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The characteristics of gelatin from fish waste: A review

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ABSTRACT

Gelatin is a commonly used ingredient in the food, pharmaceutical, and cosmetic industries. It is obtained through the hydrolysis process of collagen, the main protein found in animal connective tissues. Fish waste such as skin and bone are a promising source for gelatin, however the characteristics of gelatin can vary depending on its source. The purpose of this review is to compare the characteristics of gelatin from fish skin and bones, such as yield, gel strength, and viscosity. The research findings indicate significant differences in the characteristics of gelatin from different types of fish skin and bones. In this study, it was found that gelatin with the best characteristics was derived from the skin of mackerel fish, with a yield of 5.90%, viscosity of 7 cP, and gel strength of 328.57 g bloom. Meanwhile, gelatin from the bones of tilapia fish had a yield of 8.10%, viscosity of 5.85 cP, and gel strength of 376.21 g bloom. It was concluded that gelatin from various types of fish skin and bones had different characteristics, so the specific purpose of using the obtained gelatin had to be considered.

Introduction

Indonesia is an archipelago country with great potential in the fisheries sector. Therefore, it is crucial to maintain and sustain the fishery production potential to ensure high product quality and utilize it effectively. The marine fishery products utilization in Indonesia can be processed in the form of wet products by 57.05%, traditional products by 30.19% and modern products by 10.90%, and other processed forms by 1.86% (BPPN, 2014). Utilization of the fishery products in Indonesia with this percentage significantly contribute to the production of by-product in the form of waste. According to A'yunin *et al.* (2021), waste generated from fisheries activities is still at a significant level, which is around 20-305 from the total fish production which reaches 6.5 million tons per year.

Solid waste generated from processing fishery products has a wet nature and consists of unused fish pieces. It is produced from the weeding process of the fish entrails and the cleaning process, such as fish head, tail, skin, scales, and gills (Harianti, 2012). In a study by Shyni *et al.* (2014), it was stated that most of the fish weight is contributed by skin and bones. However, unfortunately, it is often discarded and not utilized. This fish processing waste is generally only used as an ingredient for making animal feed or fertilizer. Thus, its economic value is low (Nasution *et al.*, 2018).

Another form of fisheries waste utilization is collagen and gelatin extraction. Generally, gelatin is obtained from skin or bone collagen by treatment using acid or alkali (Haug *et al.*, 2004). Gelatin is a protein obtained from animal skins, bones and white fibrous tissue. However, due to conflicts related to religious opposition and the possibility of disease transmission from some mammals, therefore the use of these animals as sources of collagen and gelatin is being reconsidered. One of the alternatives to address the extraction problem from mammals is extracting collagen and gelatin from marine biota i.e fish (A'yunin *et al.*, 2021).

Many studies have been carried out on the analysis of gelatin on the skin and bones of fish, including; tuna, shark, salmon, rays, carp, sturgeon, snapper, tilapia, catfish, cod, mackerel, catfish, grouper, blue whiting. Nearly a third of the fish's weight comes from the skin

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and bones, even according to Shyni *et al.* (2014), the biggest contributor to fish body weight comes from bones and skin, however fish bone waste is discarded and not utilized. in fish filet processing, as product yields are only around 30-50% (Coppola *et al.*, 2021). Koli *et al.* (2012) confirmed that a potential alternative source of gelatin comes from fish skin and bones. Although currently utilization of fish skin is higher than fish bones, bone utilization is quite promising because certain fish bones such as catfish have a higher yield of gelatin among several types of fish. Collagen and gelatin produced from fish waste has various characteristics. Understanding of the properties of gelatin extracted from fish skin and bones is important because it can be used as an alternative to commercial gelatin. Therefore, in this review the authors discuss about how the properties e.g. yield, viscosity, and gel strength of gelatin from fish skin and bones.

Collagen

Collagen is a type of fiber/fibril protein that has distinctive physiological properties. Collagen can be found in various connective tissues such as skin, tendons, bones, cartilage, and others (Panjaitan, 2016). It is an example of a fiber-shaped structural protein that has a different role from globular proteins such as enzymes. Collagen is also one of the viscoelastic materials and has high tensile strength and low extensibility. That collagen content can be extracted into gelatin.

