

INCREASING THE SHELF-LIFE TROUT FILLETS BY SODIUM CASEINATE-PERSIAN GUM BIOCOMPOSITE FILM INCORPORATED WITH GINGER EXTRACT

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<https://doi.org/10.55251/jmbfs.10205>

ARTICLE INFO

Received 25. 10. 2024

Revised 16. 9. 2024

Accepted 8. 10. 2024

Published 1. 12. 2024

Regular article



ABSTRACT

The effects of sodium caseinate (SC)-Persian gum (PG) films enriched with *Zingiber officinale* extract (ZOE) were investigated on the quality of rainbow trout over a 16 day at 4°C. The trout filets were divided to 4 groups as uncoated, coated with SC-PG, SC-PG-1% ZOE and SC-PG-1.5% ZOE. Sensorial, chemical and microbial characteristics of trout samples were evaluated on 0, 4, 8, 12 and 16 days of storage. GC-MS analysis exhibited that ZOE is rich in phenolic compounds including zingiberene and cis-6-shogaol. Active films embedded with 1.5% of ZOE revealed a remarkable decline in bacterial growth over the storage time. Wrapping with SC-PG-1.5% ZOE composite film tended to delay the elevation of thiobarbituric acid and peroxide value. Samples containing 1.5% ZOE were mostly preferred by sensory panelists. Based on the results of the present study, the edible films were suitable candidates for preserving quality properties and extending the shelf life of rainbow trout filets.

Keywords: Sodium caseinate; Persian gum; Ginger extract; trout filets; Shelf life

INTRODUCTION

Currently, there are increased consumer concerns regarding the long time use of additives in food products and their harmful effects (such as cancer) (Khezerlou et al., 2023). So, herbal extracts can be used as natural alternatives additives, for that lengthen the storage time of food without negative effects. The utilization of herbal extracts in food industries is owing to the antioxidant, antifungal and antibacterial properties (Yekta et al., 2023). This has driven researchers and food producers to search for natural additive substances and incorporated into edible films to enable them to act as active packaging.

Recently, studies have evaluated the antimicrobial and antioxidative impacts of herbal extracts and their ingredients which could be effective for reducing levels of pathogenic and spoilage microorganisms and slow lipid oxidation of products (Khezerlou et al., 2023). Ginger (*Zingiber officinale*) is a plant, family *Zingiberaceae*, which is widely used in food preservation. Ginger has exhibited potential antioxidant, antifungal, and antimicrobial activities due to diverse bioactive ingredients and nutrient such as α -curcumene, zingiberene, gingerol, shogaol, and monoterpenes camphene (Khezerlou, Azizi-Lalabadi, et al., 2019). Recent studies have revealed that film-containing plant extracts are useful for rising the quality and safety of seafood (A. Mehdizadeh et al., 2021; Raeisi et al., 2020). The extract from ginger and its ingredients were successfully combined with biopolymeric films to enhance the shelf life of seafood samples by (Chaijan et al., 2020), (Rostamzad et al., 2019), and (Mi et al., 2017).

Among different methods, active biodegradable films and coatings can be developed successfully to preserve the quality and safety of meat, fish meat, and their other products (Sani et al., 2024) by retarding chemical and microbial decay (Dehghani et al., 2018). These films act as a carrier for different active ingredients (such as antimicrobial, antioxidant, nutraceuticals, colors, enzymes and flavors). They are designed such that with slow release of the active components they could prevent food contamination (Alizadeh Sani et al., 2024). Sodium caseinate (SC) is a protein in cow's milk obtained via acid precipitation (Kia et al., 2018). SC can be utilized to fabricate edible films and coatings; they also show potential protection for food products against their surroundings (Karimi Sani et al., 2019). However, the use of SC films has been limited due to high sensitivity to moisture and undesirable mechanical properties. In this regard, the functionality of protein films can be enhanced effectively by combining them with polysaccharides. Hence, in this study, Persian gum (PG) was used to meliorate the drawbacks of SC. PG (Zedo, Angum, and Shirazi) is a natural exudate of mountain almond trees and is mostly found in semi-arid areas of Iran. Persian gum has water (8–9%), carbohydrate (82–90%), protein (~2%), tannin (0.6%), lipid (> 0.19%), and an average molecular weight of 4120 kDa (Dabestani et al., 2018). It is mostly

