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Antimicrobial and antioxidant efficiency of nanoemulsion-based edible coating containing ginger (*Zingiber officinale*) essential oil and its effect on safety and quality attributes of chicken breast fillets

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ABSTRACT

Nanoemulsion-based edible sodium caseinate coating containing ginger essential oil (GEO) (3 and 6% wt) was applied onto chicken breast fillet to extend its shelf life. GC-MS analysis showed that the most components of GEO were α-zingiberene (24.96%) and then β-sesquiphellandrene (12.74%). Comparison between conventional emulsion and nanoemulsion-based coatings was applied by particle size, polydispersity index and ζ-potential analyses. Antibacterial potential of active coatings was more than their antioxidant activity and it was significantly ($p < 0.05$) increased when nanoemulsion was fabricated. Nanoemulsion based edible coatings with 6% of GEO nanoemulsion caused to significant decrease of total aerobic psychrophilic bacteria of refrigerated chicken fillets during 12 days. The effect of GEO on TBARS levels of fillets was not significant. The lowest color difference and cooking loss were obtained for nanoemulsion coated samples. The highest total acceptance was recorded for coated fillets with 6% of GEO nanoemulsion during storage. Generally the GEO nanoemulsion was more effective than its conventional emulsion in extending the durability of chicken breast fillets.

1. Introduction

The consumption of poultry meat has increased over the last decades due to the relatively low cost of production as compared to meat products, low fat content, high nutritional value and distinct flavor (Latou, Mexis, Badeka, Kontakos, & Kontominas, 2014). However, high moisture and protein content and high pH value, transform the poultry meat to a susceptible product for growth of spoilage and pathogenic microorganisms (Kerry, O'Grady, & Hogan, 2006). Nowadays, a serious challenge for the poultry industry is the shelf life extension of raw poultry meat. The short shelf life of the chicken meat (approximately 4–5 days) reveals the necessity of using novel preservation methods (Latou et al., 2014).

Antimicrobial edible coating is one new approach to control microbial growth and thus, improving safety and delaying spoilage of meat, fish and poultry products (Umaraw & Verma, 2017). Essential oils (EOs), are aromatic and volatile oily extracts obtained from plant materials, including flowers, buds, roots, bark, and leaves by means of expression, fermentation, extraction or steam distillation. EOs are commonly utilized as flavoring agent in foodstuffs. They are also known as a class of natural preservatives because their strong antimicrobial and antioxidant properties have been demonstrated in previous investigations (Jayasena & Jo, 2013). Consumers' growing concern over the safety of synthetic chemical preservatives has led to the increase of tendency to the utilization of EOs as antioxidant and antimicrobial agents in food industry (Viuda-Martos et al., 2010).

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A variety of antimicrobial edible coatings containing EOs have been developed for fresh poultry, red meat and fish products. Studies on the effect of chitosan-based coating containing cinnamon EO on rainbow trout (Ojagh, Rezaei, Razavi, & Hosseini, 2010), soy protein-based coating enriched with thyme and oregano EOs on fresh ground beef patties (Emiroğlu, Yemiş, Coşkun, & Candoğan, 2010), whey protein isolate (WPI)-based coating loaded with oregano and clove EOs on chicken breast fillet (Fernández-Pan, Carrión-Granda, & Maté, 2014) and chitosan-based coating incorporated with orange peel EO on deepwater pink shrimp (Alparslan & Baygar, 2017) are examples for using of EO activated edible coatings in meat industry.

However, adding EOs into edible coatings can increase the opacity thus affecting the appearance of products. The main reason of this effect is that the dispersion of EOs within aqueous-based products is rather difficult due to their low-water solubility. Thus, large particulate structures will be formed that causes to scatter visible light. In addition, the volatile nature of EOs causes their significant loss during coating process and storage (Ma et al., 2016). More researches are focused on improving the properties of antimicrobial coatings with EOs. Nanoemulsion-based colloidal systems are used to improve properties of EO loaded coating solutions. Oil-in-water nanoemulsions consist on lipid nano droplets (between 10 and 100 nm diameter) dispersed in an aqueous solution (McClements, 2011). The advantages of nanoemulsions are include: more transparency, enhanced physicochemical properties, more stability, masking the taste or smell of core material and thus lower effect on organoleptic properties of food, improved biological activity of EO by increasing the surface area allows using lower doses of EO (McClements & Rao, 2011). Recently, some researches have been reported on the using of active edible coating containing EO-loaded nanoemulsions for shelf life extension of green beans (Donsì et al., 2015; Severino et al., 2015, 2014), fresh-cut *Fuji* apples (Salvia-Trujillo, Rojas-Graü, Soliva-Fortuny, & Martín-Belloso, 2015), fish fillets (Wu et al., 2016) and low-fat cheese (Artiga-Artigas, Acevedo-Fani, & Martín-Belloso, 2017).

