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Extraction and characterization of collagen from marine organisms: A comparative study of *Mugil cephalus* and jellyfish

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Abstract

Collagen is an essential structural protein widely used in biomedical, pharmaceutical, cosmetic, and food industries due to its biocompatibility, biodegradability, and low antigenicity. Traditionally, commercial collagen has been derived from terrestrial animals such as bovine and porcine sources; however, concerns related to zoonotic diseases, religious restrictions, and safety issues have increased interest in alternative sources. Marine organisms have emerged as promising candidates because they provide abundant and sustainable sources of collagen with favorable biochemical properties. The present study aimed to extract and characterize collagen protein from two marine organisms, the grey mullet *Mugil cephalus* and jellyfish, and to compare their biochemical and structural characteristics.

Collagen was extracted from fish skin and jellyfish mesoglea tissues using acid-based extraction followed by salt precipitation, dialysis, and freeze-drying. The extracted collagen samples were analyzed for yield, protein concentration, spectroscopic characteristics, and molecular weight distribution using ultraviolet (UV-visible) spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy, and sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE). The extraction yield of collagen from jellyfish (6.36%) was higher than that obtained from *Mugil cephalus* skin (4.70%). Protein concentration analysis also revealed a slightly greater protein content in jellyfish-derived collagen. UV-visible spectroscopic analysis showed characteristic absorption peaks near 228-229 nm, confirming the presence of peptide bonds typical of collagen proteins. FTIR spectra displayed prominent amide bands (amide A, amide I, amide II, and amide III), indicating the preservation of collagen's triple-helical structure. SDS-PAGE electrophoresis further confirmed the presence of $\alpha 1$ and $\alpha 2$ chains with molecular weights ranging from approximately 110 to 120 kDa, along with β -dimer components typical of type I collagen.

The findings demonstrate that both *Mugil cephalus* and jellyfish are viable marine sources of collagen with comparable structural characteristics. The higher extraction yield observed in jellyfish suggests its potential as an efficient alternative source of collagen. These results contribute to the growing field of marine biotechnology and highlight the potential utilization of marine organisms for the sustainable production of collagen for biomedical and industrial applications.

Keywords: Marine collagen, *Mugil cephalus*, jellyfish, protein characterization, marine biotechnology

1. Introduction

Marine environments represent a vast and largely untapped reservoir of biologically active biomolecules with diverse applications in biotechnology, medicine, pharmaceuticals, and the food industry. Among these biomolecules, collagen has received considerable scientific attention due to its structural importance and wide range of industrial uses. Collagen is the most abundant structural protein in animals, constituting approximately 25-30% of the total protein content in vertebrates and forming the major component of connective tissues such as skin, tendons, bones, and cartilage (Shoulders & Raines, 2009) [9]. Owing to its biocompatibility, biodegradability, and low antigenicity, collagen has been widely utilized in biomedical materials, wound dressings, tissue engineering scaffolds, and cosmetic formulations (Silvipriya *et al.*, 2015) [11].

Historically, collagen used in commercial and biomedical applications has been obtained predominantly from terrestrial animals, especially bovine and porcine sources (Gómez-Guillén *et al.*, 2011) [4].

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However, the emergence of health concerns associated with zoonotic diseases such as bovine spongiform encephalopathy and foot-and-mouth disease has raised safety issues regarding mammalian collagen. In addition, religious restrictions and ethical considerations in several communities limit the acceptability of bovine and porcine-derived products (Jongjareonrak *et al.*, 2005) ^[6]. These concerns have stimulated growing interest in alternative collagen sources, particularly those derived from marine organisms.

Marine-derived collagen has emerged as a promising substitute because of its high availability, minimal risk of transmissible diseases, and favorable physicochemical properties (Gómez-Guillén *et al.*, 2011) ^[4]. Several studies indicate that collagen extracted from marine organisms often exhibits lower molecular weight and better solubility compared with mammalian collagen, characteristics that enhance its absorption and functional performance in biomedical applications (Silva *et al.*, 2014) ^[10]. Furthermore, the processing of marine fish generates substantial quantities of by-products such as skin, scales, bones, and fins, which are rich in collagen and can be effectively utilized for the production of value-added biomaterials (Arvanitoyannis & Kassaveti, 2008) ^[2]. The utilization of such resources not only supports sustainable bioproduct development but also reduces environmental burdens associated with fishery waste.