comprised of units of D-galactose linked by glycosidic β (1,3-1,6) bonds with L-arabinose (α -1,3) units as side chains (Alizadeh Khaledabad et al., 2019). It could be used in medicine as anti-parasite, anticough, mucus decreasing agent, with healing properties for toothache and swollen joints (Gharanjig et al., 2020). It also has food applications such as in dough, egg white foam, (Dabestani et al., 2019) and biodegradable packaging (Alizadeh Sani et al., 2022; Khodaei et al., 2020). Although fish meat is major source of protein, essential amino acids, minerals, vitamins and polyunsaturated fatty acids (ω -3 fatty acids), it is one of the most perishable seafood products (A. Mehdizadeh et al., 2021; Zamani et al., 2022). The foremost challenge is the short shelf life of fish meat, which is only a few days when refrigerated. The storage time and quality of fish meat is reduced because of fast growth of pathogenic bacteria such as *Pseudomonas spp.*, *Moraxella*, *Shewanella*, *Vibrionaceae*, *Aeromonadaceae*, *Micrococcus*, *Lactobacillus* and *Corynebacterium*, as well as chemical and enzymatic reactions (Moradi et al., 2023). Rainbow trout is a highly popular and demanded fish among consumers worldwide. Limitations of storing fresh fish (approximately 4-5 days) and protective the quality of trout meat before consumption highlight the obvious need for developing novel preservation methods to lengthen the shelf life.

Accordingly, due to biodegradability, antioxidant, antimicrobial and barrier properties of SC/PG/ZEO composite film and to heighten the storage-time of trout, this study examined the microbial, chemical, and sensory characteristics of rainbow trout file packed in bio-films enriched with ZOE during storage at 4°C.

MATERIAL AND METHODS

Reagents

SC powder (90 wt% protein) was prepared from Iran caseinate. The native PG was obtained from Freer Corporation (Esfahan, Iran). The dried rhizomes of ginger (*Z. officinale*) were purchased from local market of Tabriz, Iran. Media for bacterial cultures including Nutrient agar and King agar were obtained from Micromedia (Canada). All the other chemical used were of analytical grade.

Extraction and analysis of ZOE

Ginger powder (20 g) was mixed with 200 mL of 70% ethanol and extracted by continuous stirring. The mixture was filtered on Whatman filter paper. The supernatant was concentrated using rotary evaporator. Eventually, the substance was kept in airtight glass bottles covered with aluminum foil under refrigerated conditions. The gas chromatography-mass spectrophotometry (GC-MS) analysis of the extract was performed using Agilent 6890N gas chromatograph coupled with

a 5973N mass spectrometer and equipped with a HP-5 MS (30 m, 0.25 mm, 0.2 μm) capillary column. The temperature program used was as follows: initial temperature was 60°C for 5 min, followed by 220 °C at a rate of 3°C per min, then kept for 11 min up to 280 °C. The carrier gas was He with flow rate: 0.9 mL/min; split ratio: 1:40, and the injection volume: 0.5μL.

Preparation of SC/PG/ZOE films

The detailed film preparation process has been illustrated in our previous work (Khezerlou, Ehsani, et al., 2019). PG powder (0.6% w/w) was dissolved in distilled water under hot plate string at 50 °C for 1h and then kept at 4°C for 24h. SC (5 g) and glycerol (5% w/w) were added to the PG solution and heated as well as stirred at 90 °C for 60 min, to completely dissolve. The pH was adjusted to 9.0 upon adding 2N NaOH. Then, the extract of the *Z. officinale* (ZOE) was added at 1 and 1.5% to the solution. The film solutions were homogenized (at 12000 rpm for 2 min via an Ultraturrax (T-10model IKA, Germany) and degasified using an ultrasonic water bath (Elmasonic, model: S60H Germany). Finally, 55 mL of solution was spread into sterile plates and dried in an oven (37 ± 2) °C for 24 h. Films were then stored inside desiccators for further use. Film thickness was measured at least at 5 different points through a digital micrometer (Mitutoyo, Japan) with an accuracy 0.001 mm. The water vapor permeability (WVP) was determined using our previous work (Khezerlou, Ehsani, et al., 2019).

