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Chemical Composition and Characterisation of Skin Gelatins from Two Different Freshwater Fish Species in Osun State of Nigeria: A Comparative Study

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Abstract: *In this study, a comprehensive extraction of gelatin from the skin of two fresh water fish species from Osun State of Nigeria (7.5876° N, 4.5624° E), namely: tilapia and catfish by acid extraction was carried out. The extraction was carried out through series of steps involving rinsing in water, dipping in sodium hydroxide (0.1 M), and soaking in 0.1 M acetic acid at room temperature of 25 °C, followed by a final extraction with water at 45 °C for 12 h. The results obtained herein showed that the fish gelatins were comparable to the fish gelatins contained in past reports. The proximate analysis showed that the protein content of gelatin extracted from catfish gelatin contains 7.45% and that of tilapia gelatin contains 72.95%. It was found that tilapia fish skin gelatin is more hydrogen bonded than that of catfish skin gelatin. The foaming properties of tilapia fish gelatin (foaming capacity: 28%, foaming stability: 18%) were higher than the foaming properties of catfish gelatin (foaming capacity: 14%, foaming stability: 10%). The gelatins in this study contained all essential amino acids with glutamate being the most prominent ones. The viscosity at 40 °C was low in catfish gelatin (2.49 cP) compared to tilapia fish gelatin (3.58 cP). From this result, it can be concluded that gelatin from tilapia fish can act as better foaming agent as compared to gelatin extracted from its catfish.*

Keywords: *Fish skin, gelatin, tilapia, catfish, viscosity, amino acid composition*

1. Introduction

Gelatin is a clear and tasteless protein. It is a natural hydrocolloidal macromolecular material that is traditionally produced as a result of partial hydrolysis of collagen from the skin, cartilages, tendons or bone of porcine or bovine animals. The increasing demand of gelatin is as a result of its wide use in many industrial fields, such as food, material, pharmacy and photography, especially in the food and pharmaceutical industries. More importantly, gelatin has an increasing number of new applications for instance, gelatin is used as emulsifiers, foaming agents, colloid stabilisers, fining agents, biodegradable packaging materials and microencapsulating agents. These recent applications are strategies to meet the growing demands of green and sustainable chemistry which calls for replacement of synthetic agents with natural ones, in line with the growing trend to replace synthetic agents with more natural ones. Most of the past studies are dedicated to using collagens and gelatins from alternative sources to land-based animals.

However, the development of gelatin alternatives has gained importance in recent years as the demand for non-bovine and non-porcine gelatin has increased due to the bovine spongiform encephalopathy (BSE) crisis and for religious and socio-cultural reasons (Sabon et al., 2013). Since then, there has been much concern about using gelatin derived from possibly infected animal parts. Pig skin gelatin has suffered religious restrictions especially for Judaism and Islam, therefore, only beef gelatinmn is acceptable provided it has been prepared according to the religious rites (Badii and Howell, 2006). The development of gelatin alternatives is therefore highly desirable to food processors (Karim and Bhat, 2009). Due to these religious reasons and health concerns, the study of gelatin from extraction from fish parts, such as skin, bone and scales, is of great interest.

Several works have been carried out on the properties of gelatin from fish skin and bones (Rawdkuen et al., 2013; Chandra et al., 2013; Ketnawa et al., 2016; Bor-Sen et al., 2008; Jan and Asbjorn, 2007; Gómez-Estaca et al., 2009; Irwandi et al., 2009; Liu et al., 2009; Ratnasari et al., 2013; Chandra et al., 2015; Binsi et al., 2009). Go´mez-Guille´n et al. (2001) and Gudmundsson (2002) reported that the properties of gelatin such as the contents of both hydrophobic and hydroxylated amino acids, as well as molecular weight distribution and gelatin viscosity, seem to be species specific. These past findings are corroborated by a number of studies carried out on properties of fish skin gelatins showing that their properties differ from those of mammalian gelatins and vary between species (Choi

and Regenstein, 2000; Ferna´ndez-Diaz et al., 2001; Go`mez-Guille`n and Montero, 2001; Grossman and Bergman, 1992; Gudmundsson, 2002; Gudmundsson and Hafsteinsson, 1997; Holzer, 1996). However, some studies have pointed out that tropical and sub-tropical warm-water fish species (tilapia, nile perch, catfish) might have similar rheological properties and thermostability to that of mammal gelatins, depending on the species, type of raw material and processing conditions (Gilsenan and Ross-Murphy, 2000; Jamilah and Harvinder, 2002; Muyonga et al., 2004; Karim and Bhat, 2009; Gómez-Guillén et al., 2009; Rawdkuen et al., 2010).

