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Shelf-life extension and quality attributes of sauced silver carp fillet: A comparison among direct addition, edible coating and biodegradable film

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ABSTRACT

Nowadays, antimicrobial packaging materials is attracting remarkable attention as one of the preferred emerging technologies to prevent the development and spread of spoilage and pathogenic microorganisms via food foodstuffs. The aim of the present study was to incorporate *Ziziphora clinopodioides* essential oil (ZEO; 0 and 0.5%), apple peel extract (APE; 0 and 1%) and zinc oxide nanoparticle (ZnO; 0 and 0.5%) into sauced silver carp fillet using three techniques including direct addition, edible coating and composite film based on sodium alginate-carboxymethylcellulose (SA-CMC) to increase the shelf life (microbial, chemical and sensory properties) and inhibit the growth of *Listeria monocytogenes* during refrigerated storage over a period of two weeks. The fillet coated with ZEO 0.5% + APE 1% + ZnO 0.5% significantly exhibited the lowest bacterial population for the entire of storage period ($P < 0.05$). All treated samples tended to retard the increases in total volatile base nitrogen, trimethyl-amine nitrogen, pH and peroxide value. ZEO 0.5% + APE 1% + ZnO 0.5% and ZEO 0.5% + APE 1% showed the best sensory attributes (odor, color and overall acceptability). It can be concluded that the SA-CMC coatings or films enriched with ZEO 0.5% + APE 1% + ZnO 0.5% and ZEO 0.5% + APE 1% can be used as appropriate active packaging materials to preserve sauced silver carp fillets.

1. Introduction

Silver carp is one of the most commonly raised freshwater fish species throughout the world due to its wide availability, low cost of aquacultural production, high feed efficiency ratio and nutritional values (Valipour Kootenaie, Ariaii, Khademi Shurmasti, & Nemati, 2017). It is well known to be rich in proteins, polyunsaturated fatty acids, lipid soluble vitamins and micronutrients (Siddaiah, Sagar Reddy, Raju, & Chandrasekhar, 2001). Nevertheless, marine food products including fish are highly vulnerable and deteriorate during post-mortem storage owing to their high water holding capacity, free amino acids, low connective tissue, neutral pH and tissue enzymes (Kakaei & Shahbazi, 2016). Different preservation techniques have been studied to improve the quality and extend the shelf life of seafood including active and modified atmosphere packaging, addition of chemical and natural preservatives, smoking, salting, edible coatings and biodegradable films (Amanatidou et al., 2000; Kakaei & Shahbazi, 2016; Ojagh, Rezaei, Razavi, & Hosseini, 2010; Shahbazi & Shavisi, 2016).

Sodium alginate (SA) and carboxymethylcellulose (CMC) are popular candidates to be used as packaging materials due to their intriguing properties such as eco-friendly nature, biodegradability, film-forming ability, edibility and non-toxicity (Han & Wang, 2017; Hao et al., 2017). They have potential to improve physicochemical, textural and organoleptic properties of food by retarding microbial growth and lipid oxidation, preventing the loss of protein functionality, reducing dehydration and providing an excellent barrier to moisture and oxygen (Mohebi & Shahbazi, 2017). With the advent of nanotechnology, various types of nanoparticles such as cellulose (Shavisi, Khanjari, Basti, & Shahbazi, 2017), clay (Abdollahi, Rezaei, & Farzi, 2012), silver (Wei, Sun, Qian, Ye, & Ma, 2009; Zhang, Luo, & Wang, 2010) and zinc oxide (Nafchi, Alias, Mahmud, & Robal, 2012) have been used to improve the antimicrobial properties of biopolymer films. The potential application of nanocomposite polymers within the food industry, electronic, chemistry, medicine and other biotechnological approaches

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(Grunlan, Choi, & Lin, 2005; Song et al., 2013; Wu et al., 2017). Zinc oxide nanoparticle (ZnO) is an emerging additive for production of bionanocomposite coatings and/or films and has been included in the generally recognized as safe (GRAS) list of the Food and Drug Administration (Rahman, Mujeeb, & Muraleedharan, 2017). A recent study suggested that chitosan film containing ZnO 2% showed a remarkable effect against microbial population of raw beef meat during refrigerated storage over a period of six days (Rahman et al., 2017).

Numerous organic acids, enzymes, fungicides and natural compounds derived from fruits and plants have been incorporated into the edible coatings or films to develop bioactive packaging materials with antibacterial and antioxidant properties (Hao et al., 2017; Kakaei & Shahbazi, 2016; Ojagh et al., 2010; Rahman et al., 2017). Recent studies have reported that *Ziziphora clinopodioides* essential oil (ZEO) and apple peel extract (APE) have antioxidant and antimicrobial properties and subsequently help the industry to meet consumer demands for healthier seafood products (Du, Olsen, Avena-Bustillos, Friedman, & McHugh, 2011; Kakaei & Shahbazi, 2016; Mohebi & Shahbazi, 2017). Mild et al. (2011) also investigated the effect of apple-based films containing cinnamaldehyde against antibiotic resistant (D28a and H2a) and susceptible (A24a) *Campylobacter jejuni* strains on chicken breast. According to their results, films containing 1.5 and 3% cinnamaldehyde reduced the population of all strains in the range of 0.2–2.5 log CFU/g and 1.8 to 6 log CFU/g, respectively after 3 days of refrigerated storage (Mild et al., 2011).

