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Changes in physicochemical properties and protein structure of surimi enhanced with camellia tea oil

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ABSTRACT

The objective of this study was to determine the effects of different concentrations of camellia tea oil on surimi gel physicochemical properties and protein secondary structure. With the increase of camellia tea oil concentration (0–8 g/100 g of surimi), surimi gel hardness, whiteness, WHC, overall acceptability, storage modulus (G′) and the indexes of ionic bonds and hydrophobic interactions were increased significantly ($P < 0.05$). Cryo-scanning electron microscopy (Cryo-SEM) showed that the oil occupied the void spaces of the protein matrix and formed a firmer structure. The Raman spectroscopy study showed that there was a decreased trend in α-helix content and increased trend in β-sheet content in surimi protein as the oil content increased. Correlation analysis showed that the hardness was negatively correlated to the α-helix content ($r = -0.958$, $P < 0.01$) and positively correlated to the β-sheet content ($r = 0.958$, $P < 0.01$) and hydrophobic interactions ($r = 0.944$, $P < 0.01$) of surimi gels. These results suggest that the presence of the oil could change the micro-environment and molecular structure of surimi proteins and further affect the physicochemical properties of surimi gels. In general, when the concentration of camellia tea oil was 8 g/100 g of surimi, the surimi gel showed the most favorable properties.

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1. Introduction

Surimi is a commercial preparation of fish myofibrillar protein. It is produced by solubilizing myofibrillar proteins during the comminuting and salting stages of manufacturing (Kong et al., 2016). Surimi is an inexpensive source of protein and is a useful ingredient for producing various kinds of processed foods due to the unique gelling properties of the myofibrillar protein. Surimi-based products such as fish ball, fish sausage, breaded fish stick and paupiette have become increasingly popular due to the preferred textural properties and high nutritional value of surimi.

Physicochemical properties including morphology, pasting properties, and gel properties are important criteria to evaluate the quality of surimi. Lipids play an important role in the texture, juiciness, color, and flavor of comminuted meat product, and removal of fat will result in meat products with a rubbery and dry texture (Luruena-Martínez, Vivar-Quintana, & Revilla, 2004). However, in the process of frozen surimi manufacturing, fish fat is usually trimmed away to increase the concentration of myofibrillar protein and to extend the storage time. Therefore, to improve the physicochemical and gel properties of surimi, exogenous lipids are usually added during surimi product processing (Chojnicka, Sala, De Kruif, & Van de Velde, 2009; Debusca, Tahergorabi, Beamer, Partington, & Jaczynski, 2013; Pietrowski, Tahergorabi, & Jaczynski, 2012). Shi et al. (2014) reported that the addition of vegetable oil (soybean, peanut, corn, and rap oils) significantly increased the whiteness of surimi gels ($P < 0.05$). Alvarez, Xiong, Castillo, Payne, and Garrido (2012) found that canola-olive oils favored gel network formation and gel elasticity in pork frankfurters. Chojnicka et al. (2009) also observed that oil/fat could increase the brittleness and change the functional properties of fish protein gels.

Myofibrillar protein is the primary functional ingredient of surimi-based products and is very important for the gelling properties of surimi (Kong et al., 2016). Thus, the influence of lipid on surimi gel properties may be related to changes in surimi protein

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structures. The presence of lipids could alter the molecular structure of proteins, induce the exposure of hydrophobic groups, and further affect the formation and stability of emulsions and the textures of many food products (Meng, Chan, Rousseau, Eunice, & Li, 2005). Shao, Zou, Xu, Wu, and Zhou (2011) studied the protein structural changes in heated meat batters prepared with different lipids (pork fat and soybean oil) and found that there was a significant decrease ($P < 0.05$) in α-helix content accompanied by a significant increase ($P < 0.05$) in β-sheet structure. Shao, Deng, Zhou, Xu, and Liu (2015) also indicated that disulfide bonds, hydrophobic interactions, and hydrogen bonds were the main interactions at the emulsion interface of pork meat proteins and lipids (animal fat or soybean oil) by Raman spectroscopic analysis.

Camellia tea oil, also known as the "olive oil of Asia", is one of most important edible oils, and it is rich in oleic acid and contains many natural antioxidants with various biological activities (Long & Wang, 2008; Zhang, Jin, Wang, & Xue, 2013). It has been utilized in China for more than 1000 years (He & Gu, 1982). However, there has been no report on the effects of different concentrations of camellia tea oil on the properties of surimi and surimi-based products. Preliminary studies in our lab showed that camellia tea oil could improve the gel properties of surimi, improve the taste of surimi-based products and have additional nutritional value. A better understanding of the structural changes of surimi enhanced with different concentrations of camellia tea oil could be helpful for elucidating the role of lipids in the protein matrix structure and lead to the development of new surimi-based products. Therefore, the objective of this study was to determine the effects of different concentrations of camellia tea oil on the physicochemical properties (texture profile, color, water holding capacity, microstructural properties, sensory properties, rheological properties) and protein secondary structure of surimi gels using Raman spectroscopy. Additionally, the relationships between the physicochemical properties and structural changes of surimi were also analyzed by correlation analysis to provide guidelines for improving surimi gel properties.

