

## Research Article

# Chitosan-Based Coatings Incorporated with Cinnamon and Tea Extracts to Extend the Fish Fillets Shelf Life: Validation by FTIR Spectroscopy Technique

Maryam Haghghi and Sedigheh Yazdanpanah 

*Department of Food Science and Technology, Kazerun Branch, Islamic Azad University, Kazerun, Iran*

Correspondence should be addressed to Sedigheh Yazdanpanah; [yazdanpanah2004@gmail.com](mailto:yazdanpanah2004@gmail.com)

Received 9 June 2020; Revised 26 June 2020; Accepted 17 August 2020; Published 24 August 2020

Academic Editor: Hadi Hashemi Gahrui

Copyright © 2020 Maryam Haghghi and Sedigheh Yazdanpanah. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The aim of this study was to evaluate the effect of active coatings prepared from the chitosan on the quality parameters of fish fillets. Antimicrobial and antioxidant properties were improved by addition of tea and cinnamon extracts. Different quality parameters including free fatty acids (FFA), thiobarbituric acid value (TBA), trimethylamine (TMA), total volatile basic nitrogen (TVBN), whiteness, and pH of coated and noncoated samples were evaluated during storage for 20 d at  $5 \pm 1^\circ\text{C}$ . Moreover, FTIR characterization (i.e., wavenumber and absorbance values) was used to investigate the oxidative stability. Extracts addition to chitosan coating had noticeable influence on reducing FFA and TBA. Moreover, modified chitosan coating decreased TVBN and TMA significantly. Based on FTIR finding, control sample showed the highest oxidation value, while the treated samples with chitosan\incorporated with tea and cinnamon extracts (CTCECS) had the lowest oxidation. The results showed that FTIR technique could be successfully applied to monitor the lipid oxidation of fish fillet. Therefore, FTIR provides a fast approach to study the compositional changes of food products rather than conventional chemical analysis. The findings of our research showed that chitosan coating modified with tea and cinnamon extracts could be used as a novel active packaging to prolong the shelf life quality of fish fillet.

## 1. Introduction

Fish fillet is one of the main highly perishable food products, which can be spoiled with different mechanisms such as microbiological, chemical, and enzymatically changes. These mechanisms reduced the shelf life of fish fillet and the nutritional quality parameters during storage time. Over the last few years, researchers used several methods to increase storage ability of fish fillets such as high-pressure treatment, cold storage and freezing, vacuum packaging, and modified atmosphere packaging. Among them, active edible films and coatings provide the promising opportunities to extend the fish shelf life [1, 2].

The main biopolymers which can be used as bio-based coatings are proteins, polysaccharides, lipids, or their combination. The biopolymer films can be controlled by the moisture and gas barriers properties. Incorporating natural preservatives, including extracts with good antimicrobial

and antioxidant properties, flavours, spices, and colourants to film and coatings, can improve the functionality of edible packaging to shelf life extension of food products such as fish samples [3] by controlling the active components release into the surface. Chitosan shows great potential of applications in different food products [4]. Some useful technofunctional properties of chitosan are antioxidant activity, antimicrobial activity, and application as active coatings [4, 5]. Several recent studies have shown the effect of essential oils-incorporated edible films on shelf life extension of fish samples. Ojagh et al. [4] reported the effects of a chitosan coating loaded with cinnamon oil on the quality of rainbow trout. Jeon et al. [6] also confirmed the reduction of moisture loss and lipid oxidation for Atlantic cod and herring samples treated with chitosan coatings. Souza et al. [7] showed that chitosan edible films could be used as an alternative to improve the shelf life of salmon fillets due to its excellent antibacterial and antioxidant activities.

The main active components of cinnamon extract are phenolic ingredients including proanthocyanidins, which are a group of flavonoids created by flavan-3-ol polymers and oligomers [8]. The aqueous extracts extracted from different varieties of cinnamon are known to have some beneficial influence on health including antioxidant, anti-diabetic, and antimicrobial properties [9]. Tea is an important source of polyphenol ingredients, such as catechins. Tea extract also has other ingredients, including phenolic acids and flavonoids but in lower proportion [10], which is recognized by its antimicrobial, antioxidant, anti-inflammatory, and anticarcinogenic properties [11].

The aim of our research was to evaluate the influence of chitosan coatings incorporated with tea and cinnamon extracts on the quality parameters of fish fillets during refrigerated storage. Moreover, the FTIR spectroscopy was used as a promising tool to assess the fish fillet oxidation behavior in a fast and cost-effective approach.

## 2. Materials and Methods

**2.1. Materials.** Tea and cinnamon plants were prepared from a local market (Kazerun, Iran). Chitosan was obtained from Sigma-Aldrich (St. Louis, USA). 1,3,3-tetraethoxypropane, thiobarbituric acid (TBA), FRAP, methanol, hydrochloric acid, tert-butylhydroquinone (TBHQ), sodium hydroxide, trichloroacetic acid (TCA), and ethanol were prepared from Merck Co. (Darmstadt, Germany). Also, double distilled water (DDW) was applied to prepare dispersions.

