2019; DA SILVA et al., 2024), scales (XU et al., 2021), and swim bladders (KAEWDANG et al., 2015; SINTHUSAMRAM et al., 2018) are abundant sources of collagen, an essential component for gelatin production. Gelatin has been widely used as a stabilizer and to enhance elasticity and consistency in products within the food, pharmaceutical, cosmetic, and photographic industries.

Commercially produced gelatin is typically derived from the skin, tendons, and bones of animals such as swine and cattle. However, gelatin obtained from these sources may face limitations, including production disposal due to outbreaks of avian or swine influenza and concerns related to Bovine Spongiform Encephalopathy (BSE). Furthermore, cultural and religious restrictions that prohibit the consumption of pork and beef constitute an additional barrier to the acceptance of gelatin derived from these sources (AHMAD; BENJAKUL, 2010; CHANDRA; SHAMASUNDAR, 2015; JONGJAREONRAK et al., 2005; MUYONGA; COLE; DUODU, 2004; YANG et al., 2007). In this context, gelatin extracted from fish processing by-products emerges as a viable alternative to overcome these challenges.

Fish gelatin is obtained through the partial hydrolysis of collagen, a protein composed of amino acids. It is primarily characterized by repeated sequences of "Glycine–X–Y," in which X and Y are generally proline and hydroxyproline, respectively (KARIM & BHAT, 2009; AHMAD et al., 2017).

Several studies on gelatin extraction from fish skins, scales, and trimmings have reported satisfactory results in terms of yield and functional properties, such as gel strength, melting point, viscosity, structural stabilization, and emulsifying capacity, among others (SILVA et al., 2017; NEVES et al., 2019; OLIVEIRA et al., 2019; FU et al., 2021; XU et al., 2021; YANG et al., 2022). However, the scientific literature reports a limited number of studies focusing specifically on gelatin extracted from swim bladders and its potential applications (KANWATE et al., 2019; WANG et al., 2019; ZHOU et al., 2020).

The use of other fish parts, such as the swim bladder, has also been explored for gelatin production due to the collagen present in its structural composition. This approach aims to reduce the disposal of this by-product while identifying new sources of gelatin with favorable technological properties. The swim bladder is an internal fish organ responsible for buoyancy control, and several studies have indicated that it is an excellent source of gelatin, which has been applied as an adhesive agent, in beverage clarification, and in the manufacture of food packaging materials (CHANDRA, 2015; KANWATE et al., 2019; ZHOU et al., 2020).

In certain fish species, the swim bladder holds commercial value due to its antioxidant activity, and the health-related benefits associated with it have attracted considerable interest. Nevertheless, in most species, the swim bladder is still regarded as a low-value by-product without significant commercial application. Given the relevance of this topic, the present study provides a narrative review of articles published between 2015 and 2024 in the SCOPUS, Web of Science, and PubMed databases addressing the production of gelatin from fish swim bladders. The review includes a description and discussion of the processes employed for gelatin production, as well as the properties of the gelatin obtained in each study. In this manner, it offers a comprehensive and up-to-date overview of the methods applied and the findings reported in recent research.

MÉTODOS

To conduct the narrative review, the following terms were entered into the SCOPUS, PubMed, and Web of Science databases, to be identified within the title, abstract, or keywords: swim bladder and gelatin. Articles published in any country and in any language between 2015 and 2024 were considered eligible. A total of 27 articles were initially screened, of which eight were included in this review. The following types of publications were excluded: studies that did not focus on gelatin production from fish swim bladders or that employed mixtures of fish by-products for gelatin production; book chapters; and literature review articles. Table 1 presents the articles included in this revision.

Table 1. Articles included in this narrative review.

