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Shelf-life Extension of Fish Fillets Using Gelatins Edible Coating Extracted from the Skins of Nile Tilapia and Catfish

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FISH has industrial and economic importance as a food source and fishing industry. The usage of fish such as tilapia and catfish to produce healthy fillets and other substances with nutritional and economic importance is a promising business in Egypt. Annually, large amounts of by-products could be procured from tilapia and catfish processing. In this study, skin of two types of famous and cheap fish species in Egypt Nile tilapia *(Oreochromis niloticus*) and catfish were used for gelatin extraction. The quality of the gelatins was estimated and used as an edible film to prolong the storability of refrigerated tilapia fillets. The results showed that both tilapia and catfish gelatins had good chemical properties (yield, protein content, ash, fat, color, and amino acid composition), and increased the shelf life of fish fillet when has been used as an edible coating. Both types of gelatins reduced the weight loss of fish fillets, maintained and improved the fillet color, and had good sensory properties compared to the control under cold storage. No significant differences between tilapia and catfish gelatins had been reported for most studied parameters. Thus, the skin by-products of tilapia and catfish can be used to produce good quality gelatins that could be efficiently used as an edible coating to improve the storability of fillet fish.

Keywords: Fish by-products, Cold storage, Active coating.

Introduction

Fish is among the most frequently tradable food products in the industry worldwide (FAO, 2016). Capture fisheries and aquaculture provide substantial social and financial rewards to those who collaborate in the aquaculture industry (Watterson et al., 2008). Skin, bones, fins, and scales as by-products from fish account for 21% to 50% of the total weight of some fish (Vannuccini, 2004). The manufacturing of marine by products is now getting prominence due to the abundance of fish skins and bones (Ahmed et al., 2021). Gelatin is a denatured fibrous protein that has been partially hydrolyzed from collagen connective tissues (Das et al., 2017). The main commercial Gelatins are derived from pig skin and collagen (46%), mammalian skin and bones (29%), and certain other source materials (1.5%) (GME, 2020). When compared to other sources, pig's gelatin is desirable due to its low cost and remarkable functional as well as physical qualities but with limited use in some parts of the world. Recently; gelatin generated from fish and marine resources is in high demand (Grand View Research, 2020). Gelatin derived from seaweed accounts for 1.5% of worldwide gelatin output (Abedinia et al., 2020). The avoidance of infections and the fact that it is permissible in some counties are two advantages of marine gelatin.