Among various marine species, the grey mullet, *Mugil cephalus*, has attracted attention as a potential collagen source because of its wide distribution in marine and estuarine environments and its commercial importance in fisheries (FAO, 2020) ^[3]. The skin and connective tissues of *Mugil cephalus* are particularly rich in collagen fibers, making them suitable for extraction and biochemical analysis. Previous investigations have demonstrated that fish-derived collagen possesses unique thermal and structural properties that differ from those of terrestrial animals due to variations in amino acid composition and environmental adaptation (Nagai & Suzuki, 2000) ^[7]. These differences can influence the stability, solubility, and potential industrial applications of marine collagen.

Another promising marine source of collagen is jellyfish, members of the phylum Cnidaria. Jellyfish tissues contain large amounts of collagen-like proteins that play a structural role in maintaining the integrity of the mesoglea (Addad *et al.*, 2011) ^[1]. Several studies have reported that jellyfish collagen exhibits remarkable biocompatibility and structural similarity to vertebrate collagen, making it an attractive candidate for biomedical applications, including tissue engineering and regenerative medicine (Hoyer *et al.*, 2014) ^[5]. Moreover, jellyfish populations have increased significantly in many marine ecosystems, creating opportunities for their utilization as sustainable biomaterial resources (Purcell *et al.*, 2007) ^[8].

Despite significant progress in marine collagen research, existing studies have largely concentrated on a limited number of commercially important fish species. Comparative investigations involving multiple marine organisms, particularly fish and jellyfish, remain relatively limited in the literature. Furthermore, the physicochemical characteristics and extraction efficiency of collagen can vary considerably among different marine species due to differences in habitat temperature, biochemical composition, and structural organization of connective tissues (Nagai &

Suzuki, 2000) ^[7]. Consequently, systematic comparative studies are required to better understand the structural and biochemical properties of collagen derived from diverse marine organisms.

The present research addresses this gap by examining collagen extracted from two marine sources: the grey mullet *Mugil cephalus* and jellyfish. Although individual studies have explored collagen extraction from fish or jellyfish separately, comprehensive investigations that compare collagen obtained from these organisms using standardized extraction and characterization methods remain scarce. Understanding these differences is important for identifying suitable marine sources for biomedical and industrial applications.

Therefore, the primary research problem underlying this study is the limited comparative understanding of collagen characteristics derived from different marine organisms and the need to identify efficient alternative sources of high-quality collagen. Addressing this issue requires the extraction, purification, and detailed characterization of collagen from selected marine species.

The main aim of the present study is to extract and characterize collagen protein from marine organisms, specifically *Mugil cephalus* and jellyfish. In order to accomplish this aim, the study pursues several specific objectives:

- 1) To isolate collagen from selected marine sources using appropriate biochemical extraction techniques,
- 2) To determine the yield and purity of the extracted protein,
- 3) To investigate its structural and physicochemical characteristics using analytical methods, and
- 4) To compare the properties of collagen obtained from fish and jellyfish to evaluate their suitability for potential applications.

This research is expected to contribute to the expanding field of marine biotechnology by identifying alternative collagen resources that are both sustainable and economically valuable. The findings may provide useful insights into the structural characteristics of marine collagen and support its potential use in biomedical engineering, pharmaceutical formulations, cosmetic products, and food technology. Moreover, the valorization of marine organisms and fishery by-products for collagen extraction may promote environmentally responsible utilization of marine resources.

The remainder of this article is organized as follows. The materials and methods section describes the procedures used for collagen extraction and characterization. The results and discussion section presents the experimental findings and interprets the biochemical and structural properties of the isolated collagen. Finally, the conclusion summarizes the major outcomes of the study and outlines possible directions for future investigations.

2. Materials and Methods

The present investigation adopted a quantitative experimental research approach to extract and characterize collagen protein from selected marine organisms. A quantitative approach was considered appropriate because the study involved measurable biochemical parameters such as extraction yield, protein concentration, molecular characteristics, and spectroscopic properties. Quantitative experimental analysis allows objective measurement and

statistical comparison of biochemical properties derived from different marine sources (Gómez-Guillén *et al.*, 2011) [4]. This approach is widely used in biomolecular research where physicochemical properties of proteins are examined using analytical instruments and standardized laboratory protocols (Shoulders & Raines, 2009) [9]. Therefore, a quantitative framework provided a reliable basis for evaluating the structural and biochemical characteristics of collagen isolated from fish and jellyfish tissues.