Reference	Title	Journal	Impact Factor
Kanwate, and Kudre (2022)	Impact of different extraction conditions on yield, physicochemical and functional characteristics of gelatin from *Labeo rohita* swim bladder	Food Science and Biotechnology	3.7
Wang et al. (2021)	A novel extraction approach and unique physicochemical properties of gelatin from the swim bladder of sturgeon	Journal of the Science of Food and Agriculture	3.3
Nurimala et al. (2021)	Pangasius Fish Skin and Swim Bladder as Gelatin Sources for Hard Capsule Material	International Journal of Biomaterials	3.0
Kanwate et al. (2019)	Influence of spray-drying, freeze-drying and vacuum-drying on physicochemical and functional properties of gelatin from *Labeo rohita* swim bladder	International Journal of Biological Macromolecules	7.7
Sinthusamran et. al. (2018)	Characteristics and Properties of Gelatin from Seabass (*Lates calcarifer*) Swim Bladder: Impact of Extraction Temperatures	Journal of Texture Studies	3.9
Kaewdang et. al. (2016)	Characteristics of Gelatin Extracted from the Swim Bladder of Yellowfin Tuna (*Thunnus albacores*) as Affected by Alkaline Pretreatments	Journal of Aquatic Food Product Technology	1.3
Chandra and Shamasundar (2015)	Rheological properties of gelatin prepared from the swim bladders of freshwater fish *Catla catla*	Food Hydrocolloids	11.0
Kaewdang et. al. 2015	Characteristics of gelatin from swim bladder of yellowfin tuna (*Thunnus albacores*) as influenced by extracting temperatures	Italian Journal of Food Science	3.6

RESULTS AND DISCUSSION

3.1 Fish Species Used for Gelatin Production

Based on the search results, eight articles were selected from the SCOPUS, PubMed, and Web of Science databases reporting on gelatin production from fish swim bladders between 2015 and 2024. The most frequently used species were *Labeo rohita*, a carp family fish native to South Asia, and *Thunnus albacares*, a tuna species found in all oceans. Other species employed for gelatin production included *Labeo rohita*, *Catla catla*, and *Pangasius* (a genus of catfish). Table 2 presents the articles published on gelatin production using fish swim bladders.

Table 2. Articles published between 2019 and 2024, detailing different fish species used for gelatin production from swim bladders.

Reference	Fish species used
Kanwate, and Kudre (2022)	*Labeo rohita*
Wang et al. (2021)	Sturgeon
Nurimala et. al. (2021)	*Pangasius*
Kanwate et al. (2019)	*Labeo rohita*
Sinthusamran et. al. (2018)	*Lates calcarifer*
Kaewdang et. al. (2016)	*Thunnus albacores*
Chandra and Shamasundar (2015)	*Catla catla*
Kaewdang et. al. 2015	*Thunnus albacores*

2.1 Extraction Conditions of Gelatin from Fish Swim Bladders and Their Properties and Characteristics

The extraction process of gelatin from fish swim bladders was analyzed along with its physicochemical and functional properties. The most recent study identified on this topic was conducted by Kanwate et al. (2022), who investigated various treatments to optimize gelatin quality. The study examined the effects of different extraction temperatures (50, 60, and 70 °C) and durations (3, 6, and 9 hours) on gelatin production. Gelatin extracted at 60 °C for 9 hours exhibited the best overall yield, along with superior physicochemical and functional properties. All gelatin samples contained the primary protein components in the form of α, β, and γ chains. However, gelatin extracted at 70 °C for 9 hours and at 60 °C for 9 hours achieved the highest yields, with 54.91 g/100 g of gelatin, 92.35 g/100 g of protein, and 77.50 mg/g of hydroxyproline ($P < 0.05$), compared to other conditions. Despite this, gelatin extracted at 60 °C for 9 hours was considered the most suitable condition for swim bladder extraction because, when compared to gelatin extracted at 50 °C and 70 °C for the same duration, it exhibited superior foaming capacity, gel strength, and emulsifying activity.

Earlier (2017) and subsequently, Kanwate et al. (2019) produced gelatin from the swim bladder of *Labeo rohita*, investigating different parameters to improve gelatin properties, including vacuum drying, spray drying, and freeze-drying. The study found that vacuum drying led to greater collagen degradation compared to freeze-drying and spray drying. Among the three methods, freeze-drying and spray drying produced gelatin with better physicochemical and functional properties, but the highest yield was achieved with freeze-drying (54.51 g/100 g, dry weight basis), followed by vacuum drying (48.95 g/100 g) and spray drying (41.76 g/100 g).

The influence of extraction temperature was also evaluated by Sinthusamran et al. (2018). Gelatin was extracted from *Lates calcarifer* at 45, 55, 65, and 75 °C. Higher temperatures resulted in improved yields: 44.83, 71.9 g/100 g, and 49.08, 74.8 g/100 g (dry weight basis), respectively. α and β chains were detected, along with a high amino acid content (195 residues per 1000 residues). Gel strength was highest at 65 °C with a 6-hour extraction period. Kaewdang et al. (2015) also observed increased gelatin yield at higher extraction temperatures, although the α chains decreased as the temperature increased. At 80 °C, the gelatin yield was 47.3 g/100 g.