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Gelatin has multifunctional qualities that allow it to fit in number of systems, leading to its long-term popularity as an important bio-material. In the food business, gelatin has numerous functional features; nonetheless, it is utilized as an additive to improve some food attributes such as elasticity, consistency, and better food stability. Gelatin is also used as an emulsifier in dishes such as jellies, cakes, muffins, and marshmallows, as well as milk products such as yoghurt, ice cream, and sweets (Zilhadia et al., 2018). Another significant use of gelatin in confectionery items is to provide chewiness, texture, and foam stability for these products (Santoso et al., 2019), and coating to preserve meat quality (Jridi et al., 2018). Recently, there has been a lot of interest in the use of gelatin in the biofilm industries. Because of its remarkable film-forming properties, gelatin is regarded as one of the most advanced bio-polymers to be incorporated into biofilm production. This property enables it to function as film for packaging surface, protecting food from excessive light, heat, and oxygen. The two types of gelatin-based coating that could be developed are active and smart edible coating. In order to maintain food quality, active packaging is designed to extend shelf life, improve safety, or improve sensory characteristics (Said et al., 2021, Xylia et al., 2022). While smart packaging is a type of packaging that monitors the packed food state in order to deliver food quality information to producers, retailers, and customers. Gelatin is widely utilized as an antioxidant barrier, antibacterial prevention, and lipid oxidation protection. Furthermore, there is a growing demand for fresh fish fillet packaging. Packing might delay the degradation of fresh fish fillets during storage and transport. In general, packaging and coating with different materials has been widely used is required to protect food products from pathogens and extend the shelf life (Al Shaibani et al., 2022; Abdulla et al., 2023). One method is to apply a coating or film prepared using a gelatin gel that is stable at cold temperatures, which is an excellent method of coating preparation. The characteristics of gelatin molecules make this substance particularly well suited to the making of flexible coatings and films, while the remaining properties will vary depending on gelatin type, coating composition, and application procedures (Sobral & Habitane, 2001; Sobral et al., 2001). Fish skin gelatin is a realistic solution to the more widely used mammalian gelatin for coating seafood products. The properties of fish gelatin vary depending on the raw material, i.e. the source species and processed parts of the body, as well as the production process. As a result, a combination of fish gelatin and chitosan, both derived from marine sources, appears to be particularly suitable for use in the production of seafood items (Go´mez-Guille´n et al., 2000; Go´mez-Guille´n et al., 2002). Mohamed et al., (2022) indicated that there are large quantities of tilapia and catfish by-products to be used to produce healthy fish fillets and different nutrient materials with good nutritional quality which attracts business for both tilapia and catfish in Egypt. Limited studies have been found on utilizing this fish gelatin as an edible coating for fish fillit preservation. Therefore, the objective of the present study was to (i) extract the gelatin from two Egyptian fish species Catfish and Tilapia and measure different properties of the extract. (ii) The extracted gelatin was used as an edible coating either alone or in combination with chitosan; garlic oil and cumin essential oils, to extend the shelf life of fish fillets during cold storage.

Materials and Methods

Fish gelatin extraction

Fish gelatin was extracted based on a reported method (Arpi et al., 2016; Arpi et al.,2018) with some adaptations from two types of fish (Nile tilapia and catfish) that were kindly provided by Misr Aswan Fishing and Fish Processing Company (Swana), High Dam Lake, Aswan governorate. Fish skin, was soaked in a solution of 0.2N NaOH (1:10 w/v), for one hour. The samples were then washed three times with a 0.2 N NaOH (1: 5 w/v) solution, filtered, and pressed. Following that, the fish samples were immersed for 3 hours in 0.05 N acetic acid (1: 5 w/v), then, samples were washed three times with water (1:5 w/v), strained, and pressed once more before being combined with distilled water (1:4 w/v) in glass beakers and sealed with aluminium foil before being extracted in a water bath at 65 °C for three h. The samples were filtered through cheese cloth, and the filtrate was placed on plates and refrigerated overnight to ensure homogeneity before being cut with a knife. For 72 h, the product was dried in glass bottles at 60°C.

Approximate composition and yield of fish gelatin

The yield of fish gelatin was evaluated using the weight of fresh skins:

$$\% \text{ Yield (wet weight basis)} = \frac{\text{dry wight of gelatin}}{\text{wet weight of skin}} \times 100$$

Gross chemical composition

Fish gelatins' moisture, ash, fat, and protein contents were estimated using (AOAC, 2000). The protein from total nitrogen was calculated by using a conversion factor of 5.55 (Wangtueai & Noomhorm, 2009). The pH was recorded by using the pH meter for gelatin 1% (w/v) solutions.

Water-Holding and Fat-Binding capacity determination

The water-holding and fat-binding capacities (WHC and FBC) were calculated using the methods described by (Cho et al., 2004).

Analysis of amino acid composition

For amino acid analysis, all gelatin samples were hydrolyzed in 6 M HCl for 24 h at 110 °C (Morimura et al., 2002). An automated amino acid analyzer was used to examine the amino acid composition of gelatin hydrolysates. The approximate amounts of amino acid residues were calculated according to (Regenstein et al., 1984).