**2.2. Extract Preparation.** Plant powder (10 g) was completely mixed with hot distilled water (100 mL) for 30 min at 100°C followed by filtration (Whatman grade No. 1 filter papers) and concentrated in a rotary evaporator at 50°C and finally freeze-dried.

**2.3. Antioxidant Properties of Coating Materials.** TPC was determined by Folin–Ciocalteu based on the technique modified by Shahbazi et al. [12]. The method of the FRAP assay was modified by Justine et al. [13].

**2.4. Fish Sample Preparation and Coating.** To prepare coating solution, 0.2 g chitosan with 30–32 kD MW was dispersed in 100 mL distilled 1% w/w acetic acid; then, 2 g chitosan with 75 kD MW was added to it in 40°C during 3 h. Glycerol (0.75 mL for 1 g chitosan) was used as a food grade plasticizer in coating suspension. Then, fillets were immersed in the coating solutions. Then, fillets were placed to remove extra solution.

In our research, four treatment were used: (1) the untreated sample (control), (2) coated with tea extract (0.5%) (tea extract-coated sample, TECS), (3) coated with tea extract (0.25%) + cinnamon extract (0.25%) (tea and cinnamon extract-coated sample, TCECS), and (4) coated with chitosan (2%) + tea extract (0.25%) + cinnamon extract (0.25%) (chitosan, tea, and cinnamon extract-coated sample,

CTCECS). The fish fillets were kept at 5°C, and evaluations were performed every five days for twenty days.

**2.4.1. Free Fatty Acid (FFA) Measurement.** FFA of samples was determined by a standard method introduced by AOAC. Fillets (15 g) were homogenized in a solvent (120 mL) of chloroform-methanol (1 : 1 V/V). After 24 h, 48 mL of water was added, and oil was collected. The extracted oil in presence of phenolphthalein was titrated by sodium hydroxide. FFA content are reported as an oleic acid percentage in the sample [14].

**2.4.2. Thiobarbituric Acid Reactive (TBA) Measurement.** The colorimetric technique modified by Joukar et al. [1] was used for measuring the secondary lipid oxidation products content of the fillets. Homogenized fillet (10 g) was added into 97.5 mL of DDW and 2.5 mL HCl 4 M. Mixture (5 mL) was mixed with fresh thiobarbituric reactive solution (4 mL). Sample was kept in an oil bath (90°C–95°C) for 0.5 h and then arrived to 25°C immediately. The sample absorbance ( $A_s$ ) was determined against the blank (water) ( $A_b$ ) at 532 nm. TBARS contents of sample were measured based on the following equation:

$$\text{TBARS} \left( \frac{\text{mg of malondialdehyde}}{\text{kg of sample}} \right) = 50 \times \left[ \frac{A_s - A_b}{200} \right]. \quad (1)$$

**2.4.3. Total Volatile Basic Nitrogen (TVBN) Measurement.** Fish fillets and MgO were distilled by a Kjeldahl apparatus. Then, distillate vapor moved in a boric acid solution (2%) for titration. The indicators of this titration were methylene blue and methyl red solution (0.1%w/v in ethanol). Titration of suspension was performed with sulfuric acid (0.01 M). TVBN values (mg N<sub>2</sub>/100 g of sample) were determined according to Yu et al. [15].

**2.4.4. Trimethylamine (TMA) Measurement.** TMA content was measured according to the technique modified by Yu et al. [15]. Fillets (10 g) were homogenized with 30 mL TCA solution (7.5% w/v) using a high speed homogenizer for 3 min with 15,000 rpm. The sample was centrifuged at 4000 × *g* at 5°C for 10 min using a high-speed cryogenic centrifuge, and the supernatants were neutralized using NaOH (1M) for the analysis of TMA. The neutralized supernatant, formaldehyde (20%), anhydrous toluene, and saturated K<sub>2</sub>CO<sub>3</sub> were combined in 2 : 1 : 5 : 3 ratio (v/v) in a tube. Then, incubated at 32°C for ten minutes, the toluene layer was combined with anhydrous Na<sub>2</sub>SO<sub>4</sub> (0.2 g) and picric acid solution (5 mL, 0.02%, w/v). The absorbance of the sample was determined at 410 nm. TMA standard curve of was used at 0–2 mg/mL.

**2.4.5. pH Measurement.** Five gram of fillets was mixed in forty-five mL of DDW. Liquid phase was separated by a

TABLE 1: Total phenol content and antioxidant activity of coating materials.

	TPC (mg/g)	AA (mg/g)
Tea extract	4.97 ± 00.16C	1.79 ± 00.10D
Cinnamon-tea extract	80.61 ± 00.18A	34.83 ± 00.09A
Chitosan powder	0.65 ± 00.16D	3.69 ± 00.10C
Chitosan-cinnamon tea coating	7.71 ± 00.15B	18.66 ± 00.13B

Data represent mean ± standard deviation of three independent batches. Different uppercase letters in each column indicate significant differences ( $p < 0.05$ ).

filter. pH of liquid phase was determined by a pH meter (Sartorius, PB-11, Japan).

