LWT - Food Science and Technology 63 (2015) 490–496

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Optimum processing conditions for slowly heated surimi seafood using protease-laden Pacific whiting surimi

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ARTICLE INFO

Article history:
Received 25 August 2014
Received in revised form
21 January 2015
Accepted 24 February 2015
Available online 9 March 2015

Keywords:
Fish balls
Pacific whiting surimi
Protease inhibition
Transglutaminase
Calcium lactate

ABSTRACT

Pacific whiting surimi was examined to develop optimum conditions for slowly heated surimi seafood like fish balls. Breaking force and penetration distance increased significantly ($p < 0.05$) with the addition of egg white (EW), calcium lactate and microbial transglutaminase (MTG). Setting effects on textural properties were significantly ($p < 0.05$) affected by MTG addition. Even without MTG addition, breaking force and penetration distance also increased significantly ($p < 0.05$) when setting time was extended up to 6 h, possibly resulting from the role of endogenous transglutaminase (ETG). The addition of MTG resulted in a hard, but less deformable gel when setting time exceeded 2 h. Enzyme autolysis showed the addition of EW at 1 g/100 g paste effectively inhibited endogenous proteases. Results suggested Pacific whiting surimi, which is hardly used for slowly heated surimi seafood due to the textural degradation by proteases, can be successfully used to produce high quality fish balls when combined with 3 g/100 g EW, 0.2 g/100 g calcium lactate and setting at 25 °C for 2–6 h with MTG or 4–6 h without MTG.

1. Introduction

High quality fish balls possessing springy texture, white color and pleasant taste was produced using local fresh fish in earlier days. However, the use of fresh fish has become increasingly scant or even nearly impossible in Southeast Asia by effect of the massive overexploitation of some species, leading to increased demand for frozen surimi made from white fish. Fish balls is commonly prepared by comminuting surimi/fish mince with ingredients such as starch, salt, sugar, monosodium glutamate (MSG), and water, and then extruding into a ball shape and heating in 2-step cooking (setting and boiling) (Kok, Thawornchinsombut, & Park, 2014) to obtain its unique texture (rubbery and firm). It is a traditional and popular surimi/fish mince-based product in Southeast Asia and it has penetrated into the global communities of Chinese or Chinese descendants. It is estimated that about 1,000,000 t fish balls was consumed in China, 150,000 t in Thailand, 50,000 t in Singapore, 10,000 t in Malaysia, and 110 t in Brunei (Kok et al., 2014).

Pacific whiting (*Merluccius productus*) fishery in the United States has averaged harvests of 199,000 t in 2007–2011 (NMFS, 2013). Since 1991, the majority of the harvest has been used for surimi production due to its bland taste, white color, low cost, and large availability (Guenneugues & Morrissey, 2005). As so far, Pacific whiting surimi has been successfully used in fast heated surimi products, such as crabstick and fried surimi seafood (Park, 2005). But it is limitedly used in slowly heated products because Pacific whiting surimi undergoes extreme textural softening upon slow heating. Endogenous heat stable proteinases primarily hydrolyze myosin heavy chains, especially at the temperature around 55 °C for cold water species (An, Weerasinghe, Seymour, & Morrissey, 1994) or around 65 °C for warm water species (Yongsawatdigul, Hemung, & Choi, 2014). Accordingly, food grade protease inhibitors, such as egg white, beef plasma protein, whey protein concentrate, and potato extract, have been investigated and reported to effectively improve gelling properties of Pacific whiting surimi (Hunt, Park, & Handa, 2009; Morrissey, Wu, Lin, & An, 1993; Weerasinghe, Morrissey, & An, 1996).

On the contrary to endogenous proteases that affect gelation