LWT - Food Science and Technology 42 (2009) 1059–1064

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Effect of oxidised phenolic compounds on the gel property of mackerel (*Rastrelliger kanagurta*) surimi

Amjad Khansaheb Balange, Soottawat Benjakul*

Department of Food Technology, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla, 90112, Thailand

ARTICLE INFO

Article history:
Received 1 August 2008
Received in revised form
23 January 2009
Accepted 27 January 2009

Keywords:
Cross-linking
Phenolic compounds
Oxygenation
Quinone
Gelation
Surimi
Mackerel

ABSTRACT

The effects of different oxidised phenolic compounds (ferulic acid, OFA; tannic acid, OTA; catechin, OCT and caffeic acid, OCF) at different levels (0–0.60% of protein content) on the properties of gels from mackerel (*Rastrelliger kanagurta*) surimi were investigated. Gels with addition of 0.40% OFA, 0.50% OTA, 0.50% OCF or 0.10% OCT had increases in breaking force by 45%, 115%, 46.1% and 70.3% and in deformation by 12.2, 27.5, 28.1 and 28.4%, respectively, compared with the control (without addition of oxidised phenolics). Lowered expressible moisture content without any change in the whiteness of resulting gels was found. Slightly lower myosin heavy chain (MHC) band intensity of gels added with oxidised phenolics at the optimal level was noticeable compared with that of the control. A sensory evaluation study indicated that addition of oxidised phenolic compounds had no negative impact on the colour and taste of the resulting gels ($P > 0.05$). Gels with addition of all oxidised phenolics had a finer matrix with smaller strands.

1. Introduction

Phenolic compounds are a diverse group of chemicals possessing one or more aromatic rings to which at least one hydroxyl group is attached. Phenolic compounds are produced as secondary metabolites by most plants and probably function as natural antimicrobial agents and inhibitors of pre-harvest seed germination (O'Connell and Fox, 2001). These compounds generally have an *ortho*-diphenol (or a 1-hydroxy-2-methoxy) structure (Strauss & Gibson, 2004).

Surimi is a Japanese term which can be defined as washed fish mince. With the washing process, myofibrillar proteins, which mainly contribute to gel formation, are concentrated in the resulting surimi (Benjakul, Visessanguan, & Tueksuban, 2003). Thailand is one of the largest surimi producers in southeast Asia. About 16 surimi factories are located in Thailand, with a total production of 96,500–1,13,500 metric tons per year of which 80% is exported to Japan and Korea and the remainder to Singapore and other countries (Hong & Eong, 2005). In general, lean fish have been used for surimi production in Thailand. Due to the limited fish resources, especially lean fish, dark flesh fish have been paid more attention as a potential alternative raw material for surimi production, due to its high potential for capture and low price (Chaijan, Benjakul, Visessanguan, & Faustman, 2004). However, a problem with producing surimi from dark flesh fish, such as mackerel, is the high content of dark muscle associated with the high content of lipid and myoglobin. This results in difficulties in making high quality surimi as evidenced by poor gel forming ability of those species (Chaijan et al., 2004). To increase the gel strength of surimi, various food grade ingredients have been used but the addition of these ingredients poses adverse effects on the surimi gel, particularly off flavour or off colour (Rawdkuen & Benjakul, 2008). Bovine plasma protein has been prohibited due to mad cow disease, while egg white is associated with allergy problems. Therefore, alternative food-grade ingredients are still needed to increase the gel strength of surimi, particularly those produced from dark flesh fish.

Naturally derived plant phenolic compounds, especially in the oxidised form, have been shown to be the potential protein cross-linker (Rawel, Rohn, Kruse, & Kroll, 2002). Delcour et al. (1984) found the formation of a haze in beer due to protein–phenolic compound interactions. Interactions of different phenolic acids and flavonoids with soy proteins were reported by Rawel, Czajka, Rohn, and Kroll (2002). Plant phenols at pH 8 increased the bloom strength of gelatin gel (Strauss & Gibson, 2004). Addition of phenolic compound in combination with 0.1 M NaCl at pH 8.5 resulted in the improved gel properties of canola protein (Rubino, Arntfield, Nadon & Bernatsky 1996). Addition of phenolic compounds at very low amounts might

* Corresponding author. Tel.: +66 7428 6334; fax: +66 7421 2889.
E-mail address: soottawat.b@psu.ac.th (S. Benjakul).

0023-6438/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.lwt.2009.01.013

have no negative effect on colour of the resulting gel from dark flesh fish surimi, which is generally dark in colour. Nevertheless, the information regarding the effect of phenolic compounds on the gel property of dark flesh fish surimi is very scarce. Thus, this study aimed to investigate the effect of oxidised phenolic compounds, including ferulic acid, tannic acid, catechin and caffeic acid on the properties of mackerel surimi gel.

2. Materials and methods

2.1. Chemicals

Ferulic acid (FA), tannic acid (TA) and β-mercaptoethanol (βME) were obtained from Sigma (St. Louis, MO, USA). Caffeic acid (CF) and catechin (CT) were purchased from Fluka (Buchs, Switzerland). All phenolic compounds used were of analytical grade. Sodium dedocyl sulphate (SDS), *N*,*N*,*N*′,*N*′-tetramethyl ethylene diamine (TEMED) and all chemicals for electrophoresis were procured from Bio-Rad Laboratories (Hercules, CA, USA).

2.2. Fish sample

Mackerel (*Rastrelliger kanagurta*) with an average weight of 85–90 g were caught from Songkhla coast along the Gulf of Thailand during March–April, 2008, stored in ice and off-loaded approximately 36 h after capture. Upon arrival at the dock in Songkhla, the fish were iced with a fish/ice ratio of 1:2 (w/w) and transported to the Department of Food Technology, Prince of Songkla University, Hat Yai within 1 h. The fish were immediately washed and drained before using for surimi preparation.

