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Gelatin addition improves the nutrient retention, texture and mass transfer of fish balls without altering their nanostructure during boiling

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ABSTRACT

The effect of fish gelatin addition on mass transfer, nutrient loss, texture and nanostructure of fish balls was investigated. Mass transfer models were built and the root-mean-square-errors were 0.1432, 0.3178 and 0.1000 for exponential, power-law and linear models, respectively. After gelatin addition, the mass transfer coefficient/model parameter and moisture content increased, and the hardness and chewiness of fish balls decreased. Myofibrils were imaged using atomic force microscope (AFM). The length of the myofibrils was greater than 15 μm before and after boiling for 10 min; however, they decreased to around 14 and 11 μm after 20 and 30 min boiling, indicating degradation of myofibrils. Meanwhile, there was no significant difference among different groups, suggesting that the added gelatin did not affect the nanostructure of the fish balls. Furthermore, increasing gelatin addition resulted in fewer water-soluble proteins and peptides in the boiling water. The results suggest that added gelatin increased the mass transfer coefficient/model parameter by increasing the moisture content and decreasing the nutrient loss. It also improved the texture by decreasing the hardness and chewiness, and did not affect the nanostructure of fish ball myofibrils.

1. Introduction

Fish balls are popular in Australia, Germany, Japan, Southeast Asia and China (Tee & Siow, 2014). In Singapore, the fish processing industry produces 30,000 tons of fish balls annually, with a value of S$80 million, mainly for local consumption. Furthermore, around 90% of the food consumed in Singapore is imported from other countries (AVA, 2015). To improve food security, Golden Pomfret (*Trachinotus blochii*, hereafter GP) has been spawned in local farms. However, the hard texture of GP makes it unsuitable for manufacturing fish balls. Gelatin can be extracted from fishery processing byproducts, such as skin and bones (Jiang, Liu, Du, & Wang, 2010; Kittiphattanabawon, Benjakul, Sinthusamran, & Kishimura, 2016; Mohtar, Perera, & Quek, 2010). Utilising this byproduct-derived gelatin might improve the texture of the fish balls and affect their mass transfer and nutrient loss. Meanwhile, adding fish gelatin into GP fish balls could also improve food security and address the environment pollution caused by fish processing waste, which is 1500 tons annually in Singapore (Feng, Bansal, & Yang, 2016).

Boiling is the most common method of processing fish balls. During boiling, the proteins in the fish become denatured, gelatinised and form a network, which is accompanied by absorption of water. Meanwhile, water-soluble proteins and peptides leach into the boiling solution, resulting in nutrient loss. The mass transfers of frying and salting meat products (Amiryousefi, Mohebbi, Khodaiyan, & Asadi, 2011; Du, Zhou, Xu, & Li, 2010) have been studied; however, reports about mass transfer of boiling meat with added gelatin are limited.

Previous research used pork collagen (PC) in porcine myofibrillar protein (MP) gels to evaluate the changes in viscoelastic and thermal properties (Doerscher, Briggs, & Lonergan, 2004). Collagen has been added into frankfurters to determine the effect of collagen on frankfurter texture (Calhoun, Eilert, & Mandigo, 1996).

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Rheological properties of chicken balls were optimised by adding κ-carrageenan, fish gelatin and chicken meat (Yasin, Babji, & Ismail, 2016). There have also been reports of extending the shelf life of fish balls (Yi et al., 2011), developing different flavours and investigating the composition and physicochemical properties of fish balls (Kolekar & Pagarkar, 2014).

The objective of this research was to establish mass transfer models of fish balls during boiling and investigate the effect of gelatin on the mass transfer. The nanostructure of myofibrils, major component of fish muscle (Li et al., 2016; Pazos, Méndez, Vázquez, & Aubourg, 2015), was investigated to determine fish protein degradation and the effect of gelatin on the nanostructural changes in fish balls. Measuring the texture of fish ball allowed us to correlate the nanostructure and texture. Moreover, proteins and peptides in the boiling solution were analysed by Assisted Laser Desorption Ionisation Time of Flight Mass Spectrometry (MALDI-TOF-MS), which improved the understanding of mass transfer process and nutrient loss of fish balls during boiling.