Considering the advantages of ZEO, ZnO and APE, the assembling of CMC-SA film or coating with these compounds can be a promising approach for maintaining fish quality and safety. Therefore, the aim of the present study was to incorporate ZEO (0 and 0.5%), APE (0 and 1%) and ZnO (0 and 0.5%) into the silver carp fillet using three techniques including direct addition, edible coating and composite film based on SA-CMC in order to retard the deterioration of the fish fillets during storage under refrigerated condition. The characterization of resulted films were evaluated using Fourier transform infrared spectroscopy (FTIR) and scanning electron microscope (SEM).

2. Materials and methods

2.1. Materials

The *Z. clinopodioides* was obtained from Gilan-e-Gharb, Kermanshah, Iran (March–July 2016). CMC and SA powders were purchased from Sigma-Aldrich, UK. Commercial APE was purchased from Gol Adonis Daru (Tehran, Iran). Food-grade ZnO (20 nm diameter and purity >99%) was purchased from Iranian Nanomaterials Pioneers (Razavi Khorasan, Iran). All media, solvents and chemicals were purchased from Merck, Germany.

2.2. Isolation of essential oil

The collected *Z. clinopodioides* leaves were washed with distilled water and dried at room temperature in the shadow for ten days. It was ground and submitted to hydrodistillation for 3 h in a Clevenger-type apparatus. The ZEO was dried over anhydrous sodium sulfate and kept in a sealed vial at refrigerated temperature before further use.

2.3. Gas chromatography–mass spectrometry (GC-MS) analysis of essential oil

Analytical gas chromatography-mass spectrometry was carried out using a Thermo Quest Finningan apparatus fitted with HP-5MS 5% phenyl methylsiloxane capillary column (30 m length × 0.25 mm i.d. and 0.25 μm film thickness). Helium (purity: 99.99%; flow rate 1.2 ml/min and split ratio 1:20) was used as a carrier gas. Column temperature was initially set at 50 °C, then gradually increased to 265 °C at a rate of 2.5 °C/min and finally fixed at 280 °C. The MS was run in the electron ionization mode, using an ionization energy of 70 eV.

2.4. Preparation of Listeria monocytogenes

L. monocytogenes (ATCC 19118) was purchased from the culture collection of the Iranian Research Organization for Science and Technology, Tehran, Iran. Inoculum dose (5 log CFU/ml) was prepared according to the method reported by Kakaei and Shahbazi (2016).

2.5. Preparation of sodium alginate-carboxymethyl cellulose coatings and films

The composite SA-CMC coating solution was prepared by dissolving 0.75 g SA and 0.25 g CMC powders into 100 ml sterile distillated water and stirring on a magnetic stirrer/hot plate at 65 °C for 3 h. Glycerol (0.75 ml/g CMC or SA powder) was added to plasticize the solution. After stirring for 30 min, tween 80 as an emulsifier (0.25 ml/100 ml Ch or CMC emulsion) was added into the resulting dispersion, subjected to constant magnetic stirring for 30 min and homogenized at 1300×g for 1 min. Then, ZEO (0 and 0.5% v/w), APE (0 and 1% w/w) and ZnO (0 and 0.5% w/w), alone and in combination (Supplementary 1), were added to the mixture and homogenized using a homogenizer at 1300×g for 1 min to facilitate proper mixing of the compounds (Hao et al., 2017; Noshirvani, Ghanbarzadeh, Mokarram, Hashemi, & Coma, 2017). Control composite SA-CMC solution was prepared as described above without incorporating the aforementioned compounds.

To produce films, 50 ml of each solubilized SA-CMC solution was poured onto the glass petri dishes (120 mm diameter) and dried at ambient temperature for 48 h. The dried films were peeled off from the casting surface and used for packaging of sauced fillets.

2.6. Characterization of nanocompostie sodium alginate-carboxymethyl cellulose films

FTIR spectra were evaluated using an FTIR spectrometer (Bruker, model ALPHA, Germany) within the wave number range of 400–4000 cm^{-1}. Surface morphology of films was observed using a TeScan MIRA3 SEM.

2.7. Preparation of sauced fish fillets

A total of forty silver carp (average weight = 1345 ± 12 g) were acquired from a local aquaculture farm (Kermanshah, Iran). The silver carp were beheaded, skinned, eviscerated, washed in cold sterilized water and sectioned into 5 × 4 × 1 cm individual pieces. Preparation of sauced fish fillets were conducted according to the traditional Iranian method. Briefly, the samples were immersed in 100 ml of marinade composed of powdered walnut, pomegranate juice, olive oil, parsley, chopped onion, salt and red pepper, removed from the marinade and left to leak for 1min.

For inoculation of the pathogenic bacterium, the fillets were immersed for 5 min at room temperature in the diluted bacterial suspension with agitation by a shaker to ensure even distribution of the *L. monocytogenes*. The samples were air-dried for 30 min at refrigerated temperature to facilitate bacterial attachment (Mohebi & Shahbazi, 2017).