Cold storage of fish fillet experiment

Fish fillet preparation

Fresh tilapia fish were obtained from Misr Aswan Fishing and Fish Processing Company (Swana), High Dam Lake. Aswan governorate, and were caught by skilled and specialized fishermen, belonging to (the Lake Nasser Development Authority). Fishes that have not been caught for more than an hour (average weight: 950 g) were eviscerated and manually filleted using the same skilled fishermen. The skinless fillets were carried to the Laboratory in an insulated box with ice (Food Science and Technology-Aswan University), and used for storage experiments.

Gelatin-Chitosan coating solution preparation

The gelatin (6%, w/v) coating solutions were made using the procedure described by (Gómez-Estaca *et al*.,2009) with some modifications, by dissolving (6 g) of tilapia or catfish skin gelatin in 100 mL of distilled water and then heated to 70 °C for 30 min, while stirring continuously. 1.5 g of cumin and garlic essential oil in a ratio of 25% by volume per mass of gelatin was added and then, 0.22 g of egg albumin in a ratio of 15% by volume per mass of essential oil was added as a stabilizer. Chitosan solution was prepared by dissolving 2% (w/v) chitosan in 1% (v/v) acetic acid, and then mixture was stirred for 24 h. At room temperature, pH value of chitosan solution was adjusted to 6.0 and was then filtered to remove residues. As a plasticizer, glycerol (1.5 g) was added in a 25% by volume per mass of gelatin ratio, and the solution was warmed and disturbed at 45 °C for 15 min. A gelatin chitosan-solution with a ratio (1:10) 2% chitosan and 6% gelatin was prepared and heated at 45°C for 30 min with continuous stirring. Tilapia fillets were divided into three groups: uncoated fillet (CON); tilapia gelatin edible coating (TGEC); catfish gelatin edible coating (CGEC). Individually, the fillets were immersed in gelatin edible coating solution for 1 min. After draining (to remove the excess coating), the fillets were suspended for 1 min before being individually packaged in a polyethylene bags, wrapped in retractile film, and stored at 21 °C. Tilapia fillets (CON, TGEC, and CGEC) were randomly removed and examined and analyzed after 1, 3, 6, 9, and 14 days of storage.

Assessment of fish fillet quality during cold storage

Color parameters:

The color parameters of fish fillets lightness (L*), redness (a*), and yellowness (b*) were measured by using a Minolta CR-400 colorimeter (Chroma meter CR-400, Konica Minolta, Japan).

Weight loss:

The fish fillets' individual weights had recorded during the storage time. The following equation was used to calculate weight loss (WL) as a percentage of starting weight: -

$$WL\% == \frac{Wi - Wf}{Wi} x100$$

Where, Wi = initial weight (on the day of production) and Wf = final weight (on days 3, 6, 9, and 14 of cold storage).

pH analyses:

The pH was measured by using a digital (Jenway 3510, UK) pH meter.

Sensory evaluation:

Sensory evaluation of the control and gelatin-coated samples (CON, TGEC, and CGEC) was conducted by six trained persons. Panelists used 10-point qualitative scales to score sensory characteristics such as appearance, colour, odour, texture, and general acceptability. Scores on this scale ranging from (1-10) where scores between 7.0 to 10.0 indicated extreme like; scores ranging from 4.0 to 6.9 implied like; and scores > 3.9 was the limit of acceptability. (Paulus et al., 1979)

Results and Discussion

Proximate composition of fish gelatins

The proximate composition of Nile tilapia and catfish skin gelatins is shown in Table 1. Gelatin yield from both tilapia and catfish skin was significantly different (*P<0.05*). The value for catfish (18.91%) was much higher significantly (*P<0.05*) than that for gelatin from tilapia skin

