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Development of a sweet potato starch-based coating and its effect on quality attributes of shrimp during refrigerated storage

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ABSTRACT

Shrimp is enjoyed for the uniqueness of its flavor and texture. However, shrimp has limited shelf-life due to biochemical, microbiological or physical changes during postmortem storage. In this study, edible coatings from sweet potato starch (SPS) and variable levels of thyme essential oil (TEO) (0, 2, 4 and 6 g/100 g) were developed to maintain the quality of shrimp during refrigerated storage. Application of SPS-based coating resulted in lower pH ($p < 0.05$). Coated samples activated with TEO had lower counts of bacteria and lipid oxidation ($p < 0.05$) toward the end of storage. Textural and color properties of coated shrimp were generally more acceptable. Sensory scores indicated no significant changes in all samples during storage. The results of this study suggest that the TEO incorporation at 4 g/100 g into SPS- based coating could be useful in extending the shelf life of shrimp meat during refrigerated storage.

1. Introduction

Shrimp is the most popular seafood in the U.S. and the world due to its high nutritional value as well as the distinctive flavor and texture (Mejlholm, Bøknæs, & Dalgaard, 2005). In addition, mercury content of shrimp is relatively lower compared to other seafood (Bragagnolo & Rodriguez-Amaya, 2001). However, shrimp is a quite perishable seafood. The quality of shrimp is influenced by several factors such as method of handling, storage condition, and processing time. The shelf life of shrimp is mostly determined by both microbiological and enzymatic spoilage when stored at refrigerated temperature. Shrimp contains large amounts of free amino acids that are contributed to microbiological spoilage (Yassoralipour, Bakar, Abdul Rahman, Abu Bakar, & Golkhandan, 2013). In addition, shrimp may suffer from black spot (melanosis) due to the activity of polyphenol oxidase (Montville, Matthews, & Kniel, 2012). It has been reported that, 1.2 g/100 g of the lipids that are located just under the shrimp shell are highly unsaturated phospholipids (Bak, Andersen, Andersen, & Bertelsen, 1999). Therefore, lipid oxidation and rancid off-flavors may also occur even under refrigeration or freezing conditions (Montville et al., 2012). As a result, it is necessary to devise a strategy to prevent or slow down quality degradation of shrimp during storage time.

Currently, there is a great interest in the application of natural preservatives in food industry. However, direct application of them has some drawbacks including changes of organoleptic properties, fast release of active compounds and interacting with other food ingredients. These limitations have directed researchers to adopt coating as a method alone or in combination with other methods to increase the shelf-stability of perishable foods such as shrimp. The features of coating application can contribute to maintain the quality of seafood products, and delay spoilage at low temperature with minimum effects on the characteristic of the product (Dursun & Erkan, 2014). Previous studies in our laboratory have demonstrated that antimicrobial films from sweet potato starch (SPS) are effective in reducing pathogens in foods (Issa, Ibrahim, & Tahergorabi, 2017). Sweet potato (*Ipomoea batatas* Lam) is an inexpensive and readily available vegetable that is cultivated extensively for its nutritious value across many regions of the world. Sweet potato is rich in dietary fiber, minerals, vitamins, and antioxidants, such as phenolic acids, anthocyanins, tocopherol, β-carotene, and ascorbic acid (Issa, Ibrahim, & Tahergorabi, 2016). These nutrients may migrate to food if SPS is used as an edible coating and therefore, increases the nutritional value of the product. SPS with a 58–76 g/100 g starch content (on a dry basis), has properties that are similar or better than those of ordinary potato starch (Issa et al., 2017). Therefore, SPS could be a proper candidate to be used for edible coating of food products.

In addition, edible coatings are excellent vehicles for incorporating a wide variety of additives, such as antioxidants and antimicrobial agents. The effect of these additives may result in improvement of food quality and safety. The application of essential oils (EOs) has proven to be an effective preservation method that extends the shelf life of fresh foods (Anyanwu, Alakhrash, & Hosseini, Ibrahim, & Tahergorabi, 2016; Quitral et al., 2009). EOs are aromatic, oily liquids that are obtained

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from plant material. According to Tsigarida, Skandamis, & Nychas, 2000; Skandamis & Nychas, 2001, certain oils stand out as better antibacterials than others for meat applications. Thyme (*Thymus vulgaris*) essential oil (TEO) has been found to possess antimicrobial activity *in vitro* against a broad spectrum of bacteria, such as *S. Typhimurium*, *L. monocytogenes* (Singh, Sing, & Bhunia, 2003) *Escherichia coli*, *Pseudomonas fluorescens*, *Staphylococcus aureus*, *Lactobacillus plantarum*, and *Bacillus subtilis*, as well as *Shigella sonnei* and *Shigella flexneri* (Bagamboula, Uyttendaele, & Debevere, 2004). TEO has also been reported to have antioxidative activities comparable to those of α-tocopherol and BHT (Miguel et al., 2004). TEO is considered to present no risk to the health of consumers, has been registered by the European Commission (Burt, 2004), and is generally recognized as safe (GRAS) by the Food and Drug Administration (FDA, 2009). To the best of our knowledge, there is no published report of antimicrobial and antioxidant properties of SPS-based edible coating with TEO that has been tested on shrimp. Therefore, this study was designed to: (1) Investigate physicochemical (texture, color, pH, and lipid oxidation) properties; (2) assess the melanosis and sensory quality; and (3) evaluate the antibacterial activity of the coated shrimp during storage at refrigerated temperature.

