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Exploring the Potential of Fish Gelatin and Sustainable Alternatives in the Food Industry: A Comprehensive Analysis

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Abstract

Gelatin, a frequently used dietary component is produced by heat denaturing and hydrolyzing animal collagen. However, nutritional limitations associated with pig gelatin, driven by cultural and religious reasons and worries about zoonotic infections in cattle, have motivated the search for alternate gelatin sources. Despite obstacles linked to their gelling characteristics compared to human Gelatin, Fish and Fish metabolites have emerged as desirable alternatives. This study investigates the possibilities of fish gelatin and explores renewable options in the food business. PRISMA was used to assess the strength of the gel measurements of the fish gelatin from warm- and cold-water environments compared to human Gelatin to determine their adequacy as a substitute. We included a total of 15 studies after an examination of the strength of the gel and the extraction measurement techniques. The investigation found that the mean gel thickness Gelatin made from fish, including warm-water and cold-water variants, was substantially lower than that of human Gelatin. This indicates that fish skin gelatin from warm water performs similarly to human Gelatin in terms of gel formation ability, suggesting that it might be a good alternative for manufacturing food gels.The study investigates the variations in Fish and mammalian gelatin gels' melting and gelling temperatures and their structural characteristics from sole to composite gel. It highlights the necessity of researching different gelatin sources and substituting proteins to solve environmental issues and satisfy the rising demand for sustainably produced foods.

Keywords: Gelatin, Cold-Water Fish, Warm-Water Fish, Food Industry

INTRODUCTION

Gelatin, used in food manufacturing, is risky due to mammalian origins culturally and religiously incompatible with many societies. Considering these worries, looking into other food gelatin suppliers becomes important (1).Fish connective tissue is one such substitute whose industrial processing solves the problem of disposing trash but also makes most of the fishing industry's byproducts.An estimated 179 million tons of fishing were caught worldwide in 2018, with up to 85% of the catch potentially being wasted. Roughly 30% of this waste comprises collagen-rich skin, bones, and scales (2). The Gelatin of Fish as a necessary component of food-forming substance presents an incredibly encouraging direction.Fish gelatin differs from mammalian Gelatin in containing less proline and hydroxyproline (3). This difference causes fish gelatin to become less effective at gelling, which causes lower melting and gelatin temperatures, weaker gels, and more gelatin usage as a part of the hydrogel-forming process(4).Many researchers have investigated methods to reduce these side effects, such as high-pressure treatments, irradiation over various frequencies, alterations to enzymes, and adding mono- and disaccharides, ferulic and caffeic acids, among other things (5). This technique could raise the nutritional value of gelatin gels by improving their functional characteristics. This study investigates fish gelatin's composition, structure, and available

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properties of dietary gelling agents as a potential replacement for animal gelatin (6). The organic ionic fructose alters the gel-forming qualities and rheological features of fish gelatin (7).However, employing porcine Gelatin for dietary requirements sensitive to cultural and religious differences, like in Kosher and Halal dishes, presents difficulties (8).Furthermore, public health worries were sparked by the bovine spongiform encephalopathy (BSE) outbreak, later research verified the safety of the production process(9). These reasons consequently led to a concentration on fish and fish byproducts and substantial research into other sources of Gelatin. Fish gelatin can be used as a viable replacement for animal gelatin, but it also has financial advantages because it uses fish byproducts, reducing waste in the seafood sector(10). A creative and sustainable method is the extraction of Gelatin from byproducts, especially the fish scales and bones generated throughout the process of making fillets from seafood.