**2.4.6. Color Measurement.** The color of fish fillets was determined by the modified technique introduced by Gahruie et al. [16]. A Canon camera (5 MP) and a box ( $0.5 \times 0.5 \times 0.6 \text{ m}^3$ ) with a daylight source was applied for evaluating color parameters. The lab parameters of samples were extracted by Adobe Photoshop, and whiteness index was calculated based on this parameters.

**2.4.7. Fourier Transform Infrared Spectroscopy Measurement.** Fish fillets were dried, powdered, and finally homogenized with potassium bromide. The functional groups of sample were evaluated by a FTIR spectrometer (BRUKER, TENSOR, Germany).

**2.5. Statistical Analysis.** The properties of treatment was analyzed at least triplicate. The findings were evaluated using variance one-way analysis at  $p < 0.05$ . The averages' significant differences were determined by Duncan's multiple range tests (SAS, V. 9.2, USA).

### 3. Results and Discussion

**3.1. Antioxidant Properties of Coating Materials.** Table 1 shows the total phenol content (TPC) and antioxidant activity (AA) of coating materials. The TPC of tea extract, cinnamon-tea extract, chitosan, and chitosan-tea-cinnamon were 4.97, 80.61, 0.65, and 7.71 mg/g, respectively. Also, AA of tea extract, cinnamon-tea extract, chitosan, and chitosan-tea-cinnamon were 1.79, 34.83, 3.69, and 18.66 mg/g, respectively. High antioxidant activity of cinnamon extract is related to phenolic components and reported previously [9, 17]. Also, tea extract is a good source of gallic acid and catechins: catechin, epicatechin, catechin gallate, epicatechin gallate, galocatechin, epigallocatechin, galocatechin gallate, and epigallocatechin gallate [11]. The antioxidant activity of chitosan is related to OH groups on the backbone [18].

#### 3.2. Properties of Fillets

**3.2.1. Changes in FFA Content.** FFAs were produced by degradation of triglycerides, and this phenomenon was called hydrolysis. The content of FFAs can be used as a degree of lipolysis, and it is a parameter for evaluation

freshness of fish fillets. Table 2 shows that FFAs were raised during shelf life due to lipolysis of lipids, and this phenomenon decreased the quality of fillets. The same results were reported by Andevvari and Rezaei [19]. At the beginning of storage, the content of FFA in all of fish fillets was around 0.45. The FFA content significantly increased during first five days of storage. At the end of storage, CTCECS sample (chitosan coating incorporated with extracts) was the best sample in reducing the FFA production rate. Samples coated with tea (TECS) and tea-cinnamon (TCECS) had lower FFA production rate in comparison with control. Gómez-Estaca et al. [20] studied the influence of gelatin coating modified by oregano and rosemary extracts on the quality parameters of sardine. The same results on the FFA production was reported in this research.

**3.2.2. Changes in TBARS Content.** Lipid oxidation secondary products such as aldehydes and ketone were reported by TBA value. Malonaldehyde is one of the aldehyde which can produce red color with TBA reagent. There are some different aldehydes which can involve in this reaction. Therefore, the secondary products amounts (TBA value) were reported in mg MDA/kg fillets. Raeisi et al. [21] reported that TBA value under 5 mg MDA/kg of fillets is the standard level for fish quality. Based on Table 2, TBA value of uncoated sample significantly raised during storage time. In this reaction, hydroperoxides convert to secondary oxidation products such as aldehyde [22]. Based on the coating materials, various raising rates were shown in TBA value of samples. Usually, creating a coating layer had good effects on decreasing the lipid oxidation secondary products. The TBA value increase is related to the oxygen presence [23]. Contact of sample with oxygen can be reduced by polymer coatings, and thus, lipid oxidation can be controlled. So, production of aldehyde and ketone in the control was higher than that in coated samples. Phenolic compounds of extracts are potent antioxidants. At day 20, the highest TBA value was determined in control samples, and coated samples with tea and cinnamon in coating formulation with chitosan (CTCECS) had the lowest content. TBA values of untreated and treated fish fillet were under standard level during storage.

**3.2.3. TMA Content.** TMA was produced from trimethylamine oxide by microorganisms. Researcher reported that production of TMA is the main reason for bad odor in fish fillets, and it is called fishy. Table 3 shows that the TMA content at the beginning of storage was around 0.15 mg/100 g fillet. For chitosan-coated sample (CTCECS), a low increase was observed after 5 days of shelf life and it is arrived to 0.33 mg/100 g fillet. The TMA content of all samples significantly increased during storage. The TMA content of control sample was arrived to 5.17 mg/100 g sample at the end of storage. This sample had bad odor during last week of shelf life due to high content of TMA. The TMA content of tea (TECS), tea-cinnamon (TCECS), and chitosan-tea-cinnamon (CTCECS) samples at the end of storage was 3.13, 2.51, and 2.06 mg/100 g sample,

TABLE 2: Changes in FFA and TBA values of rainbow trout fillets during storage at  $4 \pm 1^\circ\text{C}$ .

