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Short Communication

Effect of electron irradiation and heat on the structure of hairtail surimi

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HIGHLIGHTS

- The effects of irradiation and heat on surimi structure were investigated.
- Disulfide bonds were the main chemical interaction of heat-induced gel.
- The myosin thermal stability of irradiated surimi was lower than unirradiated surimi.
- The decrease in α-helix structure and increase in β-sheet structure were observed.

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ABSTRACT

Hairtail surimi was treated with electron radiation and heat, the chemical interactions, thermal properties and the structural changes were determined. The chemical interaction data indicate that the contribution of disulfide bonds to heat-induced gel formation was decisive. Irradiation promoted the formation of disulfide bonds during the cooking. Differential scanning calorimetry showed that the myosin and actin thermal transitions of irradiated surimi shifted to lower temperatures. And the myosin thermal stability of irradiated surimi was lower than unirradiated surimi. The Fourier transform infrared and Raman results showed the irradiation and heat treatments decreased the α-helix structure content and increased β-sheet structure content. This study may provide useful information for the effect of irradiation on the surimi gel properties.

1. Introduction

Surimi is the myofibrillar protein concentrate made from fish meat and can be further processed into various surimi-based gel products such as kamaboko, tempura, and chikuwa, which are very popular in Asia (Jiang et al., 2000). The most important functional characteristics of surimi products are the gel properties. Gelation is the result of protein denaturation, affected by inter and intramolecular covalent and noncovalent chemical interactions that include disulfide bonds, nonspecific associations, ionic bonds, hydrogen bonds, and hydrophobic interactions (Ding et al., 2011). Therefore, to better understand the internal mechanism of the gel properties, protein–protein chemical interactions should be investigated.

Electron irradiation is an effective way to eliminate pathogens, but irradiation can bring about structural modifications that could affect the functional properties of foods. In recent years, irradiated modification has become a research hotspot and has been widely concerned. However, studies relating to the effect of irradiation on surimi gel properties were rarely reported. Our previous study (Lin et al., 2015) to investigate the effect of different doses of electron irradiation on hairtail surimi gel properties had made some progress and physicochemical changes showed that 7 kGy electron irradiation significantly improved the gelation properties of hairtail surimi. Nevertheless, there is still some uncertainty about the precise mechanism of heat-induced surimi gel after irradiation. This is in part due to fewer studies on the structural changes in the surimi proteins (Sanchez-Gonzalez et al., 2008).

The objective of this study was to get insight into the gelation process of hairtail surimi after electron irradiation and heat using Fourier transform infrared and Raman spectroscopy technique. In addition, chemical interaction and thermal property experiments were performed to better understand the structural changes caused by irradiation and heat.

2. Materials and methods

2.1. Materials

Frozen hairtail surimi was vacuum-packed in polyethylene bags and kept at −40 °C.

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Table 1
Experimental design.

Symbol	Treatment
Control	Without any treatment
H	Heat-set gel
HC	Heat-set-cooked gel
I	Irradiated surimi
IH	Heat-set gel prepared from the irradiated surimi
IHC	Heat-set-cooked gel prepared from the irradiated surimi

2.2. Sample irradiation and surimi gel preparation

The experimental design is shown in Table 1. Hairtail surimi was exposed to a dose of 7 kGy with energy set at 10 MeV by an electron linear accelerator. The absorbed doses were determined by silver dichromate dosimeters, which were calibrated by National Institute of Metrology (PR China). The absorbed dose was within $\pm$3% of the targeted dose, max/min ratio was <1.2.

Frozen hairtail surimi was thawed at 4 °C for a night and cut into small chunks. Surimi chunks were chopped at a low speed for 2.5 min. Salt (3% w/w) was added, and the surimi paste was chopped at a low speed for 7.5 min. During the chopping, the temperature was kept below 5 °C. Then, the mixture was stuffed into a polyvinylidene casing and subjected to heat treatment. Heat-set gels were prepared by setting at 40 °C for 60 min. On the other hand, heat-set-cooked gels underwent a two-step treatment: first a 40 °C heat treatment for 30 min, then a 90 °C heat treatment for 30 min. After heating, both the heat-set and heat-set-cooked gels were immediately cooled in iced water for 30 min and stored at 4 °C for further analyses.