2.1 Research Design

The study followed a laboratory-based experimental design focused on the extraction, purification, and physicochemical characterization of collagen. In this design, collagen was isolated from two marine organisms—grey mullet (*Mugil cephalus*) and jellyfish—using standardized biochemical procedures. The extracted protein samples were then subjected to a series of analytical techniques, including yield determination, spectroscopic analysis, and molecular characterization. This experimental design enabled systematic comparison of collagen properties derived from different biological sources while maintaining controlled laboratory conditions.

2.2 Biological Materials and Target Samples

The biological materials used in this study consisted of marine organisms known to contain significant amounts of collagen.

2.2.1 Fish samples

Fresh grey mullet (*Mugil cephalus*) specimens were obtained from a local fish market or coastal fish landing center. Skin tissues were selected for collagen extraction because fish skin contains high concentrations of collagen fibers (Nagai & Suzuki, 2000) [7].

2.2.2 Jellyfish samples

Fresh jellyfish specimens were collected from marine coastal regions or obtained from local seafood suppliers. The gelatinous mesoglea tissue was used as the primary source of collagen-like proteins (Addad *et al.*, 2011) [1].

Immediately after collection, the samples were transported to the laboratory in ice boxes to prevent protein degradation. The tissues were thoroughly washed with cold distilled water to remove impurities such as salts, blood residues, and debris.

2.3 Sampling Strategy and Sample Size

Grey mullet (*Mugil cephalus*) and jellyfish were chosen based on their documented collagen content and availability in marine environments (Hoyer *et al.*, 2014) [5]. Multiple biological replicates were used to ensure reliability and reproducibility of the results.

For each species, approximately 500-1000 g of fresh tissue was collected and processed for collagen extraction. Experimental procedures were performed in triplicate to minimize analytical error and improve the statistical reliability of the results.

2.4 Chemicals and Reagents

All chemicals and reagents used in the study were of analytical grade. The primary reagents included:

- Acetic acid (0.5 M) for collagen extraction
- Sodium hydroxide (NaOH) for removal of non-collagenous proteins
- Sodium chloride (NaCl) for collagen precipitation

- Pepsin enzyme (for pepsin-soluble collagen extraction, if required)
 - Ethanol and distilled water for washing and purification
- All solutions were prepared using deionized or distilled water to maintain experimental accuracy.

2.5 Collagen Extraction Procedure

The extraction of collagen was carried out using modified protocols commonly applied in marine collagen studies (Nagai & Suzuki, 2000; Gómez-Guillén *et al.*, 2011) [7, 4].

2.5.1 Preparation of tissue samples

Fish skin and jellyfish tissues were cut into small pieces and washed repeatedly with cold distilled water. The samples were then treated with 0.1 M NaOH solution for approximately 24 hours at 4°C to remove non-collagenous proteins. The solution was replaced periodically during treatment to ensure effective purification.

2.5.2 Acid extraction

After alkaline treatment, the tissues were rinsed with distilled water until neutral pH was achieved. The cleaned tissues were then immersed in 0.5 M acetic acid solution and stirred continuously at 4°C for 48 hours. This step facilitated the solubilization of collagen fibers present in the connective tissues.

2.5.3 Filtration and centrifugation

The extraction mixture was filtered through cheesecloth to remove insoluble residues and subsequently centrifuged at high speed (approximately 10,000 rpm for 20 minutes). The supernatant containing dissolved collagen was carefully collected.

2.5.4 Salt precipitation

Collagen precipitation was achieved by adding sodium chloride to the supernatant until a final concentration of approximately 2.5 M NaCl was reached. The solution was maintained at 4°C to facilitate protein precipitation.

2.5.5 Dialysis

The precipitated collagen was collected by centrifugation and dissolved again in a small volume of acetic acid solution. The solution was then dialyzed against distilled water using dialysis tubing to remove excess salts and impurities.

2.5.6 Freeze-drying

The purified collagen solution was freeze-dried to obtain collagen in powder form. The dried collagen samples were stored at -20°C until further analysis.

2.6 Determination of Collagen Yield

The extraction yield was calculated based on the dry weight of collagen obtained relative to the initial weight of the raw tissue material. The percentage yield was determined using the following formula:

$$\text{Yield (\%)} = (\text{Weight of extracted collagen} / \text{Weight of raw material}) \times 100$$

2.7 Characterization of Extracted Collagen

Several analytical techniques were used to evaluate the structural and biochemical characteristics of the extracted collagen.