	Sample	Storage (day)			
		0	5	15	20
FFA (% oleic acid)	Control	0.41 $\pm$ 0.09Ad	1.87 $\pm$ 0.09Ac	3.28 $\pm$ 0.16Ab	4.14 $\pm$ 0.26Aa
	TECS	0.35 $\pm$ 0.06Ad	1.40 $\pm$ 0.11Bc	2.44 $\pm$ 0.05Bb	3.24 $\pm$ 0.14Ba
	TCECS	0.41 $\pm$ 0.03Ad	1.13 $\pm$ 0.07Cc	2.10 $\pm$ 0.17Bb	2.45 $\pm$ 0.05Ca
	CTCECS	0.40 $\pm$ 0.04Ad	0.79 $\pm$ 0.04Dc	1.38 $\pm$ 0.07Cb	2.05 $\pm$ 0.06Da
TBA (mg malonaldehyde per kg of sample)	Control	0.33 $\pm$ 0.04Ad	0.65 $\pm$ 0.03Ac	2.52 $\pm$ 0.06Ab	3.71 $\pm$ 0.04Aa
	TECS	0.25 $\pm$ 0.02Ad	0.39 $\pm$ 0.02Bc	2.20 $\pm$ 0.03Bb	2.54 $\pm$ 0.02Ba
	TCECS	0.26 $\pm$ 0.03Ad	0.35 $\pm$ 0.03Bc	2.07 $\pm$ 0.06Cb	2.22 $\pm$ 0.03Ca
	CTCECS	0.24 $\pm$ 0.02Ad	0.31 $\pm$ 0.02Cc	1.89 $\pm$ 0.05Db	2.03 $\pm$ 0.05Da

Data represent mean  $\pm$  standard deviation of three independent batches. At a same time of storage, different uppercase letters indicate significant differences ( $p < 0.05$ ). For same sample, different lowercase letters indicate significant differences ( $p < 0.05$ ) over time. Control, sample without any coating; TECS, sample coated with tea extract (0.5%w/v); TCECS, sample coated with tea (0.25%w/v) + cinnamon (0.25%w/v) extract; and CTCECS, sample coated with chitosan (2% w/v) + tea extract (0.25%w/v) + cinnamon extract (0.25%w/v).

TABLE 3: Changes in TMA and TVB-N values of rainbow trout fillets during storage at  $4 \pm 1^\circ\text{C}$ .

	Sample	Storage (day)			
		0	5	15	20
TMA (mg/100 g)	Control	0.20 $\pm$ 0.06Ad	0.75 $\pm$ 0.03Ac	3.21 $\pm$ 0.11Ab	5.17 $\pm$ 0.15Aa
	TECS	0.17 $\pm$ 0.09Ad	0.64 $\pm$ 0.08Bc	2.56 $\pm$ 0.15Bb	3.13 $\pm$ 0.08Ba
	TCECS	0.14 $\pm$ 0.08Ad	0.42 $\pm$ 0.08Cc	1.94 $\pm$ 0.04Cb	2.51 $\pm$ 0.05Ca
	CTCECS	0.13 $\pm$ 0.06Ad	0.33 $\pm$ 0.04Cc	1.63 $\pm$ 0.11Db	2.06 $\pm$ 0.11Da
TVB-N (mg N/100 g of sample)	Control	13.09 $\pm$ 2.11Ad	31.11 $\pm$ 3.10Ac	61.44 $\pm$ 4.12Ab	113.01 $\pm$ 6.05Aa
	TECS	11.23 $\pm$ 2.09Ad	21.10 $\pm$ 2.46Bc	43.39 $\pm$ 1.20Bb	85.29 $\pm$ 4.15Ba
	TCECS	12.34 $\pm$ 1.36Ad	17.20 $\pm$ 2.12Cc	32.62 $\pm$ 3.31Cb	53.87 $\pm$ 5.23Ca
	CTCECS	11.45 $\pm$ 2.45Ac	14.19 $\pm$ 1.09Cc	22.42 $\pm$ 1.23Bb	39.50 $\pm$ 3.36Ba

Data represent mean  $\pm$  standard deviation of three independent batches. At same time of storage, different uppercase letters indicate significant differences ( $p < 0.05$ ). For same sample, different lowercase letters indicate significant differences ( $p < 0.05$ ) over time. Control, sample without any coating; TECS, sample coated with tea extract (0.5%w/v); TCECS, sample coated with tea (0.25%w/v) + cinnamon (0.25%w/v) extract; and CTCECS, sample coated with chitosan (2% w/v) + tea extract (0.25%w/v) + cinnamon extract (0.25%w/v).

respectively. Researchers reported that production of 5–10 mg TMA content in 100 g sample (sea bream and sardine) showed the starting of spoilage [24], but there are not any standard limitation for this parameter. We think, based on our results, production of 2.5 mg TMA in 100 g fillet for control sample is the starting of spoilage. This limitation was selected based on sensory attributes. Based on this standard limitation, TECS and TCECS samples were spoiled at 15~20 days of shelf life, but CTCECS sample was utilizable after 20 days of shelf life. Apparently, chitosan coating inhibited the TMA accumulation, and the inhibitory influence could be increased by addition of extracts. This finding was similar with the results by Souza et al. [7] in salmon samples. Gram and Dalgaard [25] showed that the increase of TMA content in fish was related to spoilage by microorganisms, including *Aeromonas spp* and *Shewanella putrefaciens*. The low TMA content in chitosan-coated fillets is due to the bacterial inhibition, which was confirmed by in another research [26].