Collagen conversion to gelatin involves pre-treatment of collagen using acidic or alkaline solutions. Collagen extraction process using acidic solutions has the advantage of a shorter time compared to extraction process using alkaline solutions. This is due to the ability of acidic solvents to convert the triple helix collagen fiber structure into a single chain form, while alkaline solvents are only able to produce double helix chains.

Gelatin

Gelatin is a result of hydrolysis and denaturation process of collagen derived from skin, muscle, organs and bones of animals through the process of adding water and heating (Aris *et al.*, 2020). Gelatin gelatin is composed of 19 amino acids, glycine (27–35%), proline, and hydroxyproline (20–24%) being the predominant amino acids (Nurilmala *et al.*, 2022).

Gelatin is a significant additive used as a gelling, emulsifier, and thickener for various products in the food industry, such as candy preparation, bakery products, desserts, ice cream, and meat products (Zhang *et al.*, 2020). Gelatin being exploited in numerous areas of food industries also has a substantial role in developing biodegradable packaging material. The biodegradable coatings/films can protect, maintain, extend the shelf-life of food products (Said and Sarbon, 2022).

Gelatin extraction is a process of extracting gelatin from raw materials such as fish skin and bones through a series of processing steps. The gelatin extraction process includes pre-treatment of raw materials, thermal extraction, evaporation and drying processes. Gelatin extraction process can be carried out through various methods such as acidic, alkaline, or enzyme treatment. Generally, gelatin produced from fish raw materials is usually processed using the soaking method in an acidic solution. The use of an acidic solution in this method is because the soaking process is faster using an acidic solution compared to using an alkaline solution.

Extraction of Gelatin

Gelatin is produced through collagen hydrolysis and extraction. The gelatin production process involves three main steps. The first step includes the preparation of the raw materials, including non-collagen component removals. The second step is to convert collagen to gelatin. While the third stage involves gelatin purification through filtration and drying. Gelatin extraction aims to obtain optimal gelatin quality and yield for application in the fields of food, pharmaceuticals, cosmetics, and photography (Ismail and Abdullah, 2019). The time required for gelatin extraction can vary depending on several factors, such as raw materials used, extracting method used, and the raw material volumes to be extracted (Liu *et al.*, 2009).

Various methods have been developed for the extraction of collagen from fish bones, such as maceration and ultrasonication. The use of the maceration method is most often applied because the collagen extraction process is preferred to be carried out at low temperatures to minimize damage to the collagen produced, thus, the maceration method is considered the most feasible to use. The extraction method of collagen and gelatin from fish skin and scale wastes is very similar to the maceration extraction method from fish bone waste. Maceration extraction is done by submerging the fish skin and scale waste with one solvent or a mixture of solvents in a period of time, usually 24 hours. By performing the maceration process, efficacious substances that are resistant to heating and those that are not resistant to heating can be drawn out. Technologically, maceration is an extraction process that uses the metome principle to achieve a balanced concentration (A'yunin *et al.*, 2021).

Utilization of Gelatin

The demand for gelatin in Indonesia has increased, but the industry in Indonesia has yet to respond commercially to this demand, so it still relies on imported products (Febryana *et al.*, 2018). There are considerable doubts regarding the halalness of the use of imported gelatin because the source of the imports comes from various countries, including China. Gelatin imported from China is generally made from pig bones (Permata *et al.*, 2016). The haram status of pork-based products in gelatin-producing countries has led to a lot of discussion about finding substitute gelatin sources that meet the halal standards. According to Mariod (2013), some sources that can be used to produce gelatin include poultry, marine animals, and insects. Therefore, it is important to extract gelatin from various types of fish skin and bones as an alternative to conventional gelatin, which is usually derived from pigs and cattle. In research conducted by Miskah *et al.* (2010), it was mentioned that gelatin extracted from poultry and fish has similar characteristics to gelatin derived from pigs.

Until recently, gelatin has been used by various industrial sectors, both in the food and non-food sectors. In the food industry, gelatin is used as an additive that is useful as a foam-former, stabilizer, food thickener or binder (Khirzin and Fatkhorrohman, 2019), which is applied in the manufacture of candy, jelly, marshmallow, yoghurt, ice cream and as forming ingredient in processed meat products, such as sausages, nuggets, or smoked meat (Aljawish and Chevalot, 2019). In the non-food industry, gelatin is used in the pharmaceutical industry as one of the ingredients used to make drug capsules, tablets, and supplements (Mahmood *et al.*, 2016) and in the cosmetic industry in the form of hair, skin, and nail care products (Brennan and Grandison, 2009).