2. Materials and methods

2.1. Materials

Frozen surimi (White croaker, Grade A) was provided by Zhejiang Industrial Group Co., LTD. (Zhoushan, China) and stored at −80 °C until needed. The moisture of the surimi was 76.72 g/100 g. Natural Camellia tea oil (Hangzhou Jiusheng biotechnology Co., Ltd, Hangzhou, Zhejiang, China) and salt (Zhejiang Lanhaixing Salt Industry Group Co., Ltd, Hangzhou, Zhejiang, China) were purchased from a local supermarket (Hangzhou, Zhejiang, China). Sodium tripolyphosphate, sodium pyrophosphate, and sodium hexametaphosphate were purchased from Shanghai Lingfeng Chemical Reagent Co., LTD. (Shanghai, China).

2.2. Preparation of surimi gels

Frozen surimi was thawed at 4 °C for 12 h and then cut into small pieces (about 1 × 1 × 1 cm^3). Salt (2 g/100 g of surimi), compound phosphate (sodium tripolyphosphate: sodium pyrophosphate:sodium hexametaphosphate = 2:2:1, 0.3 g/100 g of surimi), camellia tea oil, and ice water (total 20 g/100 g of surimi) were added into the surimi and mixed thoroughly for 5 min in a Philips blender (Zhuhai special economic zones, Philips domestic appliance Co., Ltd), and during the homogenization, the temperature was carefully controlled at 4–10 °C. For different treatments, the final concentrations of camellia tea oil were 0, 2, 4, 6, 8, and 10 g/100 g of surimi, respectively. Oil was added to surimi paste by replacing chilled water (1:1, wt:wt) that is normally added during formulation of surimi paste. Surimi without camellia tea oil was used as a control. The pastes were then stuffed into plastic casing (22 mm in diameter), and both ends were sealed tightly. Subsequently, the samples were kept at 4 °C for 4 h and then heated in water bath at 90 °C for 20 min. The gels were cooled and stored at 4 °C for further analysis. Three measurements were performance for each sample.

2.3. Proximate analysis

Representative samples from each treatment were honogenized and analyzed, for percentage fat (ether-extractable), protein and hydroxyproline according to standard AOAC. (1990) procedures. Moisture content was determined by drying the sample at 105 °C over 24 h until a constant weight was achieved (Sánchez-González et al., 2008). Each sampling was performed in triplicate and reported as g/100 g (wet weight basis).

2.4. Texture analysis

Texture analysis was performed with a TA.XT Plus Texture Analyzer (Stable Micro System Company, UK). Samples stored at 4 °C overnight were cut into cylinders (22 mm in diameter and 20 mm in height). TPA test conditions were as follows, probe: P/36R; pre-test speed: 2.00 mm/s; test speed: 1.00 mm/s; post-test speed: 2.00 mm/s; strain: 60%; triggering mode: automatic (power); trigger force 5.0 g; 200 points per second. Fifteen replicates of measurements were taken.

Shear force was determined using a HDP/BSK-Warner probe. The parameters were as follows, pre-test speed: 2.00 mm/s; test speed: 2.00 mm/s; post-test speed: 2.00 mm/s; displacement: 20 mm; triggering mode: automatic (power); and trigger force 5.0 g. Fifteen replicates of measurements were taken.

2.5. Color evaluation

Surimi samples were equilibrated at room temperature (about 25 °C) for 1 h prior to the color measurement. The color values of surimi batters and gel samples were determined by a Color Quest XE colorimeter (HunterLab Co., Ltd, USA). Lightness (L^*), redness (a^*), and yellowness (b^*) values were recorded respectively. The whiteness (W) was calculated using the equation: $W = 100-[(100-L^*)^2+a^{*2}+b^{*2}]^{1/2}$. Fifteen replicates of measurements were taken.

2.6. Water holding capacity (WHC)

WHC was carried out based on a method proposed by Chen, Gerelt, Jiang, Nishiumi, and Suzuki (2006) with a slight modification. Gel samples were cut into thin slices, and approximately 3 g samples were weighed and placed between two layers of filter paper. Subsequently, the samples were placed at the bottom of centrifuge tubes and centrifuged (CR21GII high-speed refrigerated centrifuge, Hitachi, Japan) at 10,000 rpm for 10 min. Gels were weighed again after centrifugation. $WHC=W_2/W_1 \times 100\%$, where W_1 is the initial weight of gels, g; W_2 is the final weight of gels, g. Three replicates of the measurements were taken.

2.7. Cryo-scanning electron microscopy (Cryo-SEM)

The microstructures of surimi gels with different concentrations of camellia tea oil were observed using Cryo-scanning electron microscopy (Cryo-SEM). The samples were loaded on the cryospecimen holder and cryo-fixed in slush nitrogen (−196 °C), then quickly transferred to the cryo-unit in the frozen state. The frozen

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