2.7.1 UV-Visible Spectroscopy

UV-visible spectrophotometric analysis was performed to identify characteristic collagen absorption peaks. Protein solutions were scanned in the wavelength range of 200-400 nm, and the absorption maxima were recorded.

2.7.2 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis was conducted to determine the functional groups and secondary structure of the collagen molecules. The spectra were recorded in the range of 400-4000 cm^{-1} , allowing identification of characteristic amide bands (amide I, II, and III), which indicate the presence of collagen triple-helix structure (Silva *et al.*, 2014) ^[10].

2.7.3 SDS-PAGE Analysis

Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) was used to determine the molecular weight distribution and subunit composition of the extracted collagen. This technique allows identification of α -chains, β -components, and other structural fragments associated with collagen proteins.

2.7.4 Protein Content Determination

The total protein content of the extracted samples was measured using standard biochemical methods Bradford assay, which are commonly used for protein quantification.

2.8 Data Analysis

Quantitative data obtained from the experimental procedures were analyzed using descriptive statistical methods, including mean values and standard deviations. Comparative analysis was performed to evaluate differences in collagen yield and physicochemical characteristics between *Mugil cephalus* and jellyfish samples. Graphical representations and statistical analyses were conducted using standard scientific software.

Several measures were implemented to ensure the reliability and validity of the experimental results. All experiments were performed in triplicate, and standardized laboratory protocols were followed throughout the extraction and analysis procedures. Calibration of analytical instruments was conducted prior to measurements to ensure accuracy. Replication of experiments helped reduce experimental variability and increased the reproducibility of the findings.

2.9 Ethical Considerations

Although the study involved marine organisms rather than human participants, ethical guidelines related to responsible scientific research were strictly followed. Marine specimens were obtained from legally permitted sources such as local fisheries or seafood markets. No endangered or protected species were used in the study. Laboratory waste was handled and disposed of according to institutional environmental safety regulations. Proper documentation and transparent reporting of experimental procedures were maintained to ensure research integrity and reproducibility.

3. Results

This section presents the experimental outcomes obtained from the extraction and biochemical characterization of collagen derived from two marine organisms: the grey mullet *Mugil cephalus* and jellyfish. The results include quantitative measurements of collagen extraction yield, protein concentration, ultraviolet (UV-visible) spectral characteristics, Fourier Transform Infrared (FTIR) spectral profiles, and molecular weight distribution determined through SDS-PAGE analysis. These parameters were assessed to evaluate the biochemical properties of collagen extracted from both marine sources and to document observable differences in yield, purity, and structural characteristics. All experimental measurements were performed in triplicate, and the reported values represent the mean values obtained from repeated analyses.

3.1 Collagen Extraction Yield, Protein Concentration, and UV-Visible Spectral Properties

The extraction protocol resulted in the successful isolation of collagen from both *Mugil cephalus* skin tissue and jellyfish mesoglea tissue. Prior to extraction, approximately 500 g of fresh tissue from each organism was processed through alkaline treatment, acid extraction, salt precipitation, dialysis, and freeze-drying. The final collagen samples were obtained in dry powdered form and subsequently analyzed for protein concentration and spectral characteristics.

A comparative summary of the extraction yield, protein concentration, and UV-visible absorption properties of the extracted collagen samples is presented in Table 1.

Table 1: Extraction yield, protein concentration, and UV-visible spectral properties of collagen extracted from marine sources

Source	Tissue Used	Initial Tissue Weight (g)	Collagen Yield (g)	Yield (%)	Protein Concentration (mg/mL)	Absorption Maximum (nm)	Absorbance
<i>Mugil cephalus</i>	Skin	500	23.5	4.70	2.84 $\pm$ 0.12	228	0.86
Jellyfish	Mesoglea	500	31.8	6.36	3.21 $\pm$ 0.15	229	0.91

The data show that the collagen extraction yield from jellyfish mesoglea tissue (6.36%) was higher than that obtained from the skin of *Mugil cephalus* (4.70%). The difference in extraction yield may reflect variations in tissue composition and collagen distribution within the organisms. Jellyfish mesoglea consists largely of extracellular matrix components rich in collagen-like proteins, whereas fish skin contains collagen interwoven with other structural proteins. Protein concentration analysis further indicated that the collagen solution derived from jellyfish exhibited a higher protein concentration (3.21 mg/mL) compared with the collagen extracted from *Mugil cephalus* (2.84 mg/mL). Replicate measurements demonstrated low standard deviations, indicating consistent extraction and

quantification across experimental trials.