Gelatin from mammals is partially hydrolyzed and thermally denaturized to produce Gelatin, a widely used ingredient in food products. The study (11) addressed gelatin sources has been sparked by dietary limitations about porcine Gelatin that are affected by cultural or religious factors as well as health safety concerns arising from prior cases of zoometric disease in cattle. The article (12) described how gelling capacity limits their employment in the food business; seafood and seafood waste have emerged as intriguing alternatives. The research (13) used meta-analysis to examine the values of fish gelatin's gel strength in warm and cold water to determine its potential compared to mammalian Gelatin.The study (14) investigated the average gelatin level of fish gel quality, which was found to be lower than that of mammalian Gelatin ($p < 0.05$) out of 13 researchers who underwent thorough extraction and gel force testing measurement methods. The article (15)investigated Gelatin from warm-water fish skin, which proved to be the most effective replacement for mammalian Gelatin when making food gels. The combined impact evaluation indicates that it was above the null effect line and performed better than other fish gelatins.The research (16) provided some unique fish gelatin characteristics that impact its use in food products. This contrasts with utilized human Gelatin in the food business. The study (17)used fish gelatin in gelled food technology to replace pig and cow gelatin, which is significantly limited by these intrinsic characteristics.The article (18) described by adding naturally occurring ionic polysaccharides to fish Gelatin, one can change the functional aspects of the protein and overcome this difficulty. The research (19) explored how polysaccharides combine with Gelatin to produce polyelectrolyte complexes under certain circumstances, adding new nodes to the gel's spatial network.The study (20) used to create a sachet that contains olive oil looks into the properties of collagen obtained from a fish in freezing water in combination with poultry gelatin (PG).

METHOD

Searching Strategy

The PRISMA flow diagram's guidelines were followed in the systematic review. They searched several databases for pertinent research publications, including Nature Forward, The Internet publication of Taylor & Francis, The Wiley Electronic Library, and Summaries of Agricultural Research and Development. Articles subjected to independent review with all dates,the date of introduction were searched utilizing the phrase "gelatin" for searches in terms with words "fish," "gelling," and "gel strength" for investigations across the complete articles. Figure (1) displays a PRISMA flowchart depicting the information flow from database search to meta-analysis.

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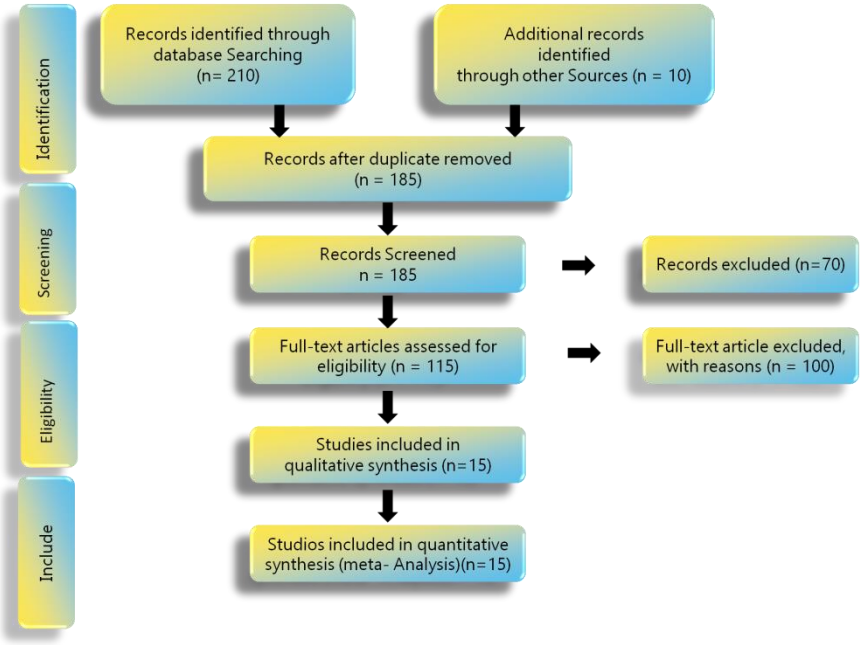

Figure (1). Study Selection Using PRISMA Flowchart

(Source: Author)

Article selection and exclusion processes

Full articles must meet the assessment requirements, which provide detailed information about the gel strength measurement and gelatin extraction procedure. To avoid unintended polypeptide chain cleavage, the raw material should be fish origin, with the specified species, and without enzymatic pretreatment. Gel strength must be given with standard deviation in replicates and calculated in grams as the force needed to penetrate the gel with a standard plunger. Though trials with warmth during gel production of ≤10 ◦C were also considered, fish gelatin's strength in the gel must be compared to control human Gelatin that was made and tested similarly.

