Radiation Physics and Chemistry 130 (2017) 316–320

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Effect of electron irradiation on the gel properties of *Collichthys lucidus* surimi

Siyao Deng [a,b,c], Liangyu Lv [a,c], Wenge Yang [a,b,c,*], Dalun Xu [a], Qiaoming Lou [a], Jinjie Zhang [a]

[a] School of Marine Sciences, Ningbo University, Ningbo 315211, China
[b] Collaborative Innovation Center for Zhejiang Marine High-Efficiency and Healthy Aquaculture, Ningbo University, Ningbo 315211, China
[c] Key Laboratory of Animal Protein Food Deep Processing Technology of Zhejiang Province, Ningbo University, Ningbo 315211, China

HIGHLIGHTS

- Electron irradiation improves the gel properties of surimi.
- 5 kGy irradiation made a compact and ordered gelation network structure.
- Irradiation could decrease the trichloroacetic acid-soluble peptide content.
- Irradition and heat treatments affect the second structure of surimi protein.

ARTICLE INFO

Article history:
Received 13 April 2016
Received in revised form
25 August 2016
Accepted 27 August 2016
Available online 12 September 2016

Keywords:
Electron irradiation
Surimi gel
Gel properties
Protein secondary structure

ABSTRACT

This study evaluated the effect of electron irradiation on the gel properties of *Collichthys lucidus* surimi. The results showed that irradiation decreased the trichloroacetic acid-soluble peptide content of the surimi gel. At 5 kGy, a more compact and ordered gel network structure was achieved, resulting in a higher gel strength, whiteness, and water-holding capacity than non-irradiated surimi gel. During heat-induced formation of the gel, the α-helix content decreased, whilst the β-sheet and β-turn content increased. Irradiation treatments also decreased the α-helix content and increased β-sheet content, and this transformation is beneficial for the protein denaturation and gel formation. Collectively, the results suggest that electron irradiation, at an optimal dose of 5 kGy, could be an effective method for application in the surimi manufacturing industry

1. Introduction

Collichthys lucidus is a commercially important fish species in China, where the annual catch rate has now reached to 300,000 t. Due to its high reproductive output and affordable price, it is an important raw material for surimi production. Surimi and its products possess enhanced elasticity and gelation properties due to the gel properties of fish myofibrillar proteins. With the advantage of being high in protein, low in fat, and in a convenient form for human consumption, processed surimi has become a modern aquatic processing product with great potential (Kristinsson and Rasco, 2000). Gel strength and color are the primary factors used to evaluate the quality of gelation in surimi gels. The improvement of surimi gel properties has become a major focus of the surimi processing industry.

Electron irradiation is well known as an effective cold sterilization method and has been widely used in industrial food preservation, as well as in food quality improvement, food safety, and other allied fields in many countries. However, few studies have assessed the effect of electron irradiation on the gel properties of surimi. It is known that electron irradiation can change the conformation of surimi proteins, leading to protein denaturation, aggregation, and gelation (Lin et al., 2015). It is hypothesized that this effect will improve the gel properties of surimi and surimi products.

Therefore, this study was designed to assess the effect of electron irradiation treatment on the gelation properties of *C. lucidus* surimi and to determine the most effective dose to enhance the properties of surimi gel. Furthermore, we adopted Raman spectroscopy to identify how electron irradiation promotes the process of heat-induced gelation at the microscopic protein structure level, in order to inform the development of beneficial guidance to the surimi industry.

* Corresponding author.
E-mail address: yangwenge@nbu.edu.cn (W. Yang).

http://dx.doi.org/10.1016/j.radphyschem.2016.08.022
0969-806X/

2. Materials and methods

2.1. Sample preparation

Frozen *C. lucidus* surimi samples (thickness 1 cm) were vacuum-packed in polyethylene bags and irradiated at doses of 1–9 kGy, at a rate of 1 kGy/s, using an electron linear accelerator. The absorbed dose was in all cases within 3% of targeted dose. Suwari were prepared by surimi setting at 40 °C for 30 min. Surimi gels underwent a two-step treatment: first a 40 °C heat treatment for 30 min, then a 90 °C heat treatment for 30 min (Alvarez et al., 1999). After heating, both the suwari and surimi gels were immediately cooled in iced water for 30 min, and stored overnight in a refrigerator at 4 °C.

2.2. Textural analysis

Gels were equilibrated at room temperature for about 30 min before analysis. Cylinder-shaped surimi gel samples measuring 25 mm in diameter and 25 mm in length were prepared and tested. Breaking force and deformation were measured by a texture analyzer equipped with a spherical plunger (5 mm diameter), with a depression speed of 60 mm/min.