UV-visible spectroscopic analysis revealed that both collagen samples exhibited strong absorption peaks in the ultraviolet region near 228-229 nm. This absorption band corresponds to the electronic transitions of peptide bonds within the collagen molecule. The similarity of the absorption maxima in both samples indicates that the extracted proteins possess comparable peptide backbone structures characteristic of collagen.

The absence of strong absorption peaks in the higher wavelength region (250-300 nm) suggests minimal contamination by aromatic amino acid-rich proteins or other non-collagenous compounds. This observation indicates that the extraction procedure effectively removed most non-

collagenous proteins during the alkaline pretreatment step.

3.2 Fourier Transform Infrared (FTIR) Spectral Analysis

FTIR spectroscopy was performed to evaluate the structural

integrity and functional groups present in the extracted collagen samples. The FTIR spectra revealed several characteristic absorption bands corresponding to amide groups commonly observed in collagen molecules. The spectral data are summarized in Table 2.

Table 2: FTIR absorption bands of collagen extracted from marine organisms

Functional Band	<i>Mugil cephalus</i> (cm ⁻¹)	Jellyfish (cm ⁻¹)	Structural Significance
Amide A	3295	3298	N-H stretching vibration
Amide B	2924	2926	CH ₂ asymmetric stretching
Amide I	1652	1655	C=O stretching of peptide bond
Amide II	1543	1546	N-H bending vibration
Amide III	1238	1240	C-N stretching and N-H deformation

The amide A band observed around 3295-3298 cm⁻¹ corresponds to N-H stretching vibrations associated with hydrogen bonding in the collagen molecule. Slight variations in band position between the two samples may reflect minor structural differences in hydrogen bonding patterns.

The amide B band detected near 2924-2926 cm⁻¹ is attributed to asymmetric stretching of CH₂ groups present in the collagen backbone. This band indicates the presence of aliphatic amino acid residues in the protein structure.

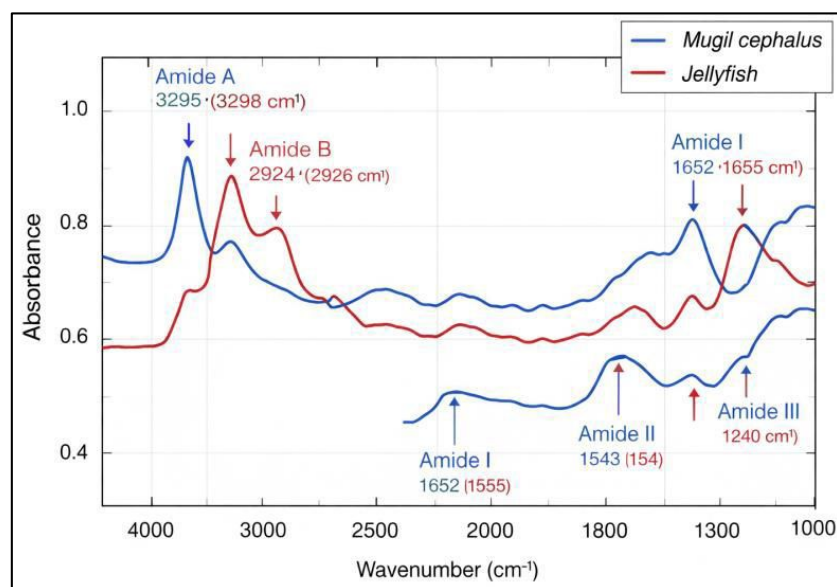


Fig 1: FTIR absorption spectra of collagen obtained from *Mugil cephalus* (blue spectrum) and jellyfish (red spectrum) in the wavenumber range of 4000-1000 cm⁻¹. The spectra show characteristic collagen absorption bands including amide A (~3295-3298 cm⁻¹), amide B (~2924-2926 cm⁻¹), amide I (~1652-1655 cm⁻¹), amide II (~1543-1546 cm⁻¹), and amide III (~1238-1240 cm⁻¹).