Fish sample preparation

Fresh rainbow trout was purchased from the Fish Market (Tabriz, Iran), then immediately transported to laboratory. Next, samples were washed, with the head, tail, skin, and spiny bones stripped and peeled off. Fillet samples (ca. 25 g and boneless fillets) were randomly classified into four treatments including: (i) control (without SC-PG) (C); (ii) SC-PG (C1); (iii) SC-PG with 1% ZOE (C2); (iv) SC-PG with 1.5% ZOE (C3). The samples were packaged in plastic bags. Wrapped fillets were subsequently labeled and stored at 4 ± 1°C for 16 days and analyzed for microbial, chemical, and sensory properties within four-day intervals: 0, 4, 8, 12, and 16.

Chemical analyses

The pH values of fish fillet sample were measured by a digital pH meter after homogenization of every 5 g of sample in 10 mL of distilled water . Briefly, 15 g of every sample was mixed in 60 ml chloroform and 60 ml methanol for 2min. Then, 30 mL of the solvent (a mixture of chloroform and acetic acid) and 30 mL of distilled water were added to the sample. Next, 0.5 mL of saturated solution of potassium iodide was added to it and placed in the dark for 10 min. Thereafter, and 0.5 mL 1% starch solution were added. The mixture was titrated with 0.01 N sodium thiosulfate. The peroxide value (PV) was calculated according to the following Equation (1):

$$PV = ((V_1 - V_2) \times 1000 \times N) / W$$

Where, V₁ is the volume of thiosulfate consumed by the sample, V₂ denotes the volume of thiosulfate consumed by the control, N represents the normality of the thiosulfate solution, and W is the weight of oil (Ehsani et al., 2017).

The modified method of Alizadeh-Sani et al. (2020) was used to measure the amount of thiobarbituric acid (TBA) using a colorimetric methodology. Briefly, 200 mg of the sample with 1- butanol was diluted to a specific volume in a 25-mL volumetric flask. A fraction (5 mL) of the above mixture was transferred into a test tube, and 5 mL of TBA reagent was added. The test tubes were vortexed, placed in a water bath at 90 °C for 1h and then cooled up to the room temperature. UV-visible spectrophotometer (Unico, UV-2100) was used to determine the absorbance of samples at 530 nm. The amount of TBA was expressed as mg of malondialdehyde per kg of sample (mg MDA/kg).

Microbial analysis

The sample (25 g) was poured in the stomacher bags enclosing 225 mL of 0.1% of sterile peptone water and mixed for 5 min in a Stomacher blender (Seward Medical, London, UK), subsequent serial dilution was prepared via the same diluent. Population of total viable count (TVC) was determined on Nutrient agar with incubation at 37 °C for 24 h. Total psychrotrophic bacteria (TPB) counts were fulfilled in Kink agar with incubation at 21 °C for 48h (Ehsani et al., 2020).

Sensory evaluation

The sensory effects of fish fillet samples coated with SC-PG films containing ZOE to were investigated using an acceptance test. A panel of 9 semi-trained were chosen from students of from the Department food science and technology. Panelists were responded to color, texture, odor, and total acceptability of samples using ranking them with a five-point hedonic scale (1=the lowest score; 5 = the highest).

Statistical analysis

Statistical analysis was performed by analysis of variance (ANOVA) in SPSS 25.0 software (IBM; Armonk, N. Y, USA) and mean difference comparison was checked by Tukey’s multiple.

RESULTS AND DISCUSSION

Chemical characterization of ginger extract

The major components in ethanolic ZOE are listed in Table 2. Thirty-one various compounds were identified by GC-MS. Zingiberene (23.11%), cis-6-shogaol (15.31%), Gingerol (11.04%), β-Sesquiphellandrene (9.80%) were the major components. In several experiments, zingiberene or β-Sesquiphellandrene were reported as the main components (Babu et al., 2018; Noori et al., 2018).