2.3. Surimi preparation

Surimi was prepared according to the method of Benjakul and Visessanguan (2003) with slight modifications. Mackerel skin and bones were removed manually and the flesh was minced to uniformity using a mincer with a hole diameter of 5 mm. The mince was then washed with cold water (5 °C) at a mince/water ratio of 1:3 (w/w). The mixture was stirred gently for 4 min and washed mince was filtered with a layer of nylon screen. The washing process was repeated twice. For the third washing, cold 0.5% NaCl solution was used. Finally, the washed mince was subjected to centrifugation using a Model CE 21K basket centrifuge (Grandi-umpiant, Belluno, Italy) with a speed of 700 × *g* for 10 min. To the washed mince, 4% sucrose and 4% sorbitol were added and mixed well. The mixture (500 g) was packed in a polyethylene bag and frozen using an air-blast freezer (−20 C). The chemical composition of the resulting surimi was determined according to the AOAC method (AOAC, 1999). Surimi contained 78.41% moisture, 14.0% protein and 0.30% lipid. The pH of the surimi was 6.8. Gel testing was performed within one week of frozen storage.

2.4. Effect of oxidised phenolic compounds on the properties of surimi gels

2.4.1. Preparation of oxidised phenolic solutions

Four phenolic compounds including ferulic acid, tannic acid, caffeic acid and catechin were dissolved according to the method of Strauss and Gibson (2004) with slight modifications. Phenolic solution (100 ml; 1% w/v) was adjusted to pH 8 using 6 N NaOH or 6 N HCl. The prepared solution was placed in a temperature-controlled water bath (40 °C) and subjected to oxygenation for 1 h by bubbling the solution with oxygen to convert the phenolic compounds to quinone. After being oxygenated for 1 h, the solution was then adjusted to pH 7 by using 6 N HCl and was referred to as 'oxidised phenolic compound'.

2.4.2. Surimi gel preparation

To prepare the gel, frozen surimi was tempered for 30 min in running water (26–28 °C) until the core temperature reached 0–2 °C. The surimi was then cut into small pieces with an approximate thickness of 1 cm. The surimi was placed in a mixer (National Model MK-K77, Tokyo, Japan). The moisture content was adjusted to 80% and 2.5% salt was added. Different oxidised phenolic compounds at various concentrations (0%, 0.10%, 0.20%, 0.30%, 0.40%, 0.50% and 0.60% of protein content of surimi) were added. The mixture was chopped for 4 min at 4 °C to obtain a homogeneous sol. The sol was then stuffed into polyvinylidine casing with a diameter of 2.5 cm and both ends of the casing were sealed tightly. Sols were incubated at 40 °C for 30 min, followed by heating at 90 °C for 20 min (Benjakul & Visessanguan, 2003). The control gels were prepared by adding the same volume of distilled water (pH 7) as that of oxidized phenolic solutions. All gels were cooled in iced water and stored overnight at 4 °C prior to analyses.

2.4.3. Texture analysis

Texture analysis of surimi gels was performed using a texture analyser Model TA-XT2 (Stable Micro Systems, Surrey, UK). Gels were equilibrated and tested at room temperature. Five cylinder-shaped samples of 2.5 cm in length were prepared. The breaking force (gel strength) and deformation (elasticity/deformability) were measured using the texture analyser equipped with a spherical plunger (5 mm diameter; 60 mm/min plunger speed).

2.4.4. Determination of expressible moisture content

Expressible moisture content was measured according to the method of Benjakul, Visessanguan, and Srivilai (2001) with slight modifications. Gel samples were cut to a thickness of 5 mm, weighed (*X*) and placed between 3 sheets of Whatman paper No. 4 at the bottom and 2 sheets on the top of the sample. The standard weight (5 kg) was placed at the top and held for 2 min. The sample was then removed from the papers and weighed again (*Y*). Expressible moisture content was calculated using the following equation:

$$\text{expressible moisture content (\%)} = 100\,[(X - Y)/X].$$

2.4.5. Determination of whiteness

The colour of the surimi gels was determined using a JP7100F colorimeter (Juki Corporation, Tokyo, Japan). L^* (lightness), a^* (redness/greenness) and b^* (yellowness/blueness) were measured and whiteness was calculated as described by Lanier, Hart, and Martin (1991) as follows:

$$\text{whiteness} = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}.$$

2.4.6. SDS-polyacrylamide gel electrophoresis (SDS-PAGE)

Protein patterns of surimi gels were analysed by SDS-PAGE according to the method of Laemmli (1970). To prepare the protein sample, 27 ml of 5% (w/v) SDS solution heated to 85 °C were added to the sample (3 g). The mixture was then homogenised using a homogeniser (IKA Labortechnik, Selangor, Malaysia) at a speed of 11,000 rpm for 2 min. The homogenate was incubated at 85 °C for 1 h to dissolve total proteins. The samples were centrifuged at 3500 × *g* for 20 min to remove undissolved debris. The samples (20 μg protein) were loaded onto the polyacrylamide gel made of 10% running gel and 4% stacking gel and subjected to electrophoresis at a constant current of 15 mA per gel, using a Mini Protein II unit (Bio-Rad Laboratories, Inc., Richmond, CA, USA). After separation, the proteins were stained with 0.02% (w/v) Coomassie Brilliant Blue R-250 in 50% (v/v) methanol and 7.5% (v/v) acetic acid and destained with 50% methanol (v/v) and 7.5% (v/v) acetic acid, followed by 5% methanol (v/v) and 7.5% (v/v) acetic acid.