As far as fish gelatin is concerned, the huge number of species having very different intrinsic characteristics, has aroused the interest of the scientific community in optimising the extracting conditions as well as characterising the yields, physico-chemical and functional properties of the resulting gelatins, obtained mainly from skin and bone residues (Gómez-Guillén et al., 2009). To reveal such properties, gelatin from each actual species must be studied. But Gómez-Guillén et al. (2009) observed that strict comparisons are difficult since methodologies may differ considerably from one work to another. In this work, gelatin extractions were carried out following the same protocol.

In Nigeria, fish farming especially catfish has become a significant fish resource. The annual production in Nigeria of catfish amounts to15,489 tonnes (Ekunwe and Emokaro, 2009) with projected domestic production to have reached 671,492 tonnes by 2015 (FDF, 2008). In the present investigation, the objective is to determine and compare the properties of tilapia and catfish skins' gelatins and to determine the effect of the species on the nature of gelatin obtained.

2. Materials and Methods

2.1 Materials

All chemicals used in this study were of analytical grade. Two different species of fresh water fishes were obtained from local vendor in Eko-ende, Osun State, Nigeria, namely catfish and tilapia fish. The two fish species caught from Otin River were obtained from local fisherman. Residual meat in the skin was removed manually with a new razor blade and the cleaned fish skin was washed with tap water. The skin fish was packed in polyethylene plastic bags and stored in the freezer at -20℃ until it was used. Before the gelatin extraction, the frozen skins were thawed with running tap water until the core temperature of the skin reached 8-10℃.

2.2 Methods

2.2.1 Extraction of gelatin from catfish and tilapia fish

The method of Kittiphattanabawon et al. (2010) was adapted for gelatin extraction with little modification. In summary, 100 g of tilapia and catfish skins were washed with running tap water and dipped in 0.5 M NaCl for 5 min at 5^0C. A Glass stirrer was used to stir the skin dipped in sodium chloride solution. The Skin was then washed with tap water three times to remove salt solution before treating with 0.1M NaOH. The skin was mixed with 0.1M NaOH at a sample to solution ratio of 1:10 (mass/volume ratio). Acetic acid concentration of 0.1 M was used because Sompie et al. (2015) reported that the higher acetic acid concentration caused decreased viscosity. The mixture was placed on a magnetic stirrer for 2 h at room temperature of 25℃ to remove non collagenous proteins. The alkali solution was changed every 40 min. The pretreated skin was washed with distilled water until the neutral pH of wash water was obtained. The pH of wash water was monitored using a pH paper. The skin was mixed with 0.1 M acetic acid at a sample to solution ratio of 1:10 (mass/volume ratio) and stirred for 40 min at room temperature. The swollen skin was washed thoroughly with tap water until pH of wash water became neutral. The final extraction was carried out in distilled water at 45°C with a skin/water ratio of 1:10 (w/v) in a controlled temperature water bath for 12 hours while the mixture was continuously stirred. Then the mixtures were filtered in two layers of cheese cloth. The resultant filtrate was freeze-dried. All gelatin samples were weighed, calculated for extraction yield and subjected to analyses.