**3.2.4. Changes in TVBN Content.** One of the most important measurement of fish fillets quality is TVBN index. Also, one of the common factors for evaluating the spoilage of fish fillet is TVBN. European Commission reported that 30–35 mg  $\text{N}_2/100$  g of sample shows the beginning of spoilage. But, for rainbow trout, 25 mg  $\text{N}_2/100$  g of sample was reported by

researchers [27]. Table 3 reports that the TVBN value was increased from 13 to 113 mg  $\text{N}_2/100$  g of sample during storage. Same findings were observed by Ojagh et al. [28] and Jouki et al. [29]. After 15 days, the TVBN value of the chitosan-coated sample was 22 mg  $\text{N}_2/100$  g of sample, but the content of TVBN in the control sample and TECS was larger than the standard level. The raising trends of the TVBN value in coated fillets were lower than that determined in control samples. Our findings showed that chitosan modified with extracts (CTCECS) can improve the shelf life due to low barrier properties. TVBN content is related to the microbial count. The lowest content of the TVBN value was determined in the chitosan-coated fillet incorporated with tea and cinnamon (CTCECS), at the storage end. This influence can be due to extract and chitosan bactericidal properties.

**3.2.5. Changes in Whiteness Index.** Table 4 shows the whiteness index of fillets during 20 days of storage. Changes in color parameters can be due to the myofibrillar proteins destruction and myofibrils disarrangement. Jung et al. [30] reported that this reaction was placed by enzymatic process and nonenzymatic process. Whiteness value of samples raised during storage. Our findings are similar with findings of Dehghani et al. [2]. The fish meat color is affected by free water content, heme pigments, and muscle physical

TABLE 4: Changes in whiteness and pH values of rainbow trout fillets during storage at  $4 \pm 1^\circ\text{C}$ .

	Sample	Storage (day)			
		0	5	15	20
Whiteness	Control	47.53 $\pm$ 0.29Ad	51.53 $\pm$ 0.40Ac	55.95 $\pm$ 0.33Ab	63.30 $\pm$ 0.46Aa
	TECS	44.23 $\pm$ 0.20Bc	46.43 $\pm$ 0.38Bc	49.07 $\pm$ 0.30Bb	56.26 $\pm$ 0.08Ba
	TCECS	45.31 $\pm$ 0.30Bc	45.58 $\pm$ 0.39Bc	48.50 $\pm$ 0.40Bb	52.10 $\pm$ 0.06Ca
	CTCECS	45.63 $\pm$ 0.32Bb	46.20 $\pm$ 0.46Bb	46.53 $\pm$ 0.40Cb	48.08 $\pm$ 0.47Da
pH	Control	5.59 $\pm$ 0.04Bc	5.70 $\pm$ 0.03Bc	6.17 $\pm$ 0.05Ab	6.54 $\pm$ 0.03Aa
	TECS	5.71 $\pm$ 0.02Ac	5.82 $\pm$ 0.04Ac	5.95 $\pm$ 0.02Bb	6.13 $\pm$ 0.04Ba
	TCECS	5.67 $\pm$ 0.03Ac	5.68 $\pm$ 0.03Bc	5.88 $\pm$ 0.01Cb	5.96 $\pm$ 0.02Ca
	CTCECS	5.51 $\pm$ 0.04Cc	5.57 $\pm$ 0.01Cc	5.70 $\pm$ 0.03Db	5.88 $\pm$ 0.02Da

Data represent mean  $\pm$  standard deviation of three independent batches. At same time of storage, different uppercase letters indicate significant differences ( $p < 0.05$ ). For same sample, different lowercase letters indicate significant differences ( $p < 0.05$ ) over time. Control, sample without any coating; TECS, sample coated with tea extract (0.5%w/v); TCECS, sample coated with tea (0.25%w/v) + cinnamon (0.25%w/v) extract; and CTCECS, sample coated with chitosan (2% w/v) + tea extract (0.25%w/v) + cinnamon extract (0.25%w/v).

structure [31]. Whiteness increasing was due to the denaturation of different proteins and reducing the bond water [2]. Based on the results, CTCECS sample was the best sample in discoloration during shelf life. This sample was fortified with cinnamon and tea extracts. Changes in double bond of carotenoids and production of free radicals by lipid oxidation were the main reasons of discoloration of fillets.

**3.2.6. Changes in pH.** pH of coated and uncoated samples during storage are reported in Table 4. pH of fillets at the beginning of storage were 5.5–5.7. Different factors including fish species and size, water composition, catching season, geographical position, and stress level have effect on this parameter [23, 28]. The lowest (5.88) and highest pH (6.54) was measured in chitosan-tea cinnamon sample (CTCECS) and control at the end of storage, respectively. Different raising rate of pH was due to the antioxidant ingredients and its properties. However, in the 5<sup>th</sup> day of shelf life, because of lactic acid presence in the fillets, the pH of sample was similar. Proteolytic and autolytic enzymes produced by microorganism react with nitrogen ingredient and raise the pH of samples [32].