Table 1 Composition of *Zingiber officinale* extract

| NO. | Compound | RT | % (peak area) |
|-----|--|-------|---------------|
| 1 | Geranyl propionate | 13.03 | 0.38 |
| 2 | trans-β-Farnesene | 14.50 | 0.38 |
| 3 | gamma-curcumene | 15.08 | 0.98 |
| 4 | Benzene | 15.18 | 5.20 |
| 5 | Zingiberene | 15.52 | 23.11 |
| 6 | delta-Cadinene | 15.62 | 2.33 |
| 7 | α-Farnesene | 15.72 | 4.05 |
| 8 | β-Bisabolene | 15.78 | 4.39 |
| 9 | β-Sesquiphellandrene | 16.14 | 9.80 |
| 10 | trans-γ-Bisabolene | 16.28 | 0.30 |
| 11 | Naphthalene | 16.91 | 0.85 |
| 12 | Germacrene B | 18.33 | 0.98 |
| 13 | 2-Butanone | 18.66 | 2.76 |
| 14 | Butanone 4-methyl-1-(3',3'-dimethyl bicyclo) | 18.84 | 1.68 |
| 15 | Humulane-1,6-dien-3-ol | 18.95 | 0.37 |
| 16 | 1,3,6,10-Dodecatetraene | 20.52 | 0.18 |
| 17 | 1H-3a,7-Methanoazulene | 22.51 | 0.27 |
| 18 | Benzene | 23.77 | 1.78 |
| 19 | 1,6,10,14-Hexadecatetraen-3-ol | 24.17 | 0.52 |
| 20 | 9,12-Octadecadienoic acid | 26.24 | 0.61 |
| 21 | 9,12-Octadecadienoic acid | 26.31 | 0.58 |
| 22 | (E,E,E)-3,7,11,15Tetramethylhexadeca | 26.54 | 0.90 |
| 23 | Albicanol | 27.50 | 0.61 |
| 24 | 3-Pyridineacetic acid | 27.61 | 1.33 |
| 25 | cis-6-shogaol | 28.45 | 15.31 |
| 26 | 3,4-Dimethoxyphenyl acetone | 28.76 | 0.56 |
| 27 | Albicanol | 28.98 | 2.25 |
| 28 | Zingerone | 30.12 | 11.04 |
| 29 | Gingerol | 31.09 | 1.03 |
| 30 | Gingerol | 31.98 | 4.29 |
| 31 | Secoisolaricresinol | 32.33 | 1.22 |

RT- Retention Time (min)

Thickness, WVP

As can be seen from Table 2, adding ZOE to the SC-PG matrix enhanced the film thickness. The thickness of the pure SC-PG film was 0.244 mm, whereas that of the SC-PG films with 1% ZOE (0.255 mm) and 1.5% ZOE (0.262 mm) was higher. WVP diminished after adding ZOE, and the WVP of the SC-PG film (1.41 × 10⁻⁹ g/m. s. Pa) was higher than that of the SC-PG-1% ZOE (1.19 × 10⁻⁹ g/m. s. Pa) and SC-PG-1.5% ZOE (1.05 × 10⁻⁹ g/m. s. Pa).

Table 2 Thickness (mm) and WVP SC-PG films with ZOE

| Properties | Film type | | |
|-----------------------------------|-------------|-------------|---------------|
| | SC-PG | SC+PG+1%ZOE | SC+PG+1.5%ZOE |
| Thickness (mm) | 0.244±0.016 | 0.255±0.009 | 0.262±0.021 |
| WVP (× 10 ⁻⁹ g/m.s.Pa) | 1.41±0.058 | 1.19±0.043 | 1.05±0.026 |

SC: sodium caseinate, PG: persian gum, ZOE: zingiber officinale extract, WVP: Water vapor permeability