Building a Database

A database was created by methodically organizing the data from relevant articles. This database included information about the authors, fish species, components of the gelatin extraction process, gel preparation, process of extraction parameters, pretreatment methods, details of gel strength values, and standard deviations. The species were divided into subgroups that lived in warm or cold water by comparing the scientific names of the fish species with the Fish Base database, which offered details on their ideal development and reproduction temperatures. Warm-water Fish had temperatures above 20 ◦C, and cold-water fish had temperatures below 20 ◦C. studying the optimization of extraction conditions led to the discovery of values for gel strength under ideal circumstances.

Analytical statistics

A meta-analysis examined the average variations in fish gelatin gel quality from warm or cold water and control mammalian Gelatin. The findings, shown in a forest plot and included effect sizes and 95% confidence intervals, made understanding the differences between different studies and subgroups easier. A random-effects model was

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utilized because foreign extraction and sample preparation methods were used, and some studies had missing intrinsic factor data. Unlike the fixed-effect model, this model provides an average intervention effect while admitting a range of study impacts. For both the total and subgroup analyses, heterogeneity was measured using the I^2 statistic from Chi-square tests.

RESULTS AND DISCUSSION

The amino acid content in marine Gelatin

The amino acid pattern of thegelatin macromolecule is generally expressed as Xls $-$ R $-$ S, where proline usually occupies a substance called R, and the location typically occupies the Sposition. Triple helices in macromolecular chains that resemble collagen are largely formed by essential amino acid triads such as Xls $-$ Pro $-$ $SGly$ $-$ R $-$ Hsxand Xls $-$ Pro $-$ Hsx. Table (1) compares the quantity of amino acids in Gelatin from different sources. Comparing fish gelatin to mammalian Gelatin, the former has a lower proline and hydroxyproline level (21). In particular, regarding these amino acid concentrations, proline and hydroxyproline concentrations in Gelatin obtained from the skins of pigs and calves are quite similar to those in Gelatin.

Table (1). Some fish gelatins' amino acid makeup in comparison to that of pig and calfskin gelatin (Source: Author)

Source	**Fish Skin from Cold Water**			**Fish Skin from Warm Water**			**hog skin (22)**	**Skin of Calf (26)**
	Cod (21)	**Hake (21)**	**Alaska Pollock (22)**	**Tilapia (23)**	**Tuna (23)**	**Black Carp (24,25)**		
Glycine (Gly)	343	330	357	346	335	313	329	312
Hydrophobic groups	285	313	279	308	320	335	321	325
Alanine (Ala)	95	118	107	121	118	118	111	113
Valine (Val)	17	18	17	14	27	21	25	21
Leucine (Leu)	21	22	19	22	20	21	23	24
Isoleucine(Ile)	10	8	10	7	8	11	9	10
Proline (Pro)	105	113	94	118	116	132	131	134
Phenylalanine(Phe)	15	14	11	12	12	13	13	12
Methionine(Met)	16	14	15	8	15	13	3	5
Carboxylic groups	129	122	124	116	114	125	117	115
Aspartic acid(Asp)	51	48	50	47	43	47	45	44
Glutamic acid(Glu)	77	73	73	68	70	77	71	71
Hydroxylic groups	141	133	145	139	149	130	146	143
Serine (Ser)	63	48	62	34	47	36	34	36
Threonine(Thr)	24	21	24	23	20	24	17	17
Hydroxyproline(Hyp)	49	58	54	78	77	68	90	85
Tyrosine (Tyr)	2	3	2	1	2	0	2	2
Basic groups	98	98	90	85	89	87	85	100
Lysine (Lys)	28	27	25	24	24	28	26	33
Hydroxylysine(Hyl)	5	4	5	7	5	1	5	10
Histidine (His)	7	9	7	5	6	3	3	4
Arginine (Arg)	55	53	50	46	51	52	48	50

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Fish gelatin has a unique secondary structure because of the restricted availability of hydroxyproline and proline. Instead of triple helices, β-turn/β-shift forms predominate in Fish gelatin's primary system, which differs from human Gelatin. Moreover, studies reveal that fish gelatin's abundance of β-structures negatively affects its functional capabilities, emphasizing a distinctive feature that makes it different from other gelatins (22).