(15.18%).The content of raw gelatin yields provides a suggestion of the potential protein content. Gelatin yields may differ depending on collagen extraction procedures and the gelatin content of the raw materials (Jongjareonrak et al., 2010; Koli et al., 2011). The two gelatin samples were extracted by using the same methodology; however, the differences in gelatin yields are thought to be due to differences in initial gelatin in the skins, skin reaction during the preparation methods, and the amount of impurity in the preparations. Different gelatin yields result from differences in the structure or constituents of the main layer of fish skin (Rawdkeun et al., 2013). Thick skins with higher collagen content are expected to produce more gelatins. Ratnasari & Firlianty (2016) reported that Freshwater catfish (*P. pangasius*) produced skin yields about 21.93%, black tilapia (*Oreochromis mossambicus)* skin yields 8.49% (Koli et al., 2014), and red tilapia skin yields 12.92% (Jamilah et al., 2011). The moisture content of tilapia and catfish gelatin was nearly identical (10.56 and 10.28%), respectively. The water content of catfish and tilapia gelatin aligned that of the laboratory standard gelatin (10.04%). Gelatin's moisture content is typically between 8 and 13% (GMIA, 2019 and Pranoto et al., 2011). Both gelatins had protein contents ranging from 80.31 to 80.71%, which was lower than the evaluated values of catfish (*P. pangasius*) gelatin (87.10%) (Ratnasari & Firlianty, 2016).

The protein content of tilapia and catfish gelatins differs insignificantly. The ash content of Nile tilapia and catfish gelatins was low, ranging from 0.57% to 0.59%. The washing process may have a significant impact on the ash content, and lower ash content indicates that the most minerals have been washed away. The type of raw material used, and the pretreatment technique affect how much ash is produced in the gelatin. Gelatins from both tilapia and catfish showed low fat content, which ranged from 1.01% for tilapia skin gelatin to 1.76 % for catfish skin gelatin, because of the high fat content was caused by an incorrect skin washing process. The nutritional value of gelatin may be reduced as a result of fat oxidation, resulting in a deteriorating odour; fat content is also related to gelatin quality. Tilapia gelatin had a pH of 5.47 and catfish gelatin had a pH of 5.48. The pH values of both gelatins are slightly higher than those of food-grade and standard edible gelatin (pH 3 – 4.5) Table 1. According to (Alfaro et al., 2013), the pH of tilapia skin gelatin was 4.66. For pH values of gelatins, the washing procedure is essential in releasing the acidic residue from gelatin of fish skin. Soaking fish skin in acid led to swelling of tissues and trapped the acid in it. During the extraction procedure, the acid passes over the fibrils, lowering the pH value (Nurilmala et al., 2017). The colour values of the gelatins samples are shown. The L* values of the gelatins tend to range from 69.81 to 78.81. The a* values ranged from 1.01 to 2.39, while the b* values of gelatins ranged from 25.63 for catfish to the highest yellowness for tilapia skin gelatin (27.99) (Table 1). The colour of fish gelatin can vary due to a variety of factors, including differences in raw materials, extraction temperature, Maillard reaction products and non-enzymatic browning (Jamilah et al., 2011, Ratnasari et al., 2013 and Chancharern et al., 2016). Gelatin's colour has no effect on its functional properties, but bright colours are desired for a variety of foods that do not require the addition of additional dyes (Shyni et al., 2014).

TABLE 1.Proximate Composition of Nile Tilapia and catfish skin Gelatins

Composition (g/100 g wet weight)		Nile Tilapia gelatine	Catfish gelatine
Gelatin yield %		15.18 [b]	18.91 [a]
Moisture %		10.56 [a]	10.28 [b]
Protein%		80.31 [a]	80.71 [a]
Fat%		1.01 [b]	1.76 [a]
Ash%		0.59 [a]	0.57 [a]
	*L**	78.81 [a]	69.81 [b]
Color	*a**	1.01 [b]	2.39 [a]
	*b**	27.99 [a]	25.63 [b]
FHC (ml/g)		1.67 ml/g [a]	1.69 ml/g [a]
WHC (ml/g)		1.70ml/ g [a]	1.66 ml/g [a]
pH		5.47 [a]	5.48 [a]

Values not followed by the same letter are significantly different at $p < 0.05$. Data are expressed as means.