Microbial changes

In this study, microbial changes for TVC and TPB counts were investigated in rainbow trout fillets samples as displayed in Figure 1a and b. The baseline TVC count of fresh trout fillets was 3.33 log CFU/g, indicating good quality of fish. Ceylan et al. (2020), reported that the initial value of control fillets varied within 3-4 log CFU/g. The mean TVC for film packed samples was significantly less than the control samples during storage at 4 °C. The count of TVC reached 4.47, 5.28,

and 5.7 log CFU/g ($P < 0.05$) for the samples packed with the SC + PG + 1.5% ZOE films on days 8, 12, and 16, respectively. On the other hand, the TAMB values were 5.16, 6.00, and 7.13 log CFU/g ($P < 0.05$) for the control samples on days 8, 12 and 16, respectively. These results demonstrate that the application of ZOE films led to a decline in microbial growth and improved storage time of trout samples. Alizadeh Sani et al. (2017) demonstrated whey protein isolate packaging containing TiO₂ and rosemary EO could reduce TVC counts in lamb meat. In another study, Radha krishnan et al. (2015) revealed that corn starch packaging with clove and cinnamon EOs reduced TVC counts of raw beef meat for 15 days, which was consistent with the result of our study.

The counts of TPB were recorded as 3.22 log CFU/g of sample on the beginning day of storage ($P < 0.05$). After day 16, populations of TPB were 7.36, 7.21, 5.63, and 5.32 log CFU/g for treatments C, C1, C2, and C3, respectively. The maximum permissible level of psychrotrophic count is 6 log CFU/g. In agreement, Uçak (2019) demonstrated a decrease in TPB count and an extent in shelf life in trout fillets using gelatin film containing garlic peel extract during refrigerated storage.

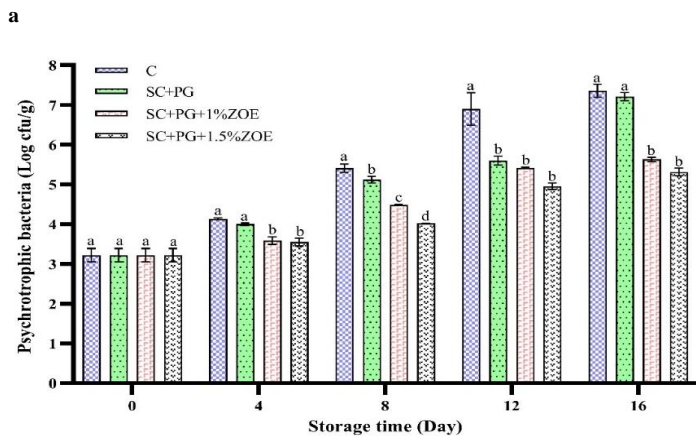
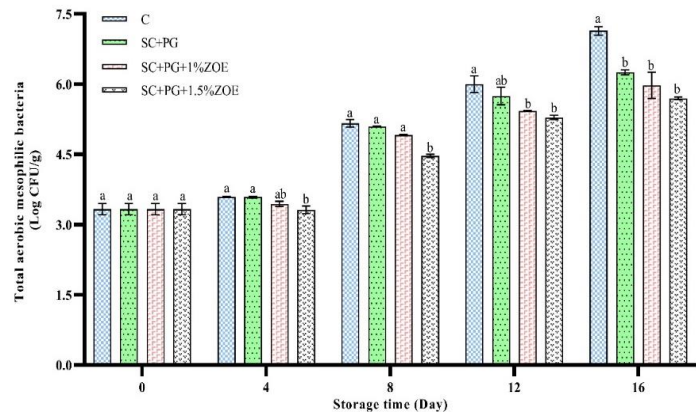


Figure 1 Effect edible films containing ZOE on the a) TAMB, b) TPB count of trout fillet during storage at 4°C.