2.2.2. Analyses of Gelatin

1) Yield of gelatin

The yield of gelatin was calculated based on dry weight of fresh skin using the following formula:

$$\%\ \text{Yield of gelatin (wet wt. basis)} = \frac{\textit{weight}\ \text{of freeze-dried gelatin}}{\text{weight of wet skin}} \times 100 \quad \ldots\ldots\ldots\ldots (1)$$

2) Proximate analysis

The moisture, ash and fat content of extracted dried gelatin were determined in triplicate according to the AOAC (2006). The crude protein content was determined by estimating its total nitrogen content by the Kjeldahl method (AOAC, 2006). A factor of 5.55 was used to convert the nitrogen value to gelatin protein. Gelatin (1.0g) was dissolved in 40 g of distilled water and the pH of the solution was then measured with Mettler Delta pH meter.

3) Determination of Viscosity

The viscosity of the gelatin (6.67% concentration at 60°C) was measured using a Brookfield digital viscometer (model DV-E, Brookfield Engineering, Middleboro, MA, USA) equipped with a No. 1 spindle at

30±0.5°C. The measured values were obtained directly in centistokes (cP) from the instrument.

4) Determination of Amino Composition

The amino acid content of the gelatins was determined using Gas chromatography (GC) according to the modified methods (AOAC, 2006; Danka et al., 2012). The dried and pulverised sample was made to be free of water by ensuring constant weight for a period of time in the laboratory. The sample of 10.0g was weighed into the 250 ml conical flask capacity. The sample was defatted by extracting the fat content of the sample with 30ml of the petroleum spirit three times with soxhlet extractor that was equipped with thimble. The sample was hydrolysed three times for complete hydrolysis to be achieved for the totality of amino acid recovery. Both the pulverised sample and defatted sample were soaked with 30ml of the 1.0 M potassium hydroxide solution and incubated for 48 hours at 110℃ hermetically closed borosilicate glass container. After the alkaline hydrolysis, the hydrolysate was neutralised to get the range of 2.5-5.0. The purified solutions were derivatised with ethylchoroformate by the established mechanism.

The derivatising agent was afterwards removed by passing streams of nitrogen. Aliquots of amino acids derivatives dissolved in dichloromethane were analysed by gas chromatography equipped with pulse flame photometric detector (GC-PTFD) -coupled gas chromatography (HP 6890). 1 µl of concentrate was injected into GC-PFPD using HP5 (30 m × 0.25 mm × 0.255 mm ID) column for individual amino acid peaks. The initial temperature of the hydrogen carrier gas and column was 60 ℃. It was ramped at 8 ℃ for 20 min and held constant for 2min and then at 12 ℃/min for 6 min and held for 2 min.

Amino acids standard solutions were repeatedly analysed five (5) times and calibration curves obtained had correlation coefficients between 0.9996 and 0.9999. Limits of detection (LOD) and quantification (LOQ) were evaluated from signal- noise ratio of 3:1 and 10:1, respectively.

5) Colour Measurement

The colour of gelatin solutions (6.67% w/v) was measured by a Hunter lab colour meter (Color Flex, Hunter Lab Inc., Reston, VA, USA). L*, a* and b* parameters, indicating lightness / brightness, redness / greenness and yellowness / blueness, respectively, were recorded. The colorimeter was calibrated with a white standard.

6) Fourier Transform Infrared (FTIR) Spectroscopic Analysis

Gelatin samples were subjected to FTIR analysis using Bruker Model EQUINOX 55 FTIR spectrometer (Bruker, Ettlingen, Germany) equipped with a deuterated L-alanine triglycinesulphate (DLATGS) detector. The horizontal attenuated total reflectance (HATR) accessory was mounted in the sample compartment. The internal reflection crystal (Pike Technologies, Madison, WI, USA), made of zinc selenide, had a 45° angle of incidence of the IR beam. Spectra were acquired in the IR range of 4000-650 cm^{-1} (mid-IR region) at 25°C. Automatic signals were collected in 32 scans at a resolution of 4 cm^{-1}. These signals were recorded against a background spectrum from the clean and empty cell at 25°C. Analysis of spectral data was carried out using the OPUS 3.0 data collection software program (Bruker, Ettlingen, Germany). Prior to data analysis, the spectra were baseline corrected and normalised.