**3.2.7. Fourier Transform Infrared Spectroscopy Analysis.** There are a lot of research papers in which FTIR technique was used for evaluating the modification of structure. FTIR analysis was carried out during storage, and the spectra obtained are shown in Figure 1. The band around  $1745\text{ cm}^{-1}$  was related to the triglycerides C=O stretching. Oxidation of fillets oil increased the intensity of this band (Figure 1 and Table 5). Researchers reported that production of secondary oxidative components such as aldehydes creates bands between  $1728\text{ cm}^{-1}$  and  $1780\text{ cm}^{-1}$  [33]. Figure 1 indicates an asymptotic response of the carboxylate absorption at  $1542\text{ cm}^{-1}$  due to increasing % FFA [34]. Figure 1 shows that the changes that determined in the  $600\text{--}1500\text{ cm}^{-1}$  are related to the oxidation of lipids. Bands at  $1382$  ( $-\text{CH}_3$  aliphatic groups or C-H bonds of cis disubstituted alkenes) and  $1461$  ( $-\text{CH}_2-$  aliphatic groups) are related to oxidation of lipids in samples. The saturated

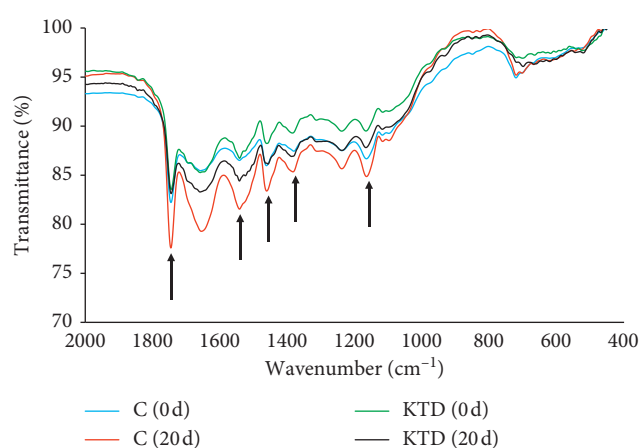


FIGURE 1: FTIR spectra of control (C) and CTCECS (KTD) samples during storage.

acyl groups contents in the fish oil can be calculated by evaluation bands at  $1166\text{ cm}^{-1}$  [35]. Changing the location of bands to higher wavenumber after oxidation of lipids is due to the production low molecular weight saturated acyl components during lipolysis of triglycerides. Moomand and Lim [36] reported that after oxidation of lipids, the absorbance around  $1099$  and  $966\text{ cm}^{-1}$  was increased. Based on our findings (Figure 1 and Table 5), the control sample had the highest oxidation, and the treated sample with chitosan, tea, and cinnamon extracts had the lowest oxidation (CTCECS). The results showed that oxidation of fish fillet can be evaluated by FTIR technique, and our results showed that the results of chemical analysis were similar to the results of FTIR.

## 4. Conclusion

The shelf life of samples improved by application of chitosan-based coating incorporated with tea and cinnamon extracts as a natural preservative. Main factors including FFA, pH, TBA, and TVBN of chitosan-coated fillets incorporated with extracts were in the standard range during storage. Our results showed that the results of chemical analysis were similar to the results of FTIR. The shelf life of

TABLE 5: FTIR peak assignments of different samples.

	Control		CTCECS	
	0 day	20 days	0 day	20 days
Saturated acyl groups	1145.10	1164.78	1166.01	1163.27
-CH <sub>3</sub> aliphatic groups	1377.23	1382.74	1382.74	1382.74
-CH <sub>2</sub> - aliphatic groups	1461.96	1461.31	1460.97	1456.81
Asymptotic response of the carboxylate absorption	1539.11	1542.00	1541.70	1542.21
C=O stretching of the triglycerides	1745.52	1745.80	1745.00	1745.00

Control, sample without any coating; CTCECS, sample coated with chitosan (2% w/v) + tea extract (0.25%w/v) + cinnamon extract (0.25%w/v).

the control and chitosan-coated sample with high quality properties was 5 and 15 days, respectively. This result showed that this coating incorporated with extracts is a good case for improving the shelf life of meat products.