Chemical properties

The pH values of rainbow trout fillets were 6.34, 7.03, 6.72, 6.52, and 6.45 (at the end of storage) for C, SC+PG, SC+PG+1%ZOE, and SC+PG+1.5%ZOE, respectively. Based on our results, the pH amounts of control were higher than acceptable limit at the end of storage (Figure 2). During storage, pH was low in SC-PG film-wrapped samples containing ZOE. The pH amounts of all fish samples diminished in 4 days, then increased until end of storage. The decrease of pH value was related to production of lactic acid by glycogenolysis which occurs after death in fish while the increase afterward was due to the production of volatile compounds by fish spoilage bacteria (T. Mehdizadeh et al., 2019). Chen et al. (2024) that showed chitosan/polyvinyl alcohol in combination with ginger EOs could notably decrease pH value in sea bass.

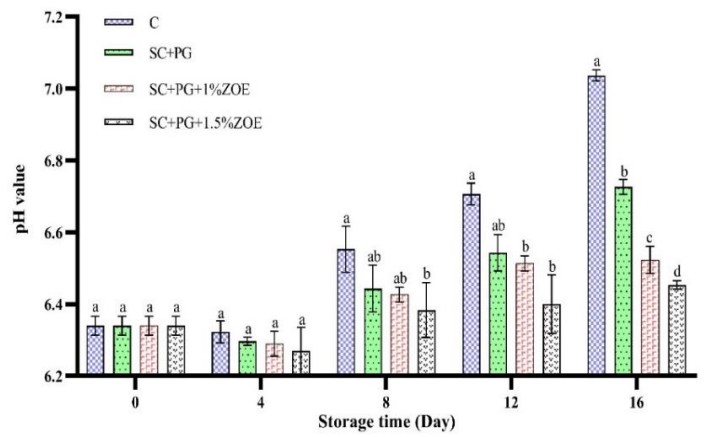


Figure 2 Effect of SC-PG films containing ZOE on the pH value of trout during storage at 4°C.

PV shows the amount of ingredients responsible for off-flavors/odors, whose detection at the initial steps of rancidity is commonly used as a quality indicator. Figure 3 represents the results of PV during the 16 days' storage at 4 °C. The initial PV in the analyzed fish fillets was 1.19±0.02 mmol per kg of fish sample. No significant difference ($P > 0.05$) was observed on the first day of storage among different samples. All films showed less PV than control. During storage, a significant rise in PV content was detected in control samples in comparison with the samples wrapped in SC+PG film or in SC+PG film containing 1 and 1.5% ZOE. At the end of the storage period (day 16), SC+PG+1.5%ZOE wrapped samples reached a remarkable ($p < 0.05$) lower PV value (4.47) as compared to the control or SC+PG samples, which reached a higher level of 6.15 and 5.78, respectively. In the control fillet, PV value revealed a rapid rise, while PV elevation of the ZOE-containing groups had slow trend. This is probably due to the antioxidant activities of zingiber officinale extract. Zhang et al. (2023) suggested that agar-sodium alginate films containing ginger EOs are effective in delaying the generation of primary lipid oxidation products in beef meat kept by refrigeration ($4 \pm 1^\circ\text{C}$). Similarly, Zhang et al. (2021) reported that a sodium alginate-agar-ginger EOs coating showed lower PV values for beef meat under refrigerated conditions.

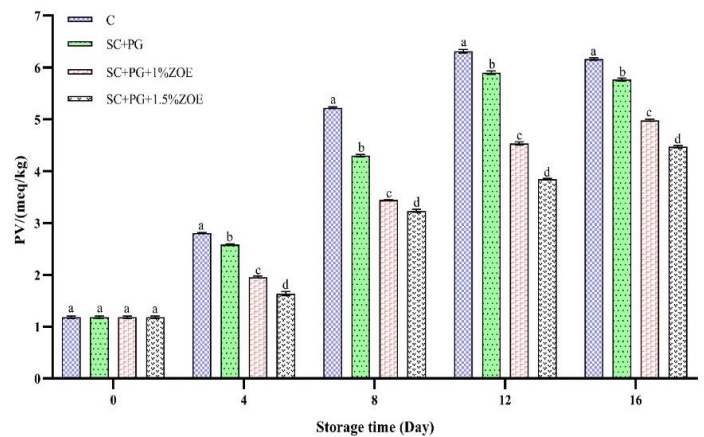


Figure 3 Effect of SC-PG films containing ZOE on the PV value of trout during storage at 4°C.