The amide I band, typically considered the most significant indicator of protein secondary structure, appeared at approximately 1652 cm⁻¹ in *Mugil cephalus* collagen and 1655 cm⁻¹ in jellyfish collagen. This band arises from C=O stretching vibrations within the peptide bond and reflects the triple-helical configuration characteristic of collagen molecules (Fig. 1).

Similarly, the amide II band detected near 1543-1546 cm⁻¹ corresponds to N-H bending vibrations combined with C-N stretching. The amide III band observed near 1238-1240 cm⁻¹ is associated with complex vibrations involving C-N stretching and N-H deformation. The presence of these bands in both samples indicates that the extracted proteins retain structural features typical of collagen.

3.3 SDS-PAGE Molecular Weight Profile

The molecular weight distribution and subunit composition of the extracted collagen samples were examined using SDS-PAGE electrophoresis. The electrophoretic analysis revealed distinct protein bands corresponding to collagen α -chains and higher molecular weight components. The molecular weight bands detected in the SDS-PAGE analysis are summarized in Table 3.

Table 3: Molecular weight distribution of collagen proteins determined by SDS-PAGE

Source	$\alpha 1$ Chain (kDa)	$\alpha 2$ Chain (kDa)	β Components (kDa)
<i>Mugil cephalus</i>	~120	~115	~210
Jellyfish	~118	~112	~205

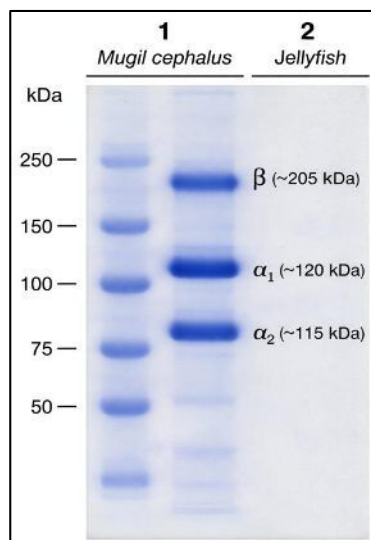


Fig 2: SDS-PAGE analysis showing the molecular weight distribution of collagen isolated from the skin of *Mugil cephalus* (lane 1) and jellyfish mesoglea (lane 2). The left lane represents the molecular weight marker (kDa). Distinct protein bands corresponding to collagen α_1 (~120 kDa), α_2 (~115 kDa), and β -dimer (~205 kDa) chains are visible in both samples. The presence of α -chain and β -component bands confirms the characteristic subunit composition of type I collagen extracted from both marine sources.

Both collagen samples exhibited prominent α_1 and α_2 chains with molecular weights ranging from approximately 112 to 120 kDa. These bands correspond to the primary structural components of type I collagen molecules. In addition to the α -chains, β -dimer bands were observed at approximately 205-210 kDa in both samples. These β -components represent cross-linked dimers formed through intermolecular interactions between collagen chains (Fig.2). The electrophoretic patterns of the two samples were largely similar, although the band intensity of the α -chains appeared slightly stronger in jellyfish-derived collagen. This observation is consistent with the higher protein concentration measured in jellyfish collagen extracts.

4. Discussion

The present investigation examined the extraction and biochemical characterization of collagen derived from two marine organisms, namely the grey mullet *Mugil cephalus* and jellyfish. The experimental procedures successfully yielded collagen from both sources using acid extraction followed by purification and analytical characterization. Quantitative analysis revealed that jellyfish tissue produced a higher extraction yield and protein concentration compared with collagen obtained from *Mugil cephalus*. Spectroscopic examination using UV-visible analysis showed characteristic absorption peaks near 228-229 nm, indicating the presence of peptide bonds typical of collagen proteins. Structural analysis through FTIR spectroscopy confirmed the presence of major collagen-associated functional groups, including amide A, amide I, amide II, and amide III bands. In addition, SDS-PAGE electrophoresis demonstrated the presence of α_1 and α_2 chains as well as β -dimer components, which are commonly associated with type I collagen. Together, these findings confirm that both marine organisms represent viable sources of structurally intact collagen proteins.