2. Materials and methods

2.1. Materials

The local farmed GP (*Trachinotus blochii*), salt and potato starch were purchased from a local market. Commercial tilapia fish gelatin (200 Bloom) was bought from Jiangxi Cosen Biology Co., Ltd (Yingtan, Jiangxi, China). The gelatin contained 83.14% protein, 0.68% ash, 9.12% moisture and 7.06% other materials, according to the product information.

2.2. Preparation of fish gelatin solution and fish balls

Fish gelatin solutions (6%, 9%, 12%, w/w) were prepared following the method of Yang and Wang (2009), with some modifications. Gelatin was soaked in distilled water at 4 °C overnight. The gelatin solution was then placed in a 55 °C water bath for 15 min until it was totally dissolved and homogeneous.

The purchased fish were transferred to the laboratory in cold storage bags with ice inside within 30 min (Singh, Benjakul, Maqsood, & Kishimura, 2011). To make the fish balls, the fish head was removed, followed by deboning and removal of the skin. Two large fillets were obtained and minced in a homogeniser. The minced fillet (100 g), 7.5 g of potato starch, 1.25 g of salt and 12.5 ml of gelatin solution were mixed and homogenised well. The concentrations of the gelatin solution were 0, 0.06, 0.12 and 0.24 g/ml, respectively. Samples of 20 g of the mixture were taken out and rolled into a ball. The fish balls were boiled for 1, 2, 3, 4, 5, 10, 15, 20, 25, 30 and 60 min respectively, in triplicate, and the fish balls were weighed after boiling.

2.3. Mass transfer models and the mass transfer coefficient/model parameter

The mass of fish balls before and after boiling for various time was recorded, and used to fit into three mass transfer models to obtain the formula and mass transfer coefficients/model parameters. Three mass transfer models, exponential, power-law and linear, were built to predict the weight of a fish ball after boiling, which are shown below.

1 Exponential model

$$\frac{M - M_0}{M_\infty - M_0} = 1 - e^{(-kt)} \tag{1}$$

2 Power-law model

$$M - M_0 = at^{0.5} \tag{2}$$

3 Linear model

$$\Delta M = qt + b \tag{3}$$

where, M_0 is the mass of the fish ball before boiling; M and M∞ are the masses of the fish ball after boiling for time t and for an infinite time, respectively. In this model, M∞ is assumed to be mass of fish ball after 60 min of boiling. Letters k, a and q represent the mass transfer coefficient/model parameter in exponential, power-law and linear models, respectively while b is a constant of each group.

$$\Delta M = \frac{(M - M_0)}{M_0} \times 100\% \tag{4}$$

The root-mean-square-error (RMSE) and percentage difference (PD) of the three models were calculated according to the equation below.

$$RMSE = \sqrt{\frac{(m_{10} - m'_{10})^2 + (m_{20} - m'_{10})^2}{2}} \tag{5}$$

$$PD = \left[\frac{m_{10} - m'_{10}}{m_{10} + m'_{10}} + \frac{m_{20} - m'_{20}}{m_{20} + m'_{20}}\right] \times 100\% \tag{6}$$

where, m_{10} is the average experimental mass value of a fish ball boiled for 10 min, and m_{10}' is the predicted mass value calculated from the mass transfer models. m_{20} is the average experimental mass value of a fish ball boiled for 20 min, while m_{20}' is the predicted mass value calculated from the mass transfer models.

2.4. Weight gain ratio and moisture

The weight gain ratio was determined by the formula below.

$$Weight\ Gain\ Ratio = \frac{M - M_0}{M_0} \times 100\% \tag{7}$$

where, M_0 and M represent the mass of the fish ball before and after boiling.

The middle part of the fish ball was cut into small pieces, and 2 g from each sample was placed onto an aluminium plate, which was put into a 105 °C oven for 24 h for moisture determination. The sample was then taken out and weighed. The moisture was calculated according to the formula below.

$$Moisture = (M_1 - M_2)/M_1 \times 100\% \tag{8}$$

where, M_1 and M_2 represent the mass before and after drying, respectively.

2.5. Texture

After boiling, the fish ball was cooled to room temperature and cut into cylinders of 15 mm height and 17 mm diameter from the centre for texture measurement using a TA.XT2-i Texture Analyser (Stable Micro System, Goldaming, Surrey, UK) (Purohit, Reed, &