Water holding and fat-binding capacities of gelatin samples are shown in Table 1. WHC values were similar in both examined gelatin. There weren't any significant differences in the water-holding and fat-binding capacities of tilapia and catfish skin gelatins, it had a low water holding capacity of (1.67 mL/g) for Tilapia gelatin and (1.69 mL/g) for catfish gelatin, respectively. Functional characteristics such as water holding capacity (WHC) and fat-binding capacity (FHC) are highly correlated to texture due to the interaction of constituents such as water, oil, and other constituents. Content of hydrophilic amino acids affects water-holding capacity. The percentage of hydrophilic amino acids in gelatins was low in this study, so the water-holding capacity was low as well. The degree of exposure of hydrophobic residues within gelatin determines fat binding capacity; according to the results of the estimated amino acid composition of gelatins in this study, the percentage of hydrophobic amino acids reached 20.78% and 20.9% for tilapia and catfish gelatins, respectively.

Nile tilapia skin gelatin

Catfish skin gelatin

Fig .1. Fish skin gelatines

TABLE 2. Amino-acid composition of Nile tilapia and catfish skin gelatins.

	Nile tilapia gelatine		Catfish gelatine	
	%	**mg/100g**	**%**	**mg/100g**
Glycine (Gly)	58.6289	469.03	59.0538	472.43
Cystine*	**Not. Determined**		**Not. determined**	
Basic groups	**7.3744**	**58.99**	**7.5763**	**60.61**
Lysine (Lys)	0.8278	6.62	0.8533	6.83
Histidine (His)	0.2681	2.14	0.2866	2.29
Arginine (Arg)	6.2785	50.23	6.4364	51.49
Carboxylic groups	**3.7758**	**30.21**	**3.8124**	**30.5**
Aspartic acid (Asp)	1.0387	8.31	1.052	8.42
Glutamic acid (Glu)	2.7371	21.90	2.7604	22.08
Hydroxylic groups	**9.4394**	**75.52**	**8.6473**	**69.18**
Serine (Ser)	3.6252	29.00	3.2477	25.98
Threonine (Thr)				
Hydroxyproline (Hyp)	5.6447	45.16	5.1547	41.24
Tyrosine (Tyr	0.1695	1.36	0.2449	1.96
Hydrophobic groups	**20.7815**	**166.25**	**20.9102**	**167.27**
Alanine (Ala)	9.8428	78.74	10.7941	86.35
Valine (Val)	2.4151	19.32	2.2064	17.65
Leucine (Leu)	1.2098	9.68	1.1452	9.16
Isoleucine (Ile)	1.4958	11.97	0.7615	6.09
Proline (Pro)	2.7431	21.94	2.8289	22.63
Phenylalanine	1.3479	10.78	1.6038	12.83
Methionine (Met)	1.727	13.82	1.5703	12.56

Amino acid composition analysis

The amino acid compositions play the main role in the physical properties of gelatin.

The amino acid contents of the gelatin obtained from tilapia and catfish skins were given in Table.2. Glycine was the most widespread amino acid, accounting for 58.6% of total amino acids in tilapia skin gelatin and 59% in catfish skin gelatin, both of which were significantly higher than in gelatin produced from the skin of various fish species.

Gelatin typically includes all 20 types of essential amino acids found in nature, which are characterised as hydrophobic (non-polar), hydrophilic (polar), and electrically charged hydrophilic (Abedinia et al., 2020). Because glycine amino acid made up approximately half of the collagen, gelatin did not preserve the parental collagen's composition. Lehninger et al. (1993) reported that the stability of collagens and gelatin is proportional to the glycine content, in addition to the total amino acid content. In this study, alanine was the second-most widespread amino acid, comprising 9.8 % and 10.8 % of the total amino acid composition for tilapia and catfish gelatins, respectively. These values were slightly lower than those revealed for gelatin derived from skin and scale of other warm water fish species (Nagarajan et al., 2012; Silva et al., 2014; Tong & Ying, 2013; Wangtueai & Noomhorm, 2009). The structure of amino acids demonstrated that methionine, histidine, tyrosine, isoleucine, and phenylalanine were all less than 1.7%, while cysteine was not found. There was no cysteine detected, indicating that there was no pollutants during extraction by elastin, another protein that, along with collagen, forms connective tissue (Bougatef et al., 2012).