7) Foaming Properties

Foam formation ability (FA) and foam stability (FS) of gelatin were determined by the procedure of (Cho et al., 2004). Gelatin solution, 1g/100 ml was put in a beaker and swollen at 60℃. The foam was prepared by homogenising at 10,000rpm for 5 min in a homogeniser (Euro turrax t20b.ika Labortechnik, Staufen Germany). The homogenised solution was then poured into a 250ml measuring cylinder. The foam formation ability was calculated according to the following equation:

$$FA\ (\%) = \frac{V_1 - V_0}{V_0} x100 \quad \text{..... (2)}$$

The foam stability was calculated by allowing the homogenised sample to stand at room temperature for 30 min and the volume of the homogenised sample was then recorded. Foam stability was calculated as follows:

$$FS\ (\%) = \frac{V_2 - V_0}{V_0} \text{x}\,100 \quad \text{..... (3)}$$

8) Statistical analysis

All experiments were performed in triplicate. Data were presented as means ± standard deviation and the probability value of $P < 0.05$ was considered significant. Analysis of variance (ANOVA) was performed, and mean comparisons were done by Duncan's multiple range test (Steel and Torrie, 1980). Analysis was performed using an SPSS package (SPSS for windows, SPSS Inc, Chicago, IL, USA).

3. Result and discussion

3.1. Yield of gelatin

The degree of conversion of collagen into gelatin depends on the processing parameters (temperature, extraction time and pH), the pretreatment conditions, the properties and the preservation method of the starting raw material (Karim and Bhat, 2009). In this work, the same condition was used. The yield of tilapia skin gelatin (TSG) and catfish skins gelatin (CSG) are 17.9% and 18.24% respectively. It was observed that tilapia

skin swelled more in alkaline and acidic solution compared to the skin of catfish. Therefore, we could say that tilapia skin gave a higher yield, possibly due to increase in opening of cross-links during swelling as evidenced in higher level of swelling. Jamilah and Harvinder (2002) stated that the difference in gelatin recovery from different species could be attributed to the intrinsic characteristics of the skin and collagen molecules, the collagen content, the amount of soluble components in the skins, the loss of extracted collagen through leaching during the series of washing steps or to an incomplete collagen hydrolysis. The yield of gelatins for both tilapia and catfish in the present study was higher than the reported values. Grossman and Bergman (1992) reported gelatin yield of about 15% for tilapia, while the gelatin yields obtained for the black and the red tilapias were 5.39 and 7.81%, respectively (Jamilah and Harvinder, 2002). Samart et al. (2012) reported gelatin yield of 10.14% for giant cat fish.

3.2. Proximate Composition of Gelatin

The proximate composition of fish gelatin extracted from fish skins is summarised in Table 1. The proximate analysis of the catfish gelatin showed 4.54% moisture, 7.54% protein, 20% fat and 1.61%, while that of tilapia fish gelatin showed 4.12% moisture, 72.95% protein, 18% fat and 1.96% ash. Moisture and ash contents of both fish sources are not significantly ($p > 0.05$) different. The moisture content of both samples was well below the prescribed limit of 15% (GME, 2005) for edible gelatin. Protein and fat contents of tilapia gelatin were significantly ($p < 0.05$) higher than that of catfish. At 6-8% moisture, gelatin is very hygroscopic and it becomes difficult to determine the physico-chemical attributes with accuracy . The gelatins were found to be low in ash content, well below the recommended maximum of 2.6% (Jones, 1997).

Table 1. Proximate analysis of two samples

Composition	Catfish gelatin	Tilapia fish gelatin
Moisture (%)	4.54±1.43[a]	4.12±0.76[a]
Protein(%)	7.45±2.43[a]	72.95±3.25[b]
Fat (%)	20±1.43[a]	18±0.21[b]
Ash(%)	1.61±0.53[c]	1.96±2.63[c]

Different letters in the same row indicate significant differences ($p<0.05$).

Values are given as mean ± SD from triplicate determinations.