Characteristics of Gelatin

There are several important parameters in gelatin characteristics, including yield, viscosity and gel strength. Gelatin yield refers to the percentage or amount of gelatin produced from raw materials such as animal skins, bones, or connective tissues containing collagen.

To calculate this yield, it can be done by comparing the weight of gelatin produced to the weight of raw materials used. The yield test is conducted to evaluate the efficiency of the extraction process and the quality of the gelatin. The greater the yield percentage obtained, the more efficient and effective the treatment used (Zulkifli *et al.*, 2014). Factors that affect gelatin yield include the type of raw materials, extraction method and raw materials quality used (Febriansyah *et al.*, 2019).

Viscosity is a measure of the thickness of a material. Industries such as food stabilizers, pharmaceuticals, and photographic emulsions require high viscosity, while the sugar industry requires gelatin with low viscosity (Gunawan *et al.*, 2017).

Gel strength is also an essential factor in gelatin characterization. It is one of the textural characteristics of a material that indicates its ability to undergo certain deformations (Wulandari *et al.*, 2013). The gel strength level is measured in bloom units, which is the compressive force required to break or destroy the deformation of the gel product. Gel strength refers to the mechanical strength of gelatin in maintaining its gel form and its resistance to deformation or separation. Gel strength tests are performed by measuring the tension or force required to break or separate gelatin under specific conditions. The sustainability and stability of gelatin under various processing or storage conditions can be evaluated through this test. The gel strength of gelatin is influenced by various factors such as the type of raw materials used, the type of pre-treatment (e.g. use of acids or alkaline), and the extraction conditions. Gel gelatin formation occurs when the gelatin molecules expand during the heating process. Heat will cause the bonds in the gelatin molecules to open and trap the previously free-flowing liquid within those structures. This process results in the formation of a viscous gel.

The viscosity and gel strength of gelatin are influenced by the raw materials distributed over its molecular weight and amino acid compositions. Gelatin with high amino acid content tends to have a high gel strength. Different raw material sources can also result in differences in the amino acid composition of the gelatin produced. The higher value indicates the better quality of the gelatin materials (Awwaly, 2017). Gelatin yield, viscosity, and strength tests can be performed using a variety of appropriate methods and instruments. The test results provide producers or researchers with important information regarding the quality and performance of the extracted gelatin. In addition, the test results can also be used to study and develop more efficient extraction processes and improve the quality of the produced gelatin. By understanding the yield, viscosity, and strength of gelatin, producers and researchers can optimize the extraction process and produce gelatin with properties suitable for various industrial applications.

The quality of gelatin is determined by its physicochemical characteristics (Iqbal *et al.*, 2015). The characteristics of gelatin are influenced by the quality of the raw materials, pH, presence of organic substances, extraction method, temperature and concentration of curing agent. Other factors that affect the properties of gelatin and its production process are species, breed, age, feed type of the animal and the raw materials storage conditions (Awwaly, 2017). Based on several observations, there are gelatin characteristics differences such as yield, viscosity, and gel strength in each study derived from fish skin and bones. Some studies on the characteristics of gelatin extracted from several fish skin and bones can be seen in Table 1.

Yield

Yield is a crucial factor in assessing the quality of gelatin produced. It refers to the percentage of gelatin formed from the raw material of origin, such as animal bones or skin. Gelatin is a type of gel-structured protein obtained through the transformation of collagen found in bones and skin (Permata *et al.*, 2016). The yield calculation process was carried out by comparing the gelatin weight produced with the raw materials weight used (Capriyanda and Mujiburohman, 2020). The yield value of each raw material used will vary, this is due to the different amount of collagen in each type of fish. In addition, there are several other factors that affect yield, including pH, extraction temperature and acid concentration (Zulkifli *et al.*, 2014). The percentage yield is also affected by the storage and freshness of the raw materials. If not managed properly, this process can result in a decrease in the yield of gelatin obtained (Finarti *et al.*, 2017).

In addition, the collagen protein content in animal skin is also affected by age, where the older the animal, the collagen protein content increases and collagen fibers become stronger. Collagen from young animals is more soluble in warm water, this property will decrease with age.