Quality of stored fish fillet measurements

pH and weight losses measurements

The pH values for fish fillets coated with gelatin-chitosan coating solutions (TGEC tilapia gelatin) and (CGEC catfish gelatin) compared with control (CON uncoated fish fillet) under cold storage conditions were showed in Table 3. During the first day of storage, there was no significant difference in the pH values of CON, TGEC, and CGEC, which ranged from 6.56 to 6.62. The pH of CON was higher than both TGEC and CGEC after three days of storage and was also higher during the whole storage period ($P<0.05$). The pH *post-mortem* values for the fish range between 6.0 and 6.8, according to the species, diet, catching stress level, season, and muscle type (Khalafalla et al., 2015). The high pH value of control with prolonged storage time may be due to the decomposition of proteins and endogenous or microbial enzymes convert additional nitrogen-containing components to volatile bases (Li et al., 2012a, b). The coating could efficiently suspend the degradation processes, consequently keeping lower pH values for TGEC and CGEC treatments. Considering the weight loss, there were no significant differences in weight loss at day 3 and for all coated groups, After 6 days of storage, the coating decreased weight loss in refrigerated stored fish fillets ($P<0.05$). Weight losses gradually increased ($P<0.05$). For all studied samples during storage time, the highest increase was especially for control that ranged from 1.06 to 7.25%, whereas ranged from 0.97 to 4.24% and from 0.90 to 4.73% for TGEC and CGEC, respectively. Water loss in fish fillets could be initiated by the degeneration of myosin and by the decrease in the water-holding capacity of the muscles as a result. Water loss in fish fillets is a complex process that could be triggered by myosin deterioration, which is followed by a reduction in water-holding capacity (Mohan et al., 2012). The gelatin-chitosan coating material could act as a water vapor barrier or it might reabsorb the water from muscle during storage. Similar results of chitosan coating were also reported by (Yu et al., 2017). Song et al. (2011) revealed that the coating has water-barrier qualities; as a result, the water remains in the fish's coating system.

Color characteristics

The results of colour analysis of tilapia fish fillets stored in refrigeration with and without a gelatin-chitosan coating (TGEC, CGEC, and CON) are shown in fig (2). Where; Lightness (L^*), redness (a^*) and yellowness (b^*) values of samples were specified during storage time. The L* values varied from 52.20 to 52.88 for control, while ranged between 52.90 to 57.57 and 53.70 to 55.17 for TGEC and CGEC exhibiting a significant difference ($P<0.05$) starting from day 3 of storage. The L* values slightly increased with storage time for control samples. similar results have been reported by (Jouki et al.,2014) showed that L* values in rainbow trout fillets wrapped with and without films of quince seed mucilage with natural preservatives typically increased during 18 days of storage at 4°C, and that the fillets' appearance became less grey and whiter. (Che´ret et al., 2005) reported that the color of fish fillets is associated with the factors which influence light dispersion such as the physical structure of fish muscle, heme-based pigment, and the unbound water amount.