It was shown that the protein content of gelatin extracted from catfish gelatin contains 7.45% and that of tilapia gelatin contains 72.95%. The protein content of tilapia fish gelatin is far higher than that of catfish gelatin (7.45%) which is surprisingly low. The 7.45% of protein content of catfish gelatin is lower than the reported values. Gelatin from splendid squid skin had protein content of 90% (Nagarajan et al., 2012), cuttlefish skin gelatin had 91.35% protein (Balti et al., 2011), giant squid skin gelatin had 88% protein (Uriarte-Montoya et al., 2011), skate skin gelatin had 92.31% protein. Jongjareonrak et al. (2006) reported a protein content of 87.9% and 88.6% in gelatin extracted from the skins of bigeye snapper and brown eye snapper, respectively. The gelatin from the skins of adult Nile perch also contained 88% protein (Muyonga et al., 2004).

3.3 Viscosity

The second important physical property is the viscosity of a gelatin (Jamilah *et al*., 2002). The viscosity of gelatin extracted from catfish at 40°C and 100°C are 2.49 and 1.38cP, whereas, those extracted from tilapia skin at 40°C and 100°C ranges from 3.58 and 1.38cP (see Table 2). Generally, viscosities of gelatin at 100 ^{o}C were significantly ($p < 0.05$) lower than at 40 ^{o}C while no significant ($p > 0.05$) difference exists between viscosities of both samples at both temperatures. The viscosity at 40°C was lower in catfish gelatin compared to tilapia fish gelatin. The viscosity is the measuring resistance force of the solution. The value is closely related to the molecular weight of the component that resulted in cohesion force between molecules.

Johnston-Banks (1990) reported that the viscosities of most of the commercial gelatins are up to 13.0 cP. The results obtained in this work are far below that of commercial values, however, they fall within the ranges reported in the literature. For instance, Jamilah and Harvinder, (2002) reported the viscosity values of 3.2 cP and 7.12 cP for red and black tilapia, respectively, and for channel catfish, it was 3.23 cP (Yang et al., 2007). From the above results, it is thus shown that natural variation in the viscosity can be expected from different fish species tested at the same condition. The difference in viscosity between gelatins could be due mainly to the molecular weight distribution of protein components in gelatins (Jongjareonrak et al., 2010).

Table 2. Viscosity of catfish and tilapia fish gelatin

Samples	Viscosity (cP) at 40 °C	Viscosity (cP) at 100°C
Tilapia gelatin	3.58±0.11[a]	1.38±0.34[a,b]
Catfish gelatin	2.49±1.01[a]	1.50±0.81[a,b]

Different letters indicate significant differences ($p<0.05$).

[a] significantly different across the column and

[b] significantly different across the row.

Values are given as mean ± SD from triplicate determinations.

3.3.1 Amino Acid Composition

The amino acid composition of different gelatins may vary depending mainly on the source, and the major variation between gelatins would be the amount of the amino acids (Zhou et al., 2006). Table 3 shows the

amino acid composition of the gelatins from skins of both tilapia and catfish.

Table 3. The amino acid composition of gelatins from the skins of catfish and tilapia fishes (as g amino acid/100g gelatin).

Amino acids	Tilapia skin gelatin (%)	Catfish skin gelatin (%)
Glycine	3.81	6.02
Alanine	3.98	4.98
Serine	4.48	4.99
Proline	4.01	4.19
Valine	4.17	3.93
Threonine	3.45	3.08
Isoleucine	5.17	3.72
Leucine	8.06	6.84
Aspartate	8.66	9.61
Lysine	5.32	3.55
Methionine	1.85	1.84
Glutamate	14.54	17.74
Phenylalanine	6.58	4.97
Histidine	3.41	2.35
Arginine	5.91	12.26
Tyrosine	3.62	3.08
Tryptophan	4.77	1.05
Cystine	1.86	1.24
Total	**93.65**	**95.44**

The amino acid content of the gelatin of catfish is higher than that of the tilapia. Both have very high contents of glutamate, followed by arginine in catfish and aspartate in tilapia. The two are essentially low in methionine when the value of methionine in both is almost the same value, while tryptophan is the lowest amino acid in cat fish. This composition is different from those reported for red and black tilapias by Jamilah and Harvinder (2002), tilapia by Zhou et al. (2006) and catfish by Jongjareonrak et al. (2010).