### Data Availability

The data used to support this study are available from the corresponding author upon request.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

### References

- [1] F. Joukar, S. M. H. Hosseini, M. Moosavi-Nasab, G. R. Mesbahi, and A. Behzadnia, "Effect of Farsi gum-based antimicrobial adhesive coatings on the refrigeration shelf life of rainbow trout fillets," *LWT*, vol. 80, pp. 1–9, 2017.
- [2] P. Dehghani, S. M. H. Hosseini, M.-T. Golmakani, M. Majdinasab, and S. Esteghlal, "Shelf-life extension of refrigerated rainbow trout fillets using total Farsi gum-based coatings containing clove and thyme essential oils emulsions," *Food Hydrocolloids*, vol. 77, pp. 677–688, 2018.
- [3] Z. S. Farag, A. M. Sharaf, and M. K. Morsy, "Influence of chitosan based coating incorporation green tea and rosemary extracts on physicochemical and microbial quality of Tilapia fish (*Oreochromis niloticus*) fillets under cold storage," *Egyptian Journal of Food Science*, vol. 46, pp. 69–82, 2018.
- [4] S. M. Ojagh, M. Rezaei, S. H. Razavi, and S. M. H. Hosseini, "Development and evaluation of a novel biodegradable film made from chitosan and cinnamon essential oil with low affinity toward water," *Food Chemistry*, vol. 122, no. 1, pp. 161–166, 2010.
- [5] X. Zhang, J. Liu, C. Qian, J. Kan, and C. Jin, "Effect of grafting method on the physical property and antioxidant potential of chitosan film functionalized with gallic acid," *Food Hydrocolloids*, vol. 89, pp. 1–10, 2019.
- [6] Y.-J. Jeon, J. Y. V. A. Kamil, and F. Shahidi, "Chitosan as an edible invisible film for quality preservation of herring and Atlantic cod," *Journal of Agricultural and Food Chemistry*, vol. 50, no. 18, pp. 5167–5178, 2002.
- [7] B. W. S. Souza, M. A. Cerqueira, H. A. Ruiz et al., "Effect of chitosan-based coatings on the shelf life of salmon (*Salmo salar*)," *Journal of Agricultural and Food Chemistry*, vol. 58, no. 21, pp. 11456–11462, 2010.
- [8] L. Jiao, X. Zhang, L. Huang et al., "Proanthocyanidins are the major anti-diabetic components of cinnamon water extract," *Food and Chemical Toxicology*, vol. 56, pp. 398–405, 2013.
- [9] V. B. de Souza, M. Thomazini, M. A. Echalar Barrientos et al., "Functional properties and encapsulation of a proanthocyanidin-rich cinnamon extract (*cinnamomum zeylanicum*) by complex coacervation using gelatin and different polysaccharides," *Food Hydrocolloids*, vol. 77, pp. 297–306, 2018.
- [10] J. M. Lorenzo and P. E. S. Munekata, "Phenolic compounds of green tea: health benefits and technological application in food," *Asian Pacific Journal of Tropical Biomedicine*, vol. 6, no. 8, pp. 709–719, 2016.
- [11] C. Martins, F. Vilarinho, A. Sanches Silva et al., "Active polylactic acid film incorporated with green tea extract: development, characterization and effectiveness," *Industrial Crops and Products*, vol. 123, pp. 100–110, 2018.
- [12] H. Shahbazi, H. Hashemi Gahruei, M.-T. Golmakani, M. H. Eskandari, and M. Movahedi, "Effect of medicinal plant type and concentration on physicochemical, antioxidant, antimicrobial, and sensorial properties of kombucha," *Food Science & Nutrition*, vol. 6, no. 8, pp. 2568–2577, 2018.
- [13] V. T. Justine, M. Mustafa, S. S. Kankara, and R. Go, "Effect of drying methods and extraction solvents on phenolic antioxidants and antioxidant activity of *scurrula ferruginea* (jack) danser (loranthaceae) leaf extracts," *Sains Malaysiana*, vol. 48, pp. 1383–1393, 2019.
- [14] A. Motalebi Moghanjoghi, G. Hashemi, M. Mizani, M. Gharachorloo, and H. Tavakoli, "The effects of refining steps on Kilka (*Clupeonella delicatula*) fish oil quality," *Iranian Journal of Fisheries Sciences*, vol. 14, pp. 382–392, 2015.
- [15] D. Yu, Y. Xu, J. M. Regenstien et al., "The effects of edible chitosan-based coatings on flavor quality of raw grass carp (*Ctenopharyngodon idellus*) fillets during refrigerated storage," *Food Chemistry*, vol. 242, pp. 412–420, 2018.
- [16] H. H. Gahruei, M. H. Eskandari, P. Van der Meeren, and S. M. H. Hosseini, "Study on hydrophobic modification of basil seed gum-based (BSG) films by octenyl succinate anhydride (OSA)," *Carbohydrate Polymers*, vol. 219, pp. 155–161, 2019.
- [17] M. Z. Shahid, H. Saima, A. Yasmin, M. T. Nadeem, M. Imran, and M. Afzaal, "Antioxidant capacity of cinnamon extract for palm oil stability," *Lipids in Health and Disease*, vol. 17, no. 116, 2018.
- [18] W. Xie, P. Xu, and Q. Liu, "Antioxidant activity of water-soluble chitosan derivatives," *Bioorganic & Medicinal Chemistry Letters*, vol. 11, no. 13, pp. 1699–1701, 2001.
- [19] G. T. Andevani and M. Rezaei, "Effect of gelatin coating incorporated with cinnamon oil on the quality of fresh rainbow trout in cold storage," *International Journal of Food Science & Technology*, vol. 46, no. 11, pp. 2305–2311, 2011.
- [20] J. Gomezstaca, P. Montero, B. Giménez, and M. Gomezguillen, "Effect of functional edible films and high pressure processing on microbial and oxidative spoilage in cold-smoked sardine (*Sardina pilchardus*)," *Food Chemistry*, vol. 105, no. 2, pp. 511–520, 2007.

