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Effect of active edible coatings made by basil seed gum and thymol on oil uptake and oxidation in shrimp during deep-fat frying

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ABSTRACT

The effect of active coating treatments on oil uptake, moisture loss, lipid oxidation, texture, color, and sensory evaluation of shrimp after deep-fat frying process was investigated. Compared with the uncoated samples, coating treatments decreased the oil uptake and moisture loss of fried shrimp by 34.50 and 13.9%, respectively. Fried shrimp samples were analyzed for peroxide value (PV) and thiobarbituric acid (TBA). The most reduction in lipid oxidation (46.4% for PV and 40.8% for TBA) was observed when shrimp samples were coated with CS4 (containing 10% thyme), while the control samples had the highest values of PV and TBA after deep-fat frying process. Coated fried samples had significantly lower toughness and stiffness than control samples ($P < 0.05$). In terms of sensory evaluation, there was no significant difference in color, smell, and taste among the treatments ($P > 0.05$). However, for the texture, juiciness, chewiness, and overall acceptability, coated fried samples had higher scores than control.

1. Introduction

Deep-fat frying is a cooking method, where fat or oil is used as the heat transfer medium, in direct contact with the food at a temperature above the boiling point of water (Chen, Chen, Chao, & Lin, 2009; Varela, Bender, & Morton, 1988;). Frying affects heat and mass transfer that causes oil to move into the product and the water to escape from the product into the oil. High temperature causes partial evaporation of water, which moves away from the food and through the surrounding oil. Oil uptake by the product is an important issue, affecting the nutritional and organoleptic qualities of the product (Pedreschi & Moyano, 2005). Shrimp is a good source of protein, mineral, vitamins, and rich in polyunsaturated fatty acids especially the n-3 fatty acids (Mohebbi, Akbarzadeh, Shahidi, Moussavi, & Ghoddusid, 2009). On the other hand, *Litopenaeus vannamei* species of shrimp have low production cost and high market demand. (Basiri, Shekarforoush, Aminlari, & Akbari, 2015).

Oil uptake is affected by oil quality, product and oil temperature, frying duration, initial moisture content of food ingredients, product shape and content, porosity of coating, and the method of frying (Blumenthal, 1999; Fan & Arce, 1986; Parimala & Sudha, 2012; Pinthus, Weinberg, & Saguy, 1993; Pinthus, Weinberg, & Saguy, 1995). Global food demand is shifted toward the consumption of low fat and low calories food products to reduce blood cholesterol, hypertension, and coronary heart diseases (Haghshenas, Hosseini, Mosavi Khanghah, Shabkoohi Kakesh, & Komeily Fonood, 2014). Therefore, modification in any one of the given factors may affect oil uptake during frying. Using of gums to reduce the oil content is one of the simplest and most convenient methods which does not require variation in equipment design. Specifically, the hydrocolloid coatings are often known to reduce the oil uptake of fried foods. The effectiveness of hydrophilic hydrocolloids in reducing oil uptake during frying has been reported in some studies. Parimala and Sudha (2012) reported that addition of guar gum at 0.5% w/w level led to puris having improved quality characteristics to a greater extent with respect to moisture retention, lowering of oil content upon frying with softer and pliable texture, and better keeping quality.

Freitas et al. (2009) investigated the influence of the use of edible coatings from three different hydrocolloids (pectin, whey protein, and soy protein isolate) during the deep frying of a pre-fried, frozen product preformed from cassava. They showed that whey protein showed the best results with respect to fat absorption, presenting a reduction of 27% for the cassava purée product. Addition of gellan gum and guar gum as hydrocolloid coatings markedly reduced the heat transfer coefficients and oil uptake in potato strips during frying process (Kim, Lima, Bae, Lee, & Lee, 2011). There is no scientific literature about reducing moisture loss and oil uptake of shrimp by gums during frying process. However, DehghanNasiri,

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Mohebbi, TabatabaeeYazdi, & Haddad Khodaparast, 2012 determined the kinetic modeling of mass transfer during deep-fat frying of shrimp nugget. The objective of this study was to investigate the effects of active coatings made from basil seed gum and thymol (as an antioxidant compound) on the oil uptake, moisture loss, and the quality properties of deep-fat fried shrimp.

2. Materials and methods

2.1. Material

The basil seeds were obtained from the local medical market in Tehran, Iran. Thymol (99.5%) and glycerol were supplied by Sigma-Aldrich (Madrid, Spain). Methanol, chloroform, acetic acid, sodium thiosulfate, and starch solution as an indicator were obtained from Merck (Darmstadt, Germany). All chemicals used were of analytical grade. Fresh, non-treated Pacific white shrimp (*L. vannamei*) were purchased from the shrimp farms (Bandar-Abbas city, Iran). Immediately after harvesting, shrimp were dipped in liquid nitrogen and transported to the Department of Food Science. Upon arrival, shrimp were deshelled, washed in cold water, and stored on ice until use.