The solubility and denaturation temperature of skin collagen is about 20-22%. The fat and mineral content of old Nile Perch is higher than young individuals. The high mineral content in old Nile Perch is probably due to increased mineralization with increasing age. The yield of gelatin from young fish skin is less (12.5%) than gelatin obtained from old fish skin (16%) (Awwaly, 2017).

Table 1. Characteristics of gelatin extracted from fish skin and bones

Reference	Type of Fish	Characterization of extracted gelatin		
		Yield (%)	Viscosity (cP)	Gel strength (g Bloom)
Fish skin				
Tabarestani *et al.* (2010)	Rainbow Trout Skin	9.36	3.20	459.00
Prommajak and Raviyan (2013)	Pangas Catfish Skin	5.60	3.88	213.75
Wulandari *et al.* (2013)	Striped Snakehead Fish Bone	3.53	3.87	202.90
Hermanto *et al* (2014)	Suckermouth Catfish Skin	11.60	12.70	416.70
Saputra *et al.* (2015)	Pangas Catfish Skin	11.94	4.13	140.57
Azara (2017)	Grouper Skin	6.99	6.75	19.73
Fan *et al.* (2017)	Salmon Skin	3.70	6.00	102.00
Gunawan *et al.* (2017)	Narrow-barred Spanish Mackerel Skin	5.90	7.00	328.57
Kumar *et al.* (2017)	Grouper Skin	2.75	3.70	193.40
Nurilma *et al.* (2017)	Yellowfin Tuna Skin	17.00	3.00	178.90
Febryana *et al.* (2018)	Featherback Fish Skin	3.29	2.50	50.25
Nasution *et al.* (2018)	Pangas Catfish Skin	14.30	3.50	141.50
Agustini (2020)	Tilapia Fish Skin	12.98	2.59	132.54
Nugraheni *et al.* (2021)	Starry Triggerfish Skin	8.69	3.61	294.47
Haris *et al* (2021)	Striped Snakehead Fish Skin	7.18	14.31	169.45
Fish bone				
Efendi *et al.* (2012)	Milkfish Bone	16.19	2.00	70.50
Wulandari *et al.* (2013)	Striped Snakehead Fish Bone	3.53	3.87	202.90
Iqbal *et al.* (2015)	Catfish Bone	2.90	3.00	136.43
Hidayat *et al.* (2016)	Tilapia Fish Bone	8.10	5.85	376.21
Minah *et al.* (2016)	Tuna Fish Bone	8.44	10.13	262.50
Panjaitan (2016)	Tuna Fish Bone	5.03	4.20	167.84
Ridhay *et al* (2016)	Skipjack Bone	7.31	3.08	47.60
Singkuku *et al.* (2017)	Skipjack Bone	2.50	3.70	62.45
Istiqlaal (2018)	Tuna Fish Bone	3.21	7.50	102.51
Mahmuda *et al.* (2018)	Featherback Fish Bone	8.80	3.45	151.45
Nurhaeni *et al.* (2018)	Mackerel Fish Bone	6.44	2.93	44.40
Pertiwi *et al.* (2018)	Pangas Catfish Bone	6.14	3.83	364.19
Ariyanto *et al.* (2022)	Narrow-barred Spanish Mackerel Bone	6.61	3.35	51.55

Mahmoodani *et al.* (2014) found that the catfish bones produced gelatin with a higher concentration among the gelatins of other fish bones. Gelatin from catfish bones has characteristics similar to those of commercial gelatin. They also claim that alkaline and acetic acid concentration as well as extraction temperature and time significantly affected the extraction process . However, it should be noted that extraction time that is too long and excessive acid concentration can cause excessive hydrolysis of the already formed gelatin. This condition will result in gelatin breakdown and decreasing yield (Nurilmala *et al.*, 2022). In this study, it was found that using 6% of HCl concentration and 7 hours of extraction time resulted in the highest yield. The result of fish gelatin extraction depends on time and process and procedure of extraction. Based on Karim and Bhat (2009), the average extraction yield of fish gelatin ranges 6 to 19 % (grams of dry gelatin per 100 g of clean skin on a wet basis).