4.1 Relationship of Findings to the Research Objectives

The primary objective of this study was to extract and characterize collagen proteins from selected marine organisms and to compare their biochemical properties. The results clearly demonstrate that collagen can be efficiently

isolated from both *Mugil cephalus* and jellyfish tissues using acid-based extraction methods. The analytical techniques employed in the study provided complementary evidence regarding the structural integrity and purity of the isolated proteins. Spectroscopic data and electrophoretic profiles confirmed the presence of characteristic collagen features in both samples, thereby addressing the central research objective of identifying potential marine-derived collagen sources. The comparative results further highlight measurable differences between the two organisms in terms of extraction efficiency and protein concentration, which contributes to understanding species-specific variations in collagen composition.

4.2 Comparison with Previous Studies

The collagen yield obtained from *Mugil cephalus* skin in this study (4.70%) is comparable to values reported for other marine fish species. For example, Nagai and Suzuki (2000) [7] documented collagen yields ranging from 3-6% in several fish skins and connective tissues. Similarly, Jongjareonrak *et al.* (2005) [6] reported extraction yields between 4% and 7% for collagen isolated from marine fish skin using acid-based extraction methods. These findings suggest that the collagen content observed in *Mugil cephalus* is consistent with previously studied marine fish species.

The higher extraction yield observed in jellyfish tissues aligns with earlier investigations indicating that jellyfish mesoglea contains large quantities of collagen-like structural proteins. Addad *et al.* (2011) [1] demonstrated that jellyfish collagen can be extracted efficiently due to the high proportion of extracellular matrix components present in the gelatinous tissue. Furthermore, Hoyer *et al.* (2014) [5] reported that collagen derived from jellyfish exhibits favorable extraction efficiency and structural stability, making it a promising biomaterial candidate. The results obtained in the present study support these earlier observations and reinforce the potential of jellyfish as an alternative marine collagen source.

The UV-visible spectral peak observed near 228-229 nm corresponds to the characteristic absorbance region associated with peptide bonds in collagen molecules. Similar absorption maxima have been reported for collagen

isolated from various marine organisms, including fish and invertebrates (Silva *et al.*, 2014) ^[10]. The absence of significant absorption peaks in the higher wavelength region suggests minimal contamination from aromatic amino acid-rich proteins, indicating effective removal of non-collagenous components during the purification process.

FTIR spectral analysis further confirmed the presence of collagen-specific structural features. The amide I band detected near 1652-1655 cm⁻¹ is widely recognized as an indicator of the triple-helical structure of collagen (Shoulders & Raines, 2009) ^[9]. Comparable FTIR spectral patterns have been reported in marine collagen studies, including those involving fish skin and jellyfish tissues (Gómez-Guillén *et al.*, 2011) ^[4]. The presence of amide II and amide III bands also supports the structural integrity of the extracted proteins.

Electrophoretic analysis revealed α -chain bands with molecular weights near 110-120 kDa, which correspond to the typical molecular weight range of collagen type I chains. Previous studies examining collagen extracted from fish species such as *Lutjanus vitta* and *Oreochromis niloticus* have reported similar electrophoretic patterns (Jongjareonrak *et al.*, 2005) ^[6]. The detection of β -dimer components further supports the presence of intact collagen molecules with intermolecular cross-linking.

The findings of this study largely align with the existing body of research on marine-derived collagen. The observed collagen yields, spectroscopic characteristics, and molecular weight profiles correspond closely with values reported in previous studies involving fish and jellyfish tissues. However, the slightly higher protein concentration detected in jellyfish collagen extracts compared with fish collagen may reflect differences in tissue composition and collagen organization within the organisms. Jellyfish mesoglea is primarily composed of extracellular matrix components, which may contribute to greater collagen availability and extraction efficiency.

In contrast, fish skin contains collagen embedded within a more complex matrix of structural proteins, lipids, and pigments, which may reduce extraction efficiency. Similar observations have been reported in earlier investigations examining collagen extraction from marine fish tissues (Gómez-Guillén *et al.*, 2011) ^[4]. Despite these differences, the overall structural characteristics of collagen from both sources remain comparable, indicating that marine organisms can provide functionally similar collagen molecules.

The results contribute to the broader theoretical understanding of marine-derived collagen as a biomaterial resource. Marine collagen differs from mammalian collagen in several biochemical aspects, including amino acid composition, thermal stability, and solubility characteristics (Silva *et al.*, 2014) ^[10]. The identification of collagen from both fish and jellyfish supports the concept that diverse marine organisms share common structural protein frameworks within their extracellular matrices. These findings reinforce the idea that marine biodiversity represents a valuable reservoir of biomolecules with unique biochemical properties.