2.2. Preparation of coating solutions

Basil seed gum was extracted according to the method of our previous work (Khazaei, Esmaiili, EmamDjomeh, Ghasemlou, & Jouki, 2014). Briefly, aqueous basil seed gum was extracted from whole seeds using distilled water. Then, the swelled seeds were stirred with a rod paddle blender at 1500 rpm, at 35 °C for 10 min to scrape the gum layer off the seed surface. The solutions were then filtered with cheese cloth and the obtained gum was dried by an oven at 45 °C. The gum was dissolved in distilled water (1 g/100 ml) at 45 °C for 15 min under continuous stirring. Thymol was added at various concentrations (0, 6, 8, and 10% w/w) and glycerol was used as plasticizer (0.35 g/100 ml). According to the formulation of edible coatings, the coating solutions (CS 1–4) were prepared.

2.3. Color measurement of coating solutions

Color of the coating solutions was determined as L (lightness, 0 = black, 100 = white), a (−a = greenness, +a = redness) and b (−b = blueness, +b = yellowness), using CIE colorimeter (Hunter associates laboratory, Inc., VA, USA). Total color difference (ΔE) and whiteness index (WI) were calculated using the following equations (Eqs. (1–2):

$$\Delta E = \sqrt{(L - L^*)^2 + (a - a^*)^2 + (b - b^*)^2}, \quad (1)$$

where L^*, a^*, and b^* are the color parameter values of the standard white plate ($L^* = 93.49$, $a^* = -0.25$ and $b^* = -0.09$) and L, a, and b are the color parameter values of the sample.

$$\mathrm{WI} = 100 - \sqrt{(100 - L)^2 + a^2 + b^2} \quad (2)$$

2.4. Shrimp coating treatments

The peeled shrimps were immersed in the coating solutions (CS1–4) for 30 s and the coated samples were allowed to dry overnight. After drying the emulsion, coating of shrimp became invisible. Then the coated shrimps were fried under frying conditions.

2.5. Frying conditions

A thermostatically temperature controlled fryer was used (Rotofriteuse190, Delonghi, France) with a capacity for 5 L. Fresh refined sunflower oil (Nina, Iran) due to its high smoking point was used for each new treatment, and maintained at the processing temperature for 1 h before starting the frying procedure, using a proportion of 1:20 (shrimp to oil). Samples were placed in a wire basket and then submerged for the required time (300 s) at 161 °C. Frying oil was replaced after each frying batch and samples were immediately removed from oil, and were blotted with tissue paper to remove excess oil on the surface after the frying time. The samples were allowed to get cool at room temperature before further tests.

2.6. Analysis of fried samples

2.6.1. Measurements of oil uptake

After frying the shrimp samples, they were cooled down in a strainer at room temperature. Then, their oil contents were determined using the soxhlet extraction method (AOAC, 1990). The oil content was obtained in terms of dry basis. The oil uptake (%) was calculated according to Eq. (3):

$$\text{Oil uptake}\,(\%) = \frac{o_f - o_r}{o_r} \times 100, \quad (3)$$

where O_f is the oil content of fried shrimps and O_r is the oil content of raw shrimp expressed as dry matter.

2.6.2. Moisture content

Moisture content analyses of the whole fried samples were performed according to the AACC (1986). The drying process was determined by a conventional oven at 105 °C for 24 h.

2.6.3. Lipid oxidation

2.6.3.1. Peroxide value (PV). PV measures the content of hydroperoxides and is often used as an indicator for primary products of lipid oxidation. Peroxide value was determined as described by Lea (1952). Briefly, lipid was extracted from the shrimp samples with a mixture of water, methanol, and chloroform (30:50:100). A total of 1 g of extracted lipid was dissolved in 25 ml of chloroform–acetic acid (2:3) blended solution. Then saturated solution of KI (1 ml) was added. The mixture was kept in dark for 10 min. After the addition of distilled water (30 ml), the mixture was titrated against sodium thiosulphate (0.01 M) using starch solution (1%) as an indicator. Peroxide values (POVs) were calculated as follows:

$$\mathrm{PV} = (S - B) \times N \times 1000/\mathrm{W}. \quad (4)$$

In the formula, PV refers to peroxide value of sample (mmol/kg); S refers to the volume of $Na_2S_2O_3$ standard solution consumed by sample (ml); B refers to the volume of $Na_2S_2O_3$ standard solution consumed in blank test (ml); N refers to the molar concentration of $Na_2S_2O_3$ standard solution (mol/L); and W is the mass of fat extracted (g).

2.6.3.2. Thiobarbituric acid reactive substances (TBARS). The TBARS test is based on the formation of colored products when TBA is reacted with malonaldhyde or other TBA reactive substances, which are presumed to be produced from oxidized lipids or fats (Kanner & Rosenthal, 1992). 2-Thiobarbituric acid reactive substances (TBARS) assay was performed according to the method of Nirmal and Benjakul (2009) and TBARS value was expressed as mg malondialdehyde (MDA)/kg shrimp muscle. White shrimp samples (2.0 g) were mixed with 50 ml of TBARS solution, containing 0.20 g of TBA, 7.5 g of TCA, and 0.50 ml of hydrochloric acid. The mixture was set in boiling water bath for 10 min and after cooling it was