TABLE 3. Effect of gelatins edible coating on pH values and weight loss percentage of stored fish fillet

	weight loss% fish fillets **Storage daysPH values fish fillets**					
Catfish						
	Tilapia (TGEC) (CGEC) Control (CON)	**Catfish (CGEC)**				
0 Control (CON)	6.62 a Tilapia (TGEC)	6.62 a	6.56 b	--------	-----------	---------
3	6.86 a	6.63 b	6.62 b	1.06 a	0.97 b	0.90 b
6	7.13 a	6.68 b	6.66 b	2.26 a	2.07 a b	2.01 b
9	7.23 a	6.83 b	6.71 c	4.60 a	3.30 b	3.15 b
12	7.56 a	6.87 b	6.74 c	7.25 a	4.24 b	4.73 b

Values not followed by the same letter are significantly different at $p < 0.05$. Data are expressed as means
CON: uncoated fish fillet; TGEC: tilapia gelatin; CGEC: catfish gelatin

Generally, the a* values decreased from red to green throughout the storage period, while the b* values increased from yellow to blue. Regarding a* values (redness), control samples showed an increase in greenness, whereas the edible coating protected the colour during storage. All of the samples' a* values were negative (-a*); changes in fish color and the changes in fish appearance, such as green and browning meat over the storage time could be related to oxidation reactions and enzymatic reactions, which caused the degradation of myofibrilla protein and disorganization of myofibrils (Jung et al., 2003; Young & Whittle 1985). The negative (a*) values may be the result of not enough red muscle in the sample caused by the processing (Zhao et al., 2016). b* values for control samples increased during the storage period. The b* value of fish fillets coated with gelatin-chitosan (TGEC and CGEC) was lower than the control sample. Fish fillets with gelatin–chitosan coating (TGEC and CGEC) showed a lower b* value than the control sample. This could be attributed to pigment oxidation; the products of lipid oxidation, such as aldehydes, could be sources of carbonyl compounds involved in the Maillard browning reaction (Jouki et al., 2014; Wu et al., 2011). In general, the presence of gelatin-chitosan coating protects the fish colour of samples during storage, based on the evolution of colour variables.

Sensorial characteristics

Sensory evaluation is an important assay to predict the freshness of fillets while they are stored. The effect of coating on odor, color, texture, and overall acceptability scores are shown in Table 4.

Firstly, the fish fillets were still fresh, and all groups of coated fillets had gotten good scores at the sensory characteristics. The fish samples will be suitable for human consumption until their sensory score reaches 4, (Fan et al., 2009) according to the panelist's evaluation, by the ninth day, the control samples have reached unacceptable levels. Whereas samples coated with the gelatin-chitosan coating (TGEC and CGEC) did not receive unacceptable scores until the 12th day. Starting on day 3 of storage, the odor scores of controls decreased rapidly and showed a significantly (p 0.05) different score compared to both gelatin-chitosan coated samples, During the cold storage odor scores of controls declined rapidly, These odious odours were produced as a result of the accumulation of metabolites such as trimethylamine and biogenic amines caused by microbial activity. Whereas there was a significantly different between the control and both gelatin-chitosan coated samples (TGEC and CGEC) from the 3rd day in the color scores. Meanwhile, higher favorite scores were obtained for both gelatin-chitosan-coated samples. The results were compatible with the results of color measurements discussed previously. Moreover, as spoilage progressed, the fish muscle's color changed. Considering the high texture scores of gelatin coating compared with the control, the softening of the flesh was possibly produced by fish enzyme activation. Considering the texture scores, both gelatin-chitosan coated samples preserved the score for fresh samples at the same level until the 6th day of cold storage, while the texture score of the control sample decreased from the 3rd day with a significant difference from the coated samples. In terms of overall acceptability, the control sample had a shelf life of less than 9 days, whereas the gelatin-chitosan coated (TGEC and CGEC) samples had a shelf life of more than 12 days. In summary, there were no differences in overall acceptability between treatments until the 12th day of storage, and similar results had been reported by (Yu et al., 2017). Therefore, gelatin-chitosan coating presented good results in extending the shelf life of refrigerated fish fillets.