Fish Gelatin Gel's Transition from Sole to Gel and Rheological Characteristics

The functional characteristics of Gelatin obtained from fish are comparatively less than those of mammalian Gelatin in areas such as gelation, melting temperatures, and rheological properties. This is attributed to differences in amino acid composition and structural features (23). Optical rotation has been used to determine the conformational shift between 35 °C and 20 °C for mammalian Gelatin and between 15 and 20 °C for cold-water fish gelatin. Gelatin creates a thermo-reversible viscoelastic hydrogel below this transition point by organizing into a spatial network of triple collagen-like helices (24). In Table (2), data on mammalian Gelatin (porcine and bovine) sourced from multiple literature sources are presented together with the 10% (w/v) gelatin gel melting and gelation temperatures of Fish from both warm- and cold-water environments.

Table (2). Fish gelatin gels are not the same temperature as human gels

(Source: Author)

Gel	Gel formation Temperature, °C	Temperature of Melting, °C	References
Fish gelatin from cold water	3–7	15–17	(22)
	6–10	10–18	(22)
	3–4	11–12	(22)
	3–11	<16	[27]
	3–9	12–15	(30)
	-	15–20	(2)
	6–8	17–19	(28)
	11	13–20	929)
Fish gelatin from warm-water Fish	20–21	27–28	(22)
	14–19	19–26	(22)
	17–18	23–28	(27)
	-	21	(30)
	-	22–29	(2)
	19–22	24–25	(29)

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Animal collagen	25–26	32–33	(22)
	19–24	27–30	(22,2)
	28	-	(30)

Fish gelatin gels generally possess lower temperatures of creation and melting than mammals, as Table (2) shows. Mammalian gelatin gels and melts at temperatures similar to warm-water fish gelatin. For example, the Black Tilapia leather gelatin gel melts at 28.9 °C. The lower rheological properties (strength, elastic moduli) of fish gelatin compared to mammalian Gelatin are a major disadvantage in food technology (25). The intensity of bloom varies between species of Fish from warm and cold water, occasionally surpassing the gel of mammals.Due to the properties of the raw materials and the manufacturing conditions, a critical attribute, solution viscosity, differs between fish species (26). Figure (2) compares the gramme gel strength of fish and mammalian gelatins.