The TBA values for controlled and packaged trout fillets during storage can be found in Fig 4. Baseline TBA values were recorded equally for all samples at 0.18 mg MDA/kg. There was no statistically significant difference ($P > 0.05$) on the first and fourth days of storage between different samples. However, there was a significant difference between the control and coated samples on days 12 and 16. Also, during the storage days for all groups, an increase in TBA values was observed. TBA values of the control group and SC+PG without LEO were higher than those of the SC+PG films with ZOE. The films containing 1.5 % ZOE caused considerable reduction in TBA contents of trout fillets ($p < 0.05$). The results of the antioxidant properties of EOs and extracts can also be concluded to stop the formation of radical chains, decomposition of peroxides, binding of transition metal ion catalysts and interaction with free radicals. In accordance with these results, studies reported that EOs were effective in diminishing TBA in rainbow trout. Barkhordari et al. (2021), who evaluated the effect of apple peel extract and zein—including ginger EOs—on the shelf-life of the chicken thigh meat at refrigerated storage, found remarkably lower TBA levels as a parameter showing oxidation.

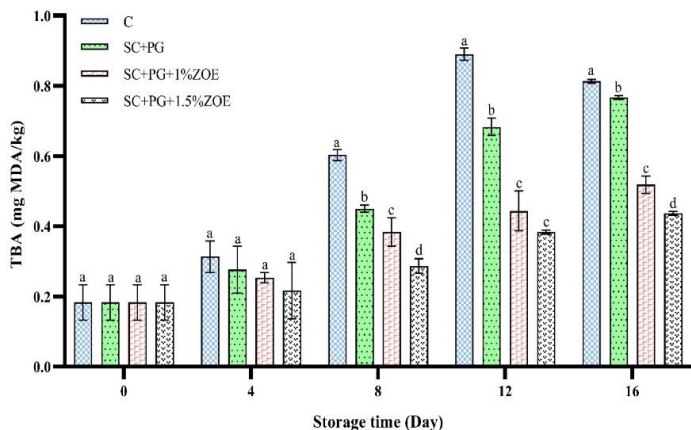


Figure 4 Effect of SC-PG films containing ZOE on the TBA value of trout during storage at 4°C.

Table 3 Effect of SC-PG films containing ZOE on the sensory properties of trout at 4°C