Additionally, the study highlights the importance of species-specific differences in collagen composition and extraction efficiency. Understanding these variations is essential for developing optimized extraction protocols and selecting appropriate marine organisms for specific industrial applications.

4.3 Industrial Implications

From an applied perspective, the results demonstrate the feasibility of utilizing marine organisms as alternative sources of collagen for biomedical and industrial purposes. Marine collagen has gained increasing attention in fields such as tissue engineering, wound healing, drug delivery, and cosmetic formulations due to its favorable biocompatibility and biodegradability (Silvipriya *et al.*, 2015) ^[11]. The identification of collagen in both *Mugil cephalus* and jellyfish suggests that these organisms could serve as sustainable raw materials for collagen-based products.

Furthermore, the use of fishery by-products such as fish skin for collagen extraction may contribute to waste reduction and value addition in the seafood processing industry. Arvanitoyannis and Kassaveti (2008) ^[2] emphasized that fish processing generates significant quantities of biological waste, which can be converted into valuable biomaterials through appropriate extraction techniques. The present study supports this concept by demonstrating the successful recovery of collagen from marine tissues.

Jellyfish utilization also presents potential economic and environmental benefits. In several coastal regions, jellyfish populations have increased substantially, sometimes disrupting fisheries and marine ecosystems (Purcell *et al.*, 2007) ^[8]. Converting jellyfish biomass into useful biomaterials such as collagen could provide a productive use for these abundant marine resources.

The study contributes to the expanding literature on marine-derived biomolecules by providing comparative data on collagen extracted from *Mugil cephalus* and jellyfish. While numerous investigations have examined collagen from individual marine species, fewer studies have directly compared collagen characteristics across different marine organisms using similar analytical techniques. The results therefore add valuable information regarding extraction efficiency, structural properties, and molecular composition of collagen derived from these two sources.

References

1. Addad S, Exposito JY, Faye C, Ricard-Blum S, Lethias C. Isolation, characterization and biological evaluation of jellyfish collagen for use in biomedical applications. *Marine Drugs*. 2011;9(6):967-983.
2. Arvanitoyannis IS, Kassaveti A. Fish industry waste: treatments, environmental impacts, current and potential uses. *International Journal of Food Science & Technology*. 2008;43(4):726-745.
3. Food and Agriculture Organization. The state of world fisheries and aquaculture 2020. Rome: FAO; 2020.
4. Gómez-Guillén MC, Giménez B, López-Caballero ME, Montero P. Functional and bioactive properties of collagen and gelatin from alternative sources: a review. *Food Hydrocolloids*. 2011;25(8):1813-1827.
5. Hoyer B, Bernhardt A, Heinemann S, Stachel I, Meyer M, Gelinsky M. Biomimetically mineralized jellyfish collagen scaffolds for bone tissue engineering. *Acta Biomaterialia*. 2014;10(2):883-892.
6. Jongjareonrak A, Benjakul S, Visessanguan W, Nagai T, Tanaka M. Isolation and characterization of acid and pepsin-solubilised collagens from the skin of brownstripe red snapper (*Lutjanus vitta*). *Food Chemistry*. 2005;93(3):475-484.
7. Nagai T, Suzuki N. Isolation of collagen from fish waste material—skin, bone and fins. *Food Chemistry*. 2000;68(3):277-281.

8. Purcell JE, Uye S, Lo WT. Anthropogenic causes of jellyfish blooms and their direct consequences for humans. *Marine Ecology Progress Series*. 2007;350:153-174.
9. Shoulders MD, Raines RT. Collagen structure and stability. *Annual Review of Biochemistry*. 2009;78:929-958.
10. Silva TH, Moreira-Silva J, Marques ALP, Domingues A, Bayon Y, Reis RL. Marine origin collagens and their potential applications. *Marine Drugs*. 2014;12(12):5881-5901.
11. Silvipriya KS, Krishna Kumar K, Bhat AR, Kumar BD, John A, Lakshmanan P. Collagen: animal sources and biomedical applications. *Journal of Applied Pharmaceutical Science*. 2015;5(3):123-127.
12. Zhang Y, Liu W, Li G, Shi B, Miao Y, Wu X. Isolation and partial characterization of pepsin-soluble collagen from the skin of grass carp (*Ctenopharyngodon idella*). *Food Chemistry*. 2007;103(3):906-912.