Ginger, the root of the plant *Zingiber officinale* Rosc. is one of the most commonly used spices around the world. The EOs of ginger (GEO) have been reported to have strong antimicrobial, antifungal and antioxidant activities (Singh et al., 2008; El-Baroty, Abd El-Baky, Farag, & Saleh, 2010). The main chemical compounds of GEO are α-zingiberene, camphene, ar-curcumene and β-sesquiphellandrene (Singh, Maurya, Catalan, & de Lampasona, 2005). There are a few reports about the using of GEO in preparation of active films (Atarés, Bonilla, & Chiralt, 2010a; Atarés, De Jesús, Talens, & Chiralt, 2010b; Tongnuanchan, Benjakul, & Prodpran, 2013). But its direct addition to a food or application in the formulation of an edible coating for real food commodities is not yet reported. Sodium caseinate (SC) is a low cost and available water-soluble biopolymer obtained by the acid precipitation of casein, the main protein in cow's milk (Audic & Chaufer, 2005). SC has a good film forming ability due to the potential of formation of hydrogen bonding, electrostatic interactions and hydrophobic forces (McHugh & Krochta, 1994). SC-based edible coatings are attractive for food applications due to their high nutritional quality, excellent sensory properties, good transparency, high water vapor and gas barrier properties and potential to provide food products with adequate protection from their surroundings (Kristo, Koutsoumanis, & Biliaderis, 2008).

The efficacy of various edible coatings on the shelf life of chicken meat have been evaluated by a number of researchers (Fernández-Pan et al., 2014; Latou et al., 2014; Seol, Lim, Jang, Jo, & Lee, 2009), however, no definite data exist on the application of SC-based edible coating in chicken meat products. Moreover, despite of approving the drastically elevated antioxidant and antimicrobial activity of EOs as a result of nanoemulsion formation in the literature, to the best of our knowledge, there are no reports on the preparation of GEO nanoemulsions-loaded edible coating. Additionally, any former study has not used GEO for preservation of chicken meat. The objective of the present work was to study the effect of SCbased edible coating containing GEO nanoemulsions to extend the shelf-life of fresh chicken breast fillets stored at 4 °C. Chemical composition, antioxidative and antimicrobial behaviors of GEO were determined. After that, the influence of edible coatings formed from conventional emulsions compared with nanoemulsions on the quality attributes of chicken fillet was assessed in order to establish a possible enhancement of GEO functionality due to the reduced droplet size.

2. Materials and methods

2.1. Materials

The mature and healthy rhizomes of ginger (*Zingiber officinale*) were purchased from the local market of Urmia, Iran. Food-grade and spray dried sodium caseinate (protein content > 80%) (obtained from Caragum Parsian, Tehran, Iran) was used for the coating formulations. Fresh chicken breast fillets were provided by a local poultry processing plant (Morghe Khanegi Co., Urmia, Iran) within one hour after slaughter in insulated polystyrene boxes on ice. Glycerol, and other reagents used were of analytical grade and were purchased from Merck (Darmstadt, Germany).

2.2. Extraction and identification of the ginger essential oil

The fresh ginger rhizomes were properly washed and thinly grated and were subjected to hydrodistillation for 4 h in the glass Clevenger-type tool according to the method recommended by the European Pharmacopoeia (Singh et al., 2008). The obtained light yellow colored oil with a pleasant odor, was dried over anhydrous sodium sulfate and stored in sealed vials at 4 °C for GC/MS analysis.

GC-MS analyses were carried out on an Aglient 8690N GC-MS system (USA) equipped with HP-5MS capillary column (phenyl methyl siloxane, 30 m × 0.25 mm i.d × 25 μm). Oven temperature was held at 60 °C for 5 min and then programmed to 250 °C at a rate of 3 °C/min and kept constant at 250 °C for 10 min. Injector and detector temperature was adjusted to 260 °C and helium was used as carrier gas at a flow rate 1.5 ml/min. Ionization voltage of mass spectrometer in the EI-mode was equal to 70 eV and ionization source temperature was 250 °C. The compounds were identified by comparison of retention indices (RI, HP-5) with those reported in the literature and by comparison of their mass spectra with the Wiley GC/MS Library, Mainlib Library and Replib Library data published mass spectra data (El-Baroty et al., 2010).

2.3. Preparation and characterization of nanoemulsion

2.3.1. Nanoemulsion preparation

GEO nanoemulsion was formulated according to the method of Ghosh, Mukherjee, and Chandrasekaran (2013) with some modifications. Non-ionic surfactant Tween80 (HLB = 15) and distilled water were used for preparation of nanoemulsion. Concentration of GEO (5% v/v) and Tween80 (30% wt of GEO) were fixed for both of emulsion and nanoemulsion formulations. Coarse emulsion was prepared by gradually and continuous adding of GEO and surfactant to water with shaking at 3000 rpm. Then, the coarse emulsion was subjected to ultrasonic emulsification using a 20 kHz Sonicator (OPTIMA, XL100K, Germany). The operation power was adjusted to 200 W and a sonotrode containing a piezoelectric crystal with a probe diameter of 15 mm was applied. Sonicator probe was