Azara (2017) used variations of acetic acid concentration and submerging time and obtained a gelatin yield of 6.99% from grouper skin gelatin. The result showed that the higher the acid acetic concentration, the lower the gelatin yield. In the treatment with 18 hours of submerging time, there was an increase in the yield percentage and the yield percentage decreased when submerged for 24 hours. The change in gelatin yield percentage can be caused by the concentration of acetic acid used in the submerging process. During submerging, acetic acid will break the helical bonds of collagen contained in bones and skin through its acid ions. The more acidic the solvent (the lower the pH value), the more collagen helices can be broken down (Rachmania *et al.*, 2013). The cause may be related to the higher amount of H+ ions in hydrolyzing collagen, while the longer extraction time causes more collagen to break down into gelatin. The extraction process serves as a continuation of the previous stage, where hydrogen bonds between tropocollagen molecules that have not been broken down by acids in the previous preparation stage will be broken during extraction.

This extraction stage causes the triple-helix molecules to lose their stability and eventually break down into a single chain of gelatin (Rahayu and Fithriyah, 2015).

Iqbal *et al.* (2015), in their research, obtained a 2.90% gelatin yield value from Catfish bones. Meanwhile, Ariyanto *et al.* (2022) obtained a 6.61% gelatin yield value from mackerel bones, and Agustini (2020) obtained a 12.98% yield value from Tilapia skin. The difference in yield values produced is influenced by different factors according to the observations and variations in the factors used. The difference in yields produced from different types of fish may be influenced by several factors. Different habitats can cause differences in the structure and physical properties of gelatin. The characteristics of gelatin are determined based on the intrinsic properties of the skin and collagen content, the water-soluble portion, and the collagen loss through cross-linking and breakdown during the swelling process of the skin through washing or incomplete hydrolysis. The conversion rate of collagen to gelatin depends on the raw material preparation method, processing steps, extraction time, temperature, pH, pre-treatment conditions, and raw materials characteristics. Another factor is the acid treatment which can remove acid-soluble protein components, gats, unwanted compounds, and break cross-links in collagen molecules. As a result, the skin becomes swollen and collagen extraction becomes efficient (Nurilmala *et al.*, 2022).

There is a direct relationship between solvent concentration and the resulting yield value, where the higher the solvent concentration, the higher the resulting gelatin yield value. This could be due to the influence of the H+ ions amount in the solvent that hydrolyzes collagen from triple helical chains into single chains. This tendency will reach its limit when excessive H+ ions hydrolyze collagen excessively, causing changes in the physical and chemical properties of the gelatin formed. According to Pertiwi *et al.* (2018), the gelatin yield from catfish bones using 1% citric acid with pre-treatment for 48 hours and 75°C was 6.14%. This value is higher than the results of Iqbal *et al.* (2015), which only reached 2.90%. The study used 5.8% citric acid with a pre-treatment time of 41 hours and an extraction temperature of 70°C. The difference in yields produced can be caused by differences in the fish bones types, the citric acid concentration, pre-treatment time, and the extraction temperatures in the two studies. In Azara's (2017) research, it was mentioned that pre-treatment time has an influence on the hydrolysis process. If the pre-treatment time is short, the gelatin formed during submerging will dissolve in the submerging solution, which can eventually lead to yield decrease. On the other hand, according to Wulandari (2013), the gelatin extraction process was carried out at a temperature higher than the collagen shrinkage temperature (60-70°C). If the extraction temperature exceeds this limit, the triple helix fibers in the collagen will split into longer lengths, resulting in the collagen turning into gelatin. Thus, both studies emphasize that pre-treatment time and extraction temperature play an important role in the conversion process of collagen into gelatin.

Viscosity

Viscosity measures the thickness or the gelatin ability to flow. According to Ulfah (2011), high viscosity is related to higher gelatin molecule weight and longer amino acid chains. The higher the molecular weight and the longer the amino acid chains in gelatin, the more likely the viscosity will increase. Gelatin viscosity measurements can provide information on the suitability of gelatin for various applications, such as the use in the production of jellies, sauces, or other products that require stability and consistent texture. Gelatin viscosity can be measured using a viscosimeter. There are various types of viscosimeters available, including Ostwald viscosimeter and Brookfield viscosimeter. This measurement method involves measuring the time required for a gelatin solution to flow through a specific pipe or mold, and the results are expressed in specific units such as centipoise (cP) or millipascal-second (mPa·s).