2. Material and methods

2.1. Edible coating preparation

The coating solution was prepared according to the previously described method with slight modifications (Ghanbarzadeh & Almasi, 2011). An aqueous solution of SPS was prepared by dissolving 50 g of SPS in 1000 ml distilled deionized H_2O, moderately stirred at room temperature, and then heated to 80 °C for 30 min. After gelatinization, glycerol (Fisher Scientific, Fair Lawn, New Jersey) was added as a plasticizer at a concentration of 2 g/100 g (*w/w*, on dry basis of the weight of starch) and the resulting dispersion was subjected to further mixing for 5 min. Then, TEO (*Thymus Vulgaris*, New Direction Aromatics, Mississauga, ON, Canada), previously mixed with Tween 80 (Fisher Scientific, Fair Lawn, NJ, USA) (0.25 g/g of essential oil) to help create a uniform and stable distribution, was incorporated into the coating solution at several concentrations (0, 2, 4, and 6 g/100 g *v/v* on the basis of neat film solution). Samples were then homogenized at 20,000 rpm for 5 min using a laboratory homogenizer (Homogenizer, OMNI International, Kenneswa, GA, USA), after being degassed using an ultrasonic bath (Branson sonifier, Model 3800, Danbury, CT, USA).

2.2. Treatment of shrimp samples

Medium size, beheaded, unpeeled, and deveined frozen shrimp were purchased from a local grocery and delivered to laboratory by using a cold box. Frozen shrimp had been treated with phosphate according to the information provided at the label of product. Shrimp samples were thawed at refrigerator temperature (4 °C) before application of the coating solutions. Shrimp samples were randomly assigned to five lots consisting of one control lot (un-coated) and four lots treated with the following coating solutions: SPS coating and SPS coating with TEO, final concentrations of 0.0, 2.0, 4.0, or 6.0 g/100 g (v/v) with a shrimp/solution ratio of 1:2 (w/v) at 4 °C for 15 min. The shrimp were gently swirled in the coating solution using a sterile glass rod to ensure complete contact of the shrimp with the coating solution. Shrimp were removed and allowed to drain for 5 min on a pre-sterilized metal net under a biological containment hood. After draining of the excess coating solution, samples were placed into sterile Petri plates. All the plates were stored at 4 °C and triplicate samples were taken at days 1, 4, and 8 for physico-chemical, antibacterial, sensory, and melanosis assessments.

2.3. Determination of pH

The measurement of pH was performed by the method described by Alakhrash, Anyanwu, and Tahergorabi (2016) with slight modifications. Shrimp meat (2 g) was homogenized with 10 vol of deionized water for 1 min using a homogenizer (OMNI International, Kenneswa, GA, USA). The homogenate was kept at room temperature for 5 min. The pH was determined using a hand-held pH meter (Oakton, Vernon Hills, Il, USA).

2.4. Texture properties

Texture profile analysis (TPA) was measured using a texture analyzer (Model TA-XT2, Texture Analyzer, Texture Technologies Corp., Scarsdale, NY, USA) according to the method described by Tahergorabi, Beamer, Matak, and Jaczynski (2013). The result of force-time curves for TPA was defined by Bourne (2002), which includes hardness, cohesiveness, springiness, gumminess, chewiness, and resilience. The TPA is an empirical test which can be directly related to overall acceptance or hedonic ratings (Kim, Park, & Yoon, 2005).

2.5. Color properties

The color properties of coated shrimp were determined using a Minolta Chroma Meter CR-400/410 colorimeter (Konica Minolta Co. Ltd., Osaka, Japan), calibrated with a white calibration plate ($L^* = 97.57$, $a^* = -1.08$ and $b^* = 1.25$) supplied by the manufacturer that was placed in the slot of the instrument (Tahergorabi, Beamer, Matak, & Jaczynski, 2011). According to the CIE (Commission Internationale d'Eclairage of France) color system, the L* (lightness), a* (red to green), and b* (yellow to blue) tristimulus color values were determined (Lanier, 1992).

2.6. Lipid oxidation

Using the 2-thiobarbituric acid reactive substance (TBARS) assay of malondialdehyde (MDA) the oxidative rancidity of coated shrimp was measured as described by Tahergorabi et al. (2013). The calculation of TBARS values was determined by using a molar absorptivity of MDA (156,000 M^{-1} cm^{-1}) and results reported as mg MDA/kg of sample.

2.7. Aerobic plate count

All samples were subjected to microbiological analysis. A total of 1 g of shrimp muscles was added into peptone water (0.1 g/100 g), then the samples were homogenized for 1 min, samples were then serially diluted in 9 ml peptone water (0.1 g/100 g). The aerobic plate counts were enumerated by spread-plating of 1 ml of sample solution on sterile Petri-plates containing Plate Count Agar (Difco Laboratories, Detroit, MI, USA). Plates were incubated for 24 h at 35 ± 1 °C (Caballero, Alles, Le, Mozola, & Rice, 2015).

2.8. Melanosis assessment

A 10-point scoring test was used to evaluate black spots on the surface of shrimp. The melanosis was rated from 0 to 10. If there is no black spot on the surface of shrimp then it was rated as zero (0) while 10 indicating that 80–100 g/100 g of the shrimp's surface is covered by black spots (Nirmal & Benjakul, 2009).

2.9. Sensory evaluation

Over 100 untrained panelists volunteered to evaluate the shrimps stored in refrigerator on days 1 and 8. Raw samples which were labeled by random three digit codes were placed on trays and served to the panelists. Panelists were asked to score appearance, odor, and texture

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