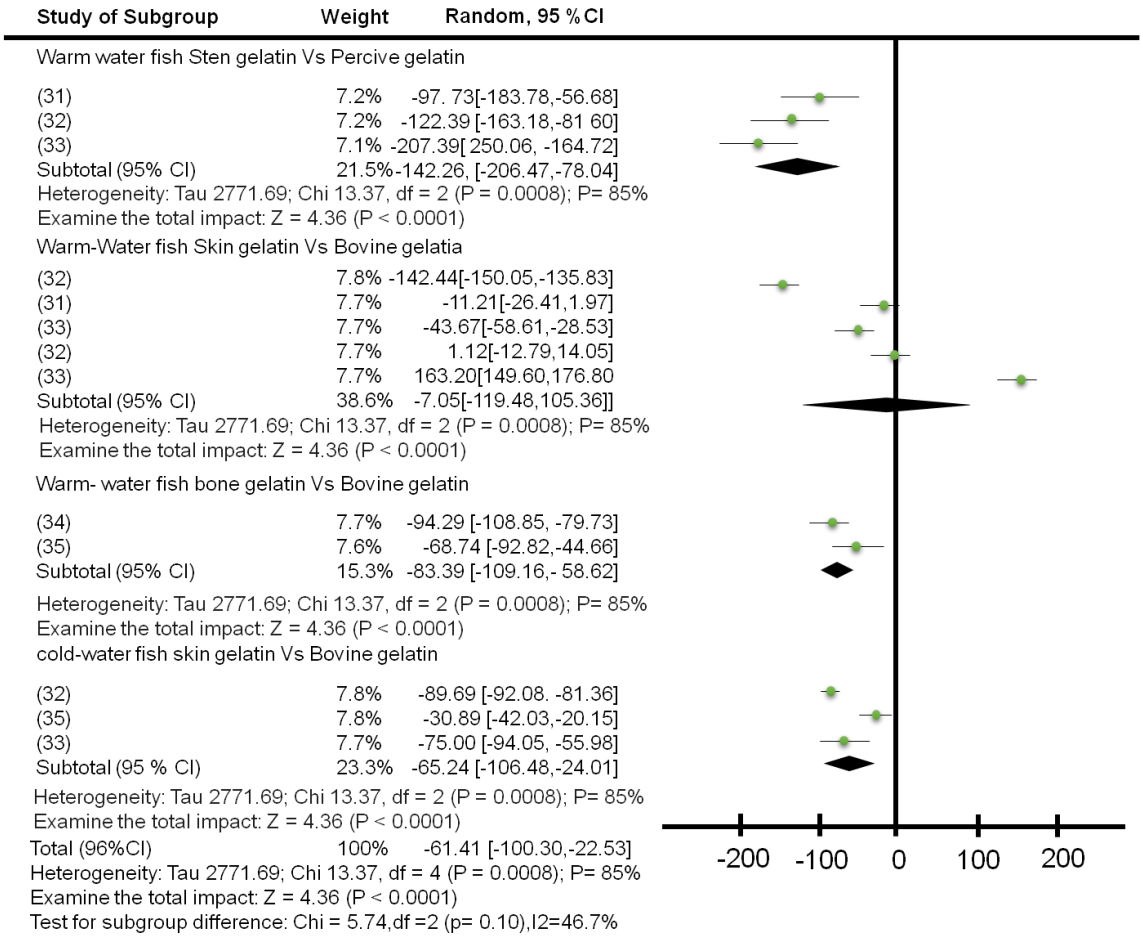

Figure (2). Fish and mammalian gelatins are compared for gramme gel strength

(Source: Author)

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Bovine control and Gelatin from warm-water Fish are contrasted

Compared to bovine Gelatin, the impact size dispersion is wider, with study codes used to identify positive and negative outliers (27). With overlapping confidence intervals suggesting a non-significant difference favoring fish gelatin, the total effect estimate (-7.1) has a broad 95% confidence interval (-120.5 to 106.4). Elevated I^2 readings suggest high heterogeneity and variance, probably caused by variations in the fish species employed to extract Gelatin (28). There is a significant degree of variation among warm-water fish species. Careful selection is recommended to obtain Gelatin with strength comparable to bovine Gelatin, taking into account characteristics such as Pangasius sutchi skins (29).

Bovine Gelatin served as the control subgroup for Fish with a gelatinous bone broth

Compared to cow's Gelatin, the warm-water fish bone cartilage showed an average effect size of -84.4, with a 94% confidence interval of -108.1 to -58.5 (30). This suggests notably reduced gel strength ($p < 0.05$). Given the lack of published research on fish bone gelatin extraction, it's notable that the comparison included only two experiments, even if the variation between subgroups is negligible (31).

Bovine versus fish boan gelatin in warm water

Gel potency is a critical feature in food applications that distinguishes fish bone gelatin from warm water from cow's gelatin (32). Fish gelatin from warm-water species may provide gel strength similar to bovine Gelatin despite possible differences between species. For these reasons, it could be a viable alternative in some situations. Based on the intended gel strength results in different food formulations, the study highlights the necessity of carefully choosing fish species for gelatin extraction (33).

Bovine Gelatin served as the control subgroup in the case of cold-water fish gelatin

However, the influence of mammalian Gelatin on gel strength was supported by the investigations in the subgroup comparing Change to bovine Gelatin from Fish (34). With a 95% confidence interval from -107.5 to -25.0, the magnitude of the effect for fish gelatin from cold water is -65.24. Compared to warm-water fish bone gelatin.It appears to have more promise for superior gel strength (35). However, cold-water fish gelatins have lower hydroxyproline concentrations than warm-water and mammalian gelatins, making them better suited to producing edible films.

CONCLUSION

Finally, a systematic study that used PRISMA standards revealed the unique properties of fish gelatin, especially those from warm-water species. Variations in rheological qualities, distinct secondary structures, and differences in amino acid makeup compared to mammalian Gelatin were apparent. Despite its lower gelatin temperatures and strength, the study acknowledged the possible use of warm-water fish gelatin in some situations. The results highlight the significance of choosing fish species for gelatin extraction by the planned services. In summary, this study provides significant new understandings of the distinct qualities of fish gelatin, opening the door for its use in various industrial and food-related formulations.

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