Viscosity is one of the important rheological characteristics in evaluating gelatin quality. It is also known as the thickness, which refers to the ability of a liquid to resist flow. The viscosity value of gelatin has a significant impact on the properties of the gel formed, especially its gel formation and melting points. Viscosity also affects the flow process of the liquid and can be affected by adsorption. The viscosity measurement aims to determine the gelatin thickness in solution form at a specific temperature and concentration. This measurement is important in observing the flow characteristics of gelatin and understanding its effect on the quality and use of gelatin. Gelatin with high viscosity tends to have a lower melting rate and forms a better gel quality compared to gelatin which has a low viscosity (Hasdar and Rahmawati, 2016). This property is due to the fact that low-viscosity gelatin tends to produce short and easily brittle gels, while high-viscosity gelatin produces stronger and longer-lasting gels (Wahyuningtyas *et al.*, 2019). In British Standard (1975), the viscosity value of gelatin ranges from 15-40 cP (Centipoise), while according to GMIA (2012), the viscosity value range is 1.5-7.5 cP.

According to Zhang *et al.* (2011), there are several factors that affect the viscosity of gelatin, including temperature, extraction time, acid concentration, and the number of soluble molecules. Several factors can affect the gelatin viscosity value in fish, i.e., chemical composition, molecular structure, extraction method and species variability (Rera and Suprayitno, 2019). The gelatin chemical composition is influenced by the type and concentration of amino acids contained in the fish tissue. Differences in amino acid composition can result in different gelatin viscosity properties. Molecular structure factors in gelatin can also affect its viscosity. Factors such as molecular weight, degree of polymerization, and amino acid sequence in the gelatin polypeptide chain can contribute to different viscosities. Tissue composition differences, collagen concentration, and other physical and chemical properties between fish species can lead to differences in gelatin viscosity.

The highest viscosity value was found in gelatin derived from Striped Snakehead fish skin by Haris *et al.* (2021) with 14.31 cP and from Tuna bones by Minah *et al.* (2016) with 10.13 cP (Table 1). The viscosity value of gelatin is influenced by several factors, such as gelatin pH, temperature, gelatin concentration, and the addition of other electrolytes in the gelatin solution. The low temperature of the gelatin solution (maximum 40ºC) and the high gelatin concentration result in a higher viscosity. The gelatin viscosity has an important impact on the final product (Johns, 1977). In the context of gelatin derived from Striped Snakehead fish skin, the viscosity tends to be higher compared to gelatin derived from fish bones. Therefore, the Striped Snakehead fish skin gelatin is often used in the pharmaceutical and filmmaking industries where high viscosity is required. The high viscosity value is caused by the optimization of the collagen breakdown process into gelatin so that the amino acid chains formed have sufficient length and cause the viscosity to increase. The gelatin viscosity is influenced by molecular weight, where the lowest viscosity value of gelatin ranges from 6-8 cP. Gelatin derived from Striped Snakehead fish skin and Tuna bones has a viscosity value that meets the Norland Product (2001) food gelatin standard, which is more than 2.5 cP.

Partiwi *et al.* (2018) research showed that the gelatin viscosity value derived from Catfish bones was 3.83 cP. Meanwhile, Tabarestani *et al.* (2010) reported that the viscosity of Rainbow Trout skin gelatin was 3.2 cP. Hidayat *et al.* (2016) measured the viscosity of Featherback fish gelatin to be around 5.85 cP, while Mahmuda *et al.* (2018) reported the viscosity of Featherback fish gelatin to be around 3.45 cP. In this case, there are differences in the viscosity values of gelatin from fish skin reported by various studies. Research by Febryana *et al.* (2018) showed that the lowest gelatin viscosity value came from Featherback fish skin amounted to 2.50 cP. Meanwhile, Efendi *et al.* (2012) reported that the lowest gelatin viscosity value came from Milkfish bones, which amounted to 2.00 cP. Differences in gelatin viscosity values can be caused by the extraction process and the composition of the raw materials used. Each raw material has a different level of tropocollagen crosslink strength, in addition, factors such as age, genetics, and environmental factors can also influence the different viscosity values. Weak crosslinks resulted in a more easily hydrolyzed collagen. This hydrolysis can reduce the gelatin's molecular weight and eventually decrease the viscosity of the gelatin solution (Choi *et al.*, 2000). According to Songchotikunpan *et al.* (2007), the viscosity value of gelatin is strongly related to the molecular weight and amino acid chain length of the gelatin.