- [21] M. Raeisi, H. Tajik, J. Aliakbarlu, S. H. Mirhosseini, and S. M. H. Hosseini, "Effect of carboxymethyl cellulose-based coatings incorporated with *Zataria multiflora* Boiss. essential oil and grape seed extract on the shelf life of rainbow trout fillets," *LWT-Food Science and Technology*, vol. 64, no. 2, pp. 898–904, 2015.
- [22] S. Taheri, A. Motalebi, and A. Fazlara, "Antioxidant effect of ascorbic acid on the quality of Cobia (*Rachycentron canadum*) fillets during frozen storage," *Iranian Journal of Fisheries Sciences*, vol. 11, pp. 666–680, 2012.
- [23] L. Cai, X. Wu, Z. Dong, X. Li, S. Yi, and J. Li, "Physicochemical responses and quality changes of red sea bream (*Pagrosomus major*) to gum Arabic coating enriched with ergothioneine treatment during refrigerated storage," *Food Chemistry*, vol. 160, pp. 82–89, 2014.
- [24] C. O. Mohan, C. N. Ravishankar, K. V. Lalitha, and T. K. Srinivasa Gopal, "Effect of chitosan edible coating on the quality of double filleted Indian oil sardine (*Sardinella longiceps*) during chilled storage," *Food Hydrocolloids*, vol. 26, no. 1, pp. 167–174, 2012.
- [25] L. Gram and P. Dalgaard, "Fish spoilage bacteria-problems and solutions," *Current Opinion in Biotechnology*, vol. 13, no. 3, pp. 262–266, 2002.
- [26] D. Yu, Q. Jiang, Y. Xu, and W. Xia, "The shelf life extension of refrigerated grass carp (*Ctenopharyngodon idellus*) fillets by chitosan coating combined with glycerol monolaurate," *International Journal of Biological Macromolecules*, vol. 101, pp. 448–454, 2017.
- [27] M. G. Volpe, F. Siano, M. Paolucci et al., "Active edible coating effectiveness in shelf-life enhancement of trout (*Oncorhynchus mykiss*) fillets," *LWT-Food Science and Technology*, vol. 60, no. 1, pp. 615–622, 2015.
- [28] S. M. Ojagh, M. Rezaei, S. H. Razavi, and S. M. H. Hosseini, "Effect of chitosan coatings enriched with cinnamon oil on the quality of refrigerated rainbow trout," *Food Chemistry*, vol. 120, no. 1, pp. 193–198, 2010.
- [29] M. Jouki, F. T. Yazdi, S. A. Mortazavi, A. Koocheki, and N. Khazaei, "Effect of quince seed mucilage edible films incorporated with oregano or thyme essential oil on shelf life extension of refrigerated rainbow trout fillets," *International Journal of Food Microbiology*, vol. 174, pp. 88–97, 2014.
- [30] S. Jung, M. Ghoul, and M. de Lamballerie-Anton, "Influence of high pressure on the color and microbial quality of beef meat," *LWT-Food Science and Technology*, vol. 36, no. 6, pp. 625–631, 2003.
- [31] M. Jouki, S. A. Mortazavi, F. T. Yazdi, A. Koocheki, and N. Khazaei, "Use of quince seed mucilage edible films containing natural preservatives to enhance physico-chemical quality of rainbow trout fillets during cold storage," *Food Science and Human Wellness*, vol. 3, no. 2, pp. 65–72, 2014.
- [32] Y. Song, L. Liu, H. Shen, J. You, and Y. Luo, "Effect of sodium alginate-based edible coating containing different anti-oxidants on quality and shelf life of refrigerated bream (*Megalobrama amblycephala*)," *Food Control*, vol. 22, no. 3-4, pp. 608–615, 2011.
- [33] J. Van der Weerd, A. Van Loon, and J. J. Boon, "FTIR studies of the effects of pigments on the aging of oil," *Studies in Conservation*, vol. 50, no. 1, pp. 3–22, 2005.
- [34] A. N. A. Aryee, F. R. Van de Voort, and B. K. Simpson, "FTIR determination of free fatty acids in fish oils intended for biodiesel production," *Process Biochemistry*, vol. 44, no. 4, pp. 401–405, 2009.
- [35] M. D. Guillén and N. Cabo, "Characterization of edible oils and lard by Fourier transform infrared spectroscopy. Relationships between composition and frequency of concrete bands in the fingerprint region," *Journal of the American Oil Chemists' Society*, vol. 74, no. 10, pp. 1281–1286, 1997.
- [36] K. Moomand and L.-T. Lim, "Oxidative stability of encapsulated fish oil in electrospun zein fibres," *Food Research International*, vol. 62, pp. 523–532, 2014.