| Sensory attributes | Treatment | Storage period (days) | | | | |
|--------------------|------------------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| | | 0 | 4 | 8 | 12 | 16 |
| Texture | Control | 5 ± 0.00 ^a | 3.83 ± 0.41 ^b | 2.83 ± 0.41 ^b | 1.83 ± 0.41 ^c | 1.5 ± 0.55 ^b |
| | SC+PG | 5 ± 0.00 ^a | 4 ± 0.00 ^b | 3.17 ± 0.41 ^b | 3 ± 0.00 ^b | 2 ± 0.00 ^b |
| | SC+PG+ 1% ZOE | 5 ± 0.00 ^a | 4.67 ± 0.52 ^a | 3.67 ± 0.52 ^{ab} | 2.83 ± 0.75 ^b | 2.33 ± 0.82 ^b |
| | SC+PG+ 1.5 % ZOE | 5 ± 0.00 ^a | 4.83 ± 0.41 ^a | 4.33 ± 0.82 ^a | 3.83 ± 0.41 ^a | 3.33 ± 0.52 ^a |
| Odour | Control | 5 ± 0.00 ^a | 3.67 ± 0.52 ^b | 3 ± 0.00 ^c | 2.33 ± 0.52 ^c | 1.33 ± 0.52 ^c |
| | SC+PG | 5 ± 0.00 ^a | 3.83 ± 0.41 ^b | 3.5 ± 0.55 ^{bc} | 2.5 ± 0.55 ^{bc} | 2 ± 0.00 ^b |
| | SC+PG+ 1% ZOE | 5 ± 0.00 ^a | 4.67 ± 0.52 ^a | 4 ± 0.00 ^b | 3.17 ± 0.41 ^{ab} | 2.67 ± 0.52 ^a |
| | SC+PG+ 1.5 % ZOE | 5 ± 0.00 ^a | 5 ± 0.00 ^a | 4.67 ± 0.52 ^a | 3.83 ± 0.41 ^a | 3 ± 0.00 ^a |
| Colour | Control | 5 ± 0.00 ^a | 3.67 ± 0.52 ^b | 3 ± 0.00 ^c | 2 ± 0.00 ^b | 1.33 ± 0.52 ^c |
| | SC+PG | 5 ± 0.00 ^a | 4 ± 0.00 ^{ab} | 3 ± 0.63 ^a | 2.5 ± 0.55 ^b | 1.83 ± 0.41 ^{bc} |
| | SC+PG+ 1% ZOE | 5 ± 0.00 ^a | 4.33 ± 0.52 ^{ab} | 3.67 ± 0.52 ^a | 2.83 ± 0.75 ^{ab} | 2.33 ± 0.52 ^{ab} |
| | SC+PG+ 1.5 % ZOE | 5 ± 0.00 ^a | 4.67 ± 0.52 ^a | 4.67 ± 0.52 ^a | 3.67 ± 0.52 ^a | 2.83 ± 0.41 ^a |
| Overall | Control | 5 ± 0.00 ^a | 3.67 ± 0.52 ^b | 3 ± 0.00 ^c | 2.17 ± 0.41 ^b | 1.67 ± 0.52 ^c |
| | SC+PG | 5 ± 0.00 ^a | 4 ± 0.00 ^b | 3.17 ± 0.41 ^{bc} | 2.5 ± 0.55 ^b | 2 ± 0.00 ^b |
| | SC+PG+ 1% ZOE | 5 ± 0.00 ^a | 4.17 ± 0.41 ^b | 3.83 ± 0.41 ^{ab} | 2.83 ± 0.41 ^b | 2.5 ± 0.55 ^b |
| | SC+PG+ 1.5 % ZOE | 5 ± 0.00 ^a | 4.83 ± 0.41 ^a | 4.33 ± 0.82 ^a | 3.83 ± 0.41 ^a | 3.33 ± 0.52 ^a |

SC: sodium caseinate, PG: persian gum, ZOE: zingiber officinale extract.

CONCLUSION

To summarize, SC-PG based films contain ZOE were utilized to lengthen the storage time of trout. The microbial analysis revealed that the TVC and TPB counts increased during trout storage and were lower in the treatment groups compared to control. In addition, the PV and TBA indices of trout grew meaningfully during storage days. Sensory properties indicated that the texture, odor, color and overall acceptance of the trout samples packaged in SC+PG +1.5% ZOE active film was significantly higher than those of control. The results suggested that the shelf life of trout increased for 9-10 days using this composite film. Thus, the application of antimicrobial/antioxidant films based on eco-friendly polymers such as SC+PG loaded with ZOE has proved to be a beneficial system to retain microbial, oxidation, and sensory quality of perishable foods such as seafoods and meats. However, in order to overcome some limitations, these systems can be used in combination with other protecting methods such as modified atmosphere packaging (MAP), and non-thermal techniques.

Acknowledgments: This study was supported by Tabriz University of Medical Sciences, Tabriz, Iran (Grant No: 61993).

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Sensory evaluation

Sensory properties of trout fillet samples are presented in Table 3. The results showed that with increasing storage time, a decrease in sensory scores is observed, while fish samples are considered acceptable for human consumption until the sensory score reaches 4. Also, the non-film samples showed lower scores than the others. The texture and color properties as well as the overall acceptability of the SC + PG and SC + PG + 1 % ZOE samples were good for 8 days. Samples containing 1.5% ZOE showed the highest scores in sensory evaluation up to day 12. According to the sensory results, the score of the control samples was lower while that of the SC-PG + 1.5% ZOE samples was higher than the other groups. Our results were consistent with a study by Noori et al. (2018) that improved the sensory properties of chicken breast fillet by adding ginger essential oil (6%) for 12 days.

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