Effendi *et al.* (2012) mentioned that the presence of acid in the extraction process resulted in excessive peptide bond breaking. As a result, gelatin with shorter peptide chains was produced. These short peptide chains produced smaller shear forces, thus, the gelatin viscosity value decreased. Other factors that influence the change in viscosity value are temperature, pH, and gelatin concentration. An increase in temperature above 40ºC can cause a decrease in the viscosity value. With an increase in gelatin concentration, the amino acid chains tend to break sequentially, which in turn results in a decrease in viscosity. When a high acid concentration is used, the acid will interact strongly and break the covalent bonds between the amino acids. High extraction temperatures are also associated with a decrease in viscosity, as high heat can cause further hydrolysis. The gelatin formed will release amino acid chains, resulting in decreased viscosity. Therefore, there is an inverse relationship between temperature and viscosity, i.e., the higher the temperature, the lower the viscosity (Wulandari *et al.*, 2013).

Longer submerging times can cause a decrease in gelatin viscosity value. This occurs due to the breaking of the amino acid chains in gelatin, which causes the chains to become shorter. The gelatin structure is easily degraded by heat, so the longer the heating process, the shorter the chain structure of the produced gelatin. The shorter amino acid chains will contribute to a decrease in viscosity value. Viscosity is also affected by the extraction method and the ingredients used in the gelatin hydrolysis process. For example, the microwave extraction method can result in low viscosity values. This is due to the working principle of microwave, which causes random movement of particles, generating heat that can cause the bonds between atoms to weaken and eventually lower the viscosity. In addition, the molecular weight of gelatin is also affected by the concentration of the acid solution.

Gel Strength

Gel strength is one of the factors used to evaluate gelatin quality. It is a physicochemical parameter that can affect the characteristics of gelatin, especially in its role as an emulsifier and gelling agent. Gelatin strength is measured using Bloom unit, which reflects the load required to achieve a pressure on the surface of gelatin up to 4mm. Gelatin strength or bloom gel strength is an indicator of the texture and formability of an object, and is the force required to change its shape. The importance of gelatin strength in the gelatin extraction process was emphasized by Ayudiarty *et al.* (2020) because of the gelatin's ability to convert liquids into solids or form reversible gels, which is one of its main properties. This ability of gelatin Is called reversible properties (Aziza, 2019). The advantage of reversible properties is that gelatin has the flexibility to be used in various products, both in the food and non-food industries (Zulkifli *et al.*, 2014).

The highest gel strength value of gelatin from fish skin derived from the Rainbow Trout fish studied by Tabarestani *et al.* (2010) with 459 g bloom, while the highest gel strength value of gelatin from bones extracted from the tilapia fish studied by Hidayat *et al.* (2016) with 376.21 g bloom (Table 1). Research on Rainbow Trout used 0.19 N NaOH and 0.121 N acetic acid for 3 hours. According to research by Nugraheni *et al.* (2021), a higher acidity level causes a decrease in the strength of fish skin gelatin. This finding is consistent with previous research by Kusumawati *et al.* (2008), which showed that lower acidity levels in the submerging solution resulted in higher gel strength. The use of acetic acid, which has a high acidity level, can cause further denaturation in the gelatin, resulting in shorter amino acid chains. This condition limits gel formation and weakens the gel strength formed. In the Rainbow Trout study, it was also found that the submerging time of 3 hours has a significant effect. The finding is in accordance with previous research by Devi *et al.* (2014), who stated that the longer the submerging time using NaOH, the less the removal of non-collagenous proteins and reduced collagen protein losses, thus increasing gelatin strength (Hao *et al.*, 2009). Gelatin strength is influenced by several factors, including the number of polypeptides α-chain, β-chain, and γ-chain components, amino acid composition (Kumar *et al.*, 2017), amino acid chain length, gelatin concentration, and gelatin molecular weight distribution (Ratnasari *et al.*, 2014).

The lowest gelatin gel strength value derived from fish skin was from Grouper skin studied by Azara (2017), with 19.73 N. The results showed that gel strength tended to increase with submerging time of 18 and 24 hours, along with the increase in acetic acid concentration. However, after 12 hours of submersion, the gel strength increased until the acetic acid concentration reached 4%, then decreased at 6% acetic acid concentration. The average gel strength also showed an increase from 12 to 18 hours but decreased at 24 hours. It is suspected that 18 hours was the optimal hydrolysis time, which resulted in high gel strength. This soaking process involves the hydrolysis of collagen by H+ ions. It is estimated that collagen degradation continues with a longer submerging time, which ultimately affects the length of the resulting polypeptide chain. According to research conducted by Muyonga *et al.* (2004), differences in gelatin strength are caused by several factors, such as amino acid composition and amino acid chain size. In addition, gelatin strength also depends on the concentration of gelatin used and the molecular weight distribution of the gelatin. Meanwhile, according to research by Said *et al.* (2011), gelatin strength value decreases due to excessive amino acid polymer chain breakage, which is caused by an increase in acidity.