2.3. Determination of chemical interactions

The chemical interactions were determined according to the methods reported by Gomez-Guillen et al. (1997) and Careche et al. (1995).

2.4. Differential scanning calorimetry

The denaturation behavior of proteins in the irradiated hairtail surimi and control samples were determined using a differential scanning calorimetry analyzer equipped with an air cooling compressor and a liquid nitrogen cooler, respectively. Approximately 15 mg sample was hermetically sealed in an aluminum pan, and an empty hermetic pan was used as the reference. The samples were scanned between 5 and 90 °C at a heating rate of 10 °C/min.

2.5. Fourier transform infrared measurement

FTIR spectra were obtained from disks containing 1 mg freeze-dried sample in approximately 100 mg potassium bromide (KBr). All the spectra were obtained using an infrared spectrophotometer from 4000 to 400 cm^{-1} at a data acquisition rate of 4 cm^{-1} per point. The curve-fitting procedure was performed to determine the percentage of the absorption peaks using the PeakFit Version 4.12 software. Spectral data were analyzed using the Origin 8.0 software.

2.6. Raman measurement

Raman spectra of the samples were acquired using a Raman microscope, equipped with a solid-state laser, emitting at a wavelength of 785 nm. The conditions used were as follows: an incident laser power of 12 mW, a spectral resolution of 1.0 cm^{-1}, and an exposure time of 10 s. Raman spectra were obtained in the range 300–1800 cm^{-1}.

The phenylalanine band at 1003 cm^{-1}, insensitive to conformation or microenvironment, was normalized as the internal standard (Herrero et al., 2009). Percentages of protein secondary structures were determined according to the method reported by Alix et al. (1988). Raman spectra were processed using the Origin 8.0 software.

2.7. Statistical analysis

For each sample treatment (Table 1), three replications were conducted. All the samples were measured once in the whole experiment. The data were the average of the three replications' results. The results are expressed as mean $\pm$ standard deviation.

3. Results and discussion

3.1. Analysis of chemical interactions

Before studying the effect of irradiation on the chemical interactions of hairtail surimi protein, it was necessary to identify the major chemical interactions in the formation of surimi gels. The formation process of surimi can be divided into three stages: surimi, heat-set gel, and heat-set-cooked gel. Each of these three stages has distinct gelation properties: surimi does not gel at all; heat-set gel partly gels; and heat-set-cooked gel completely gels. The following section analyzes the changes in the chemical interactions of hairtail surimi protein during gel formation and the effects of irradiation on such interactions.

3.1.1. Bonding mechanisms during the heat-induced gelation of hairtail surimi protein

As shown in Fig. 1, the extent of nonspecific associations first increased and then decreased in the thermal gelation of surimi. The increase in the nonspecific associations was caused by sufficient grinding or comminution accompanied by salt addition to enhance protein solubilization and dispersion. In contrast, the decrease in the nonspecific associations was due to the reduced protein solubility in the heating process, which was caused by protein denaturation and aggregation (Gomez-Guillen et al., 1998). With increasing heating, the ionic and hydrogen bonds were significantly disrupted, indicating that they were not the main chemical interaction of surimi protein gel; Gomez-Guillen et al. (1998) also hold the same view. The higher hydrophobic interactions exhibited by the H compared to the HC can be attributed to the exposure of nonpolar peptides buried in the interior of the protein

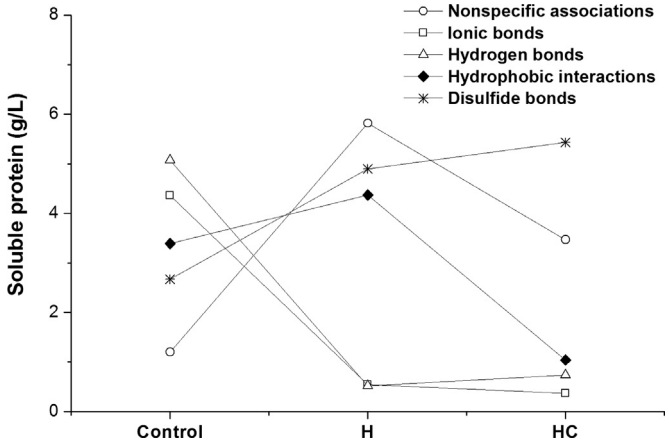

Fig. 1. Changes in chemical interactions during gel formation.