From this work, the amino acid content in skin gelatin from tilapia fish was higher than that reported in red tilapia and black tilapia (76.4 and 86.5 residues per 100 residues, respectively) (Jamilah and Harvinder, 2002). Ledward (1986) reported that the stability of the triple helical structure in renatured gelatins was associated with the total content of pyrrolidine amino acids, and hydroxyproline plays an essential role in the stabilisation of the triple-helix strands of collagen via its hydrogen bonding ability through its –OH group. Gelatin with higher content of hydroxyproline is believed to have higher visco-elastic properties and its ability to develop triple helix structures, which are important for stabilising the gelatin gel structure (Go` mez-Guille`n et al., 2009). In addition, the size of the proteinchains also determines the gelatin properties. From the result, cysteine, tryptophan, asparagine and glutamine were not found in gelatin from both sources. In this work, cysteine and tryptophan are present contrary to Foegeding et al. (1996) who reported that cysteine and tryptophan are not commonly present in gelatin.

3.4. Colour

The colour of a gelatin gel is important aesthetic properties, depending on the application for which the gelatin is intended. In general, light colour is preferred because it is easier to incorporate gelatins into any food system without imparting any strong colour attribute to the product. The colours of gelatin solution from tilapia and catfish skins at the concentration of 6.67% are shown in Table 4. The L* values of gelatin gel from catfish skin, 41.46 was significantly ($p < 0.05$) higher than that of tillapia skin, 37.51, even though, gelatin gel from tilapia skin gave significantly ($p < 0.05$) higher a* and b* values than catfish skin. These results suggested that gelatin gels from catfish skin had a lighter colour but lower yellowness and greenness than that of tilapia skin. From the previous work, L^*, a^* and b^*, the values of gelatin from the skin of giant catfish are 63.07, -0.08 and 9.35 (Sai-Ut et al., 2012), while Jongjareonrak et al. (2010) also reported the values of 20.43, -0.61 and 1.36 for L^*, a^* and b^* respectively for giant catfish. The colour of gelatin is generally dependant on the raw materials extracted and whether it is the first, second or later extraction.

According to the instrumental colour measurement, catfish gelatin was significantly lighter/whiter than the tilapia fish gelatin. By visual observation catfish gelatin appeared pearly white while tilapia gelatin was light brown in colour.

3.4.1 FTIR Spectroscopy

FTIR spectroscopy has been used to monitor the functional groups and secondary structure of gelatin (Muyonga et al., 2004), as well as studying collagen cross-linking, gelatin denaturation, and melting. The FTIR spectra of gelatin extracted from catfish and tilapia are depicted in Figures 1 and 2, respectively. It was showed that the characteristic absorption of amide I peaks at 1635.64 cm^{-1}, represents C=O stretching and gives most useful information about secondary structure protein (Thiansilakul and Roytrakul, 2009). The values of C=O obtained in this study are similar to values reported by Nagarajan et al. (2012) and Sai-Ut et al. (2012).

Table 4. The values of instrumental colour and visual observation of gelatins from tilapia and catfish

	Colour attribute			
Source of gelatin	L^*	a^*	b^*	Observed colour
Catfish	41.46 ± 0.63^a	-1.02 ± 1.35^a	0.53 ± 0.33^a	pearly white
Tilapia	37.51 ± 2.51^b	4.21 ± 2.11^b	1.20 ± 0.12^b	light brownish

Different letters in the same column indicate significant differences ($p<0.05$). Values are given as mean ± SD from triplicate determinations.

Characteristic absorptions of amide A occurred at 3305.99 cm-1 for gelatin from cat fish skin and 3286.70 cm for gelatin from tilapia fish skin. These represent hydrogen bonded N-H stretching vibrations. The result shows that tilapia fish skin gelatin is more hydrogen bonded and is similar to report of Nagarajan et al. (2012) while that of catfish skin gelatin shows a value similar to report of Sai-Ut et al. (2012). The lower peak value of figure with catfish gelatin indicates the lower protein secondary structure (α – helix) that was due to the degradation of the gelatin molecules, providing greater free amino acids (Muyongaal. 2004).