There are several factors that affect the strength value of gelatin. These factors include the concentration of gelatin in solution, pH, the molecular weight of gelatin, and the composition of amino acids such as glycine, proline, and hydroxyproline . In addition, research by Gomez-Guillén *et al.* (2002) stated that differences in fish species could also influence the differences in gelatin structure and content, which in turn affects the strength of the gelatin produced. Differences in habitat, type, and amount of collagen content in each type of fish also have an influence on the quality of gelatin, as stated by Aziza (2019). There are several factors that affect gelatin strength, including raw materials, pre-treatment, extraction conditions, amino acid chain length, pH, molecular weight, gelling of amino acids, and temperature. The strength of gelatin will be greater and increase if the constituent amino acid chains are longer. The amount of collagen hydrolyzed and the ability of the gelatin to absorb water will also affect the length and density of the amino acid chains. A very low pH value will reduce the gelatin strength due to continued hydrolysis of the protein chains used. Continued gelatin hydrolysis process at high temperature (>75ºC) will result in shorter peptide chains, which in turn reduces the strength of the gelatin. High temperatures can also cause gelatin denaturation and impair gelatin strength. A large molecular weight indicates a greater number and size of amino acids that make up the peptide chain, resulting in longer peptide chains. The greater the gelatin molecular weight, the greater the gelatin strength. As mentioned by Febriana *et al.* (2021), glycine, proline, and hydroxyproline are some of the important amino acids that affect gelatin formation.

According to research by Saputra *et al.* (2015), gelatin extracted from Catfish skin has a gel strength of 140.57 bloom. Research conducted by Gunawan *et al.* (2017) using Mackerel fish skin produced gelatin with a gel strength of 328.57 bloom. In addition, research by Hermanto *et al.* (2014) showed that gelatin extracted from Suckermouth Catfish skin has a high gel strength of 416.7 g bloom. In the study, gelatin was produced by submerging the fish skin in a mixture of phosphoric acid and acetic acid with a fish skin and acid ratio of 1:3 and a submerging time of 16 hours.

According to Santoso *et al.* (2019), there are several factors that affect the strength value of gelatin, one of which is the gelatin molecular weight. The gelatin molecular weight is closely related to the length of the amino acid chain bonds that forms the gelatin. The larger and longer the amino acid chain, the greater the gelatin molecular weight and the higher the gelatin strength value. In addition, the length of the amino acid chains in gelatin is also affected by the temperature used during the extraction process. High temperatures can cause further collagen hydrolysis that has been converted into gelatin. Thus, the amino acid will be broken and decreases the gelatin strength.

Sanaei *et al.* (2013) claimed that gel strength is affected by the composition of the amino acid proline and hydroxyproline gelatin. In addition, gel strength is also affected by the extraction method and the molecular weight of the gelatin (Nurul and Sarbon, 2015)

High gelatin quality is shown by its gelling ability, which is formed with a low extraction temperature. The low temperature resulted in less occurrence of polypeptide chain hydrolysis. At 50ºC, the extraction process can separate the collagen structure and hydrolyze some covalent bonds. High-quality gelatin can be obtained using low extraction temperatures, although high extraction temperatures will increase the amount of produced gelatin. The use of chemicals before and during extraction, including extraction temperature and time, can also affect the polypeptide chain length and functional properties of gelatin. In addition, extraction temperature and time also have an influence on the extraction yield, gelatin strength, and viscosity.

Conclusions

The by-products generated by the fish-processing industry are a potential source for the production of gelatin. Where the skin and bones of fish are the biggest contributor to fish body weight bones and skins which become waste and are not utilized. The extraction yield of fish gelatin depends on the time and process of the extraction procedure. One of the main limitations on the use of fish gelatin is due to its low rheological properties when compared to mammalian gelatin. Fish gelatin generally exhibits lower gelation and melting temperatures and also lowers gel strength than the gelatins from mammals. High gelatin quality is shown by its gelling ability, which is formed with a low extraction temperature.

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