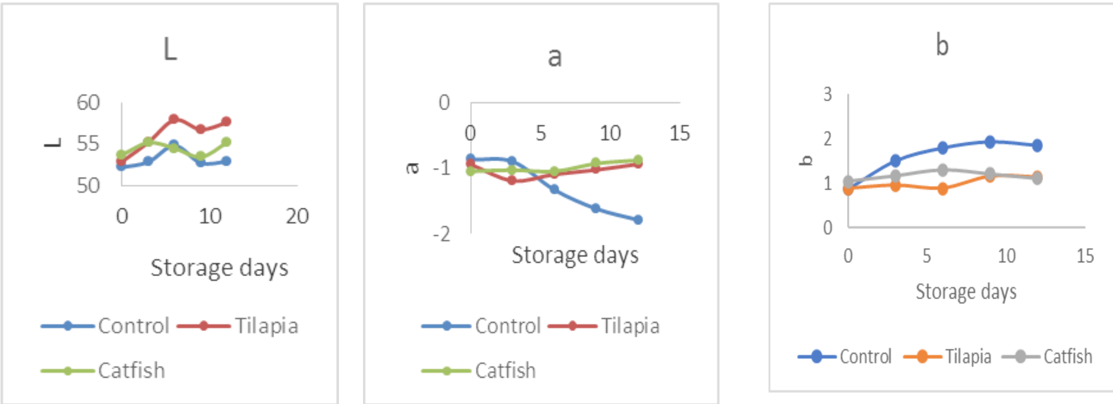

Fig. 2.a **Fig. 2.b** **Fig.2.c**

Fig. 2. Effect of gelatins edible coating on color (*L, a and b*) measurements of stored fish fillets.

TABLE 4. Effect of gelatins edible coating on sensorial characteristics of stored fish fillets

Sensory attributes	*samples*	*t*(storage)/days				
		Zero time	**3 days**	**6days**	**9 days**	**12 days**
color	CON	10 a	8.6 b	7.8 b	6.8 b	--------
	TGEC	10 a	9.3 a	8.8 a	8.0 a	7.6 a
	CGEC	10 a	9.5 a	9.0 a	8 a	7.8 a
odor	CON	10 a	7.8 b	6.8 b	4 c	-----------
	TGEC	10 a	9.2 a	8.8 a	7.3 b	6.5 a
	CGEC	10 a	9.3 a	9.0 a	8.2 a	6.8 a
texture	CON	9.6 a	8.3 b	7.5 b	6.2 b	-------------
	TGEC	9.8 a	9.3 a	8.6 a	7.6 a	7.3 a
	CGEC	10 a	9.6 a	8.8 a	7.8 a	7.5 a
General aceptabiliy	CON	10 a	8.3 b	6.5 b	4.6 b	---------
	TGEC	10 a	9.6 a	9.0 a	8.3 a	7.5 a
	CGEC	10 a	9.6 a	9.5 a	8.8 a	7.8 a

Values not followed by the same letter are significantly different at $p < 0.05$. Data are expressed as means
CON: uncoated fish fillet; TGEC: tilapia gelatin; CGEC: catfish gelatin

CON: *uncoated fish fillet at end of storage*

TGEC: tilapia gelatin at end of storage

CGEC: catfish gelatin at end of storage

Fig. 3. Effect of gelatins edible coating on tilapia fish fillets stored under refrigerated storage

Conclusion

Our study clearly proved that the skin as a byproduct of both tilapia and catfish can be used to produce good yield gelatin with high protein content, low fat, and ash percentage, and has good color properties. The resulting gelatin can be used after mixing with chitosan as an edible coating to extend the storage time of fish fillets. Fish gelatins were effective in reducing the decline in weight loss, pH, and color. Furthermore, they prevented the deterioration of the sensory properties of the fish fillet stored under refrigeration conditions. Catfish gelatin was more effective than tilapia gelatin in some sensorial characteristics. So, tilapia fish fillets coated with edible gelatin coating can be stored for up to 12 days with good quality.

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