2.3. Determination of whiteness

The color of the surimi gels was determined with a HunterLab spectrophotometer, by measuring L*(lightness), a*(redness/greenness), and b*(yellowness/blueness) values. The 'whiteness' of the gels was subsequently calculated according to the following formula:

$$\text{Whiteness} = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}}$$

2.4. Determination of water holding capacity (WHC)

Determination of the WHC of surimi gels was performed according to the method of Sánchez-González et al., (2008).

2.5. Determination of TCA-soluble peptide content

The TCA-soluble peptide content of surimi gels was determined as follows: 3 g gel samples were weighed and homogenized with 27 ml of cold TCA (5%). The homogenate was incubated at 4 °C for 1 h and then centrifuged at 8000*g* for 5 min. TCA-soluble peptides in the supernatant were quantified according to the Lowry method (Lowry et al., 1951) and expressed as l μmol tyrosine/g sample.

2.6. Scanning electron microscopy (SEM)

Gel samples were cut into small cubes ($1 \times 1 \times 1$ mm^3) and immersed in 2.5% glutaraldehyde in 0.2 M potassium phosphate buffer overnight. The fixed specimens were dehydrated by treatment with serial concentrations of ethanol and tertbutyl alcohol solutions. Samples were then vacuum-freeze-dried and observed using a scanning electron microscope.

2.7. FT-Raman spectroscopic analysis

Samples were analysed using a Raman spectrometer, equipped with a solid-state laser, emitting at a wavelength of 785 nm. Raman spectra were collected from each sample with a detection range of 300–1800 cm^{-1}. Normalization of individual spectral band intensities was achieved using the peak near 1003 cm^{-1} as an internal standard. This spectral peak is attributed to phenylalanine amino acid, which was known to be insensitive to the micro-environment. Protein secondary structures were determined as the percentage of α-helix, β-sheet, random turn and random coil structures in accordance with Alix et al. (1988).

2.8. Statistical analysis

For each irradiation dose treatment, three replicate samples were analysed. Data points represent the average of the three replicates. The results are expressed as means ± standard deviations. Significant differences between mean values were identified using Duncan's multiple range test and a significance level of $P < 0.05$.

3. Results and discussion

3.1. Textural properties of surimi gels

Breaking force and deformation indicates the hardness and elasticity of surimi gel. The product of these two factors determines the gel's strength (Sakamoto et al., 1995). A substantial increase in the breaking force was observed with increasing dose, from 0 kGy to 5 kGy, as shown in Fig. 1. A higher breaking force indicates an enhancement of gel hardness. In contrast, breaking force decreased at doses above 5 kGy. Jaczynski and Park (2003) similarly found a remarkable reinforcement of gel hardness with increasing doses of irradiation. They deduced that the increased hardness might result from an increase in hydrophobic interactions after irradiation. Meanwhile, an irradiation dose of 5 kGy resulted in the highest breaking deformation of the surimi gels. Gel strength is an important index of the quality of surimi products because it directly affects customer acceptability. Surimi gel strength revealed a tendency to increase and then decrease with increasing irradiation dose. The highest gel strength and strongest elasticity were achieved at 5 kGy.

3.2. Whiteness of surimi gel

The color of surimi products is a crucial sensorsy factor for consumers, and in case of surimi gel, whiteness is an important quality factor. As shown in Fig. 2, the whiteness values of the gels in the 3 kGy and 5 kGy irradiation groups were statistically significantly higher than those of the non-irradiated gels samples

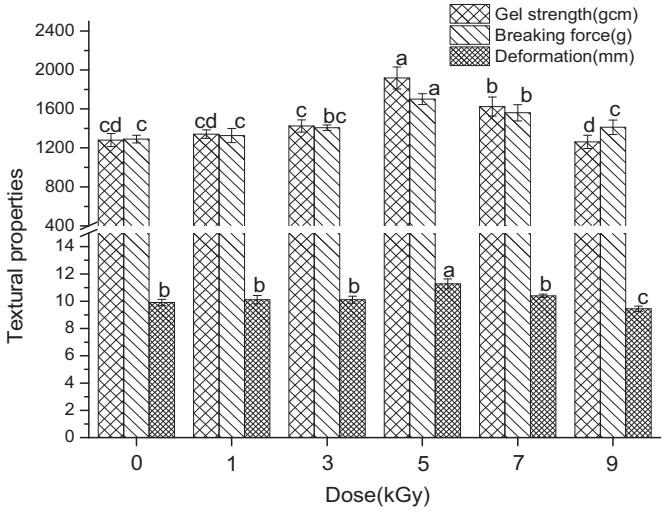

Fig. 1. Effect of doses on gel strength, breaking force and deformation of surimi gels. Bars represent the standard deviation (n=3). Different letters on the top of bars indicate statistically significant differences ($P < 0.05$).