Wang et al. (2021) extracted gelatin from sturgeon swim bladders after defatting with ethanol and hexane at a 1:5 (w/v) ratio for 24 hours. Following hot air drying at 40 °C for 2 hours, the sturgeon gelatin was extracted with water under continuous agitation, then centrifuged and freeze-dried, achieving a yield of 94.15 % under optimized conditions of 50 °C, 30 minutes, and 10 mL/g. The authors highlighted that their method is clean, efficient, and produces gelatin with unique properties and significant potential for application in the food industry.

The comparison between commercial gelatin from pork, bovine, and fish sources revealed that gelatin extracted from sturgeon swim bladders exhibited higher whiteness (3.38), viscoelasticity (0.03), water-holding capacity (92.37 %), emulsifying activity (171.76 $m^2 g^{-1}$), and gel strength (853.23 g). However, parameters such as transmittance (40.56 % at 450 nm and 59.07 % at 620 nm), expansion (203.00), emulsion stability (30.09 min), gelling temperature (16.88 °C) and melting point (21.80 °C), and foam stability (26.92) were lower. Vertical electrophoresis analysis of the bands indicated that its amino acid profile and subunit composition were similar to type I collagen.

Nurimala et al. (2021) performed hydrolysis by immersing the sample in 0.05 N NaOH solution for 1 hour. The swim bladder was then rinsed with water and immersed, under agitation, in 0.2 % citric acid for 1 hour, followed by further rinsing with distilled water until neutral pH was achieved. Hydrolysis was carried out after this pre-treatment at 65 °C for 7 hours, resulting in a yield of 19.5 %. This yield was lower than that reported by Wang et al. (2021) and Kanwate et al. (2022). The gelatin obtained contained 20.50 % (w/w) protein, and electrophoresis revealed α1 and α2 bands. Its physicochemical properties were as follows: pH 5.16; gel strength 272.85 g; viscosity 74.7 mP. Although the yield reported by Nurimala et al. (2021) was lower than those of Wang et al. (2021) and Kanwate et al. (2022), the gelatin was successfully applied in capsule production, with product characteristics (diameter, pH, and rupture time) comparable to gelatin derived from fish skin and from a combination of skin and swim bladder, demonstrating its potential applicability.

Alkaline pre-treatment was also conducted by Kaewdang et al. (2016) for gelatin extraction from *Thunnus albacares* swim bladders. Alkaline mixtures (Na_2CO_3:NaOH) in different ratios (9:1, 8:2, 7:3, and 6:4) at a 4 % (w/v) concentration were applied. Results showed that the α chain was the main component in all gelatins, with β chains also present. The highest yield was obtained with the 7:3 alkaline mixture ratio (35.96 g/100 g), which also exhibited higher amino acid content and gel strength compared to other conditions.

Chandra et al. (2015) extracted gelatin from *Catla catla* swim bladders, obtaining a gel with a gel strength of 264.6 g and a yield of 13.5 % (w/w), classifying it as a high-bloom gel. The protein content of the swim bladder was 20.8 %. The melting and gelling temperatures of the gelatin were 23.3 °C and 13.7 °C, respectively. Similar to the findings of Kaewdang et al. (2016), α and β chains were detected by SDS-PAGE.

CONCLUSION

Studies have investigated the potential of gelatin extracted from various fish parts, including skins, scales, viscera, heads, and bones, and more recently, swim bladders. Although recent research on fish swim bladders has highlighted their promising technological and functional properties, gelatin derived from this part of the fish has demonstrated good yields and suitable characteristics for application across multiple industrial sectors. Different extraction and drying methods, as well as variations in time and temperature, have been evaluated in the literature, yielding satisfactory results in terms of gel strength, stability, and foaming capacity. However, more specific investigations are still needed to fully understand these properties and their potential applications. Additionally, studies should focus on the swim bladders of different fish species, which are currently discarded as waste by the fishing industry, generating potential environmental impacts. Converting these materials, often considered of no commercial value, into raw materials for the food, pharmaceutical, and biomedical industries could provide a sustainable and valuable solution for the utilization of these by-products.

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