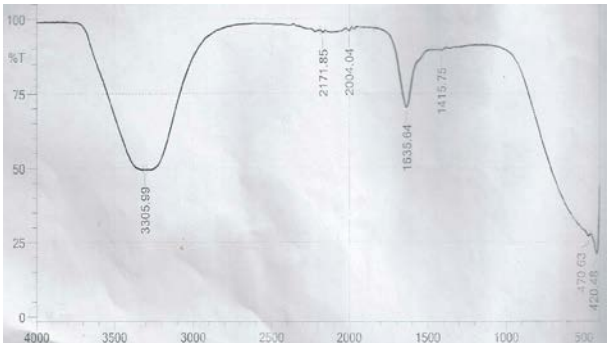

Figure 1. FTIR spectra of gelatin from catfish

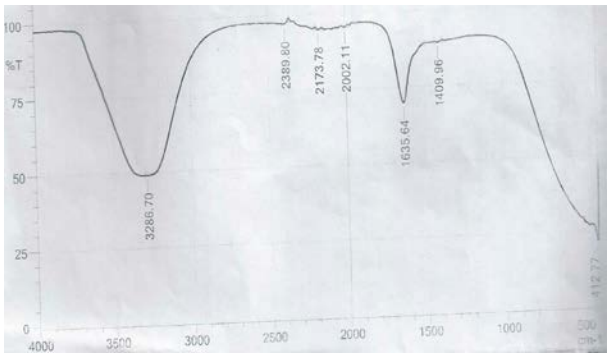

Figure 2. FTIR spectra of gelatin tilapia fish

3.5. Foaming Properties

Foaming capacity and foaming stability become important parameters to characterise the functional properties of proteins. Gelatin is one of the most widely used protein foaming agent. The good protein foaming agent should stabilise foams rapidly and effectively at low concentration and become an effective foaming agent over the pH range that exists in various foods. The foaming properties of both gelatins were tabulated in Table 5. Both foaming capacity and foaming stability of the tilapia fish gelatin were significantly ($p < 0.05$) higher than that of catfish gelatin. From the result obtained, it showed that the foaming properties of tilapia fish gelatin were higher than the foaming properties of catfish gelatin.

Nagarajan et al. (2012) reported that gelatin with the less degradation and longer chain length more likely formed the stronger films surrounding the air bubbles, especially when the sufficient concentration was used. The results obtained in this work is not in agreement with Jongjareonrak et al. (2010) who obtained values of 130% and 35 % for foam capacity and foam stability respectively for giant catfish. However, it is well comparable with Shyni et al. (2014) who reported values of 21.5 %, 17.4 % and 19.2 % for foam capacity, and 17.6 %, 10.5 % and 14.4 % for tuna, dog shark and rohu fish skins, respectively.

From this result, it can be concluded that gelatin from tilapia fish can act as better foaming agent as compared to gelatin extracted from catfish.

Table 5. The foaming properties of gelatins from the skins of catfish and tilapia fishes

Sample	Foaming Capacity %	Foaming Stability%
Tilapia gelatin	28±2.34[a]	18±3.54[a]
Catfish gelatin	14 ± 2.34[b]	10 ± 6.43[b]

Different letters in the same column indicate significant differences ($p<0.05$).
Values are given as mean ± SD from triplicate determinations.

4. Conclusion

This study has investigated chemical compositions and characterization of gelatin from catfish and tilapia fish. The functional properties such as viscosity, foaming capacity and stability of gelatin from tilapia skin were greater than that of the catfish skin indicating that tilapia fish gelatin has a higher application in food industries.

Nonetheless, the physicochemical properties of the two fish gelatins showed the potential of high quality of gelatins that could be used in food applications. The potential is higher for catfish skins than tilapia skin because catfish skin gives higher gelatin yield. Catfish skin gelatin had a slightly higher amino acid composition compared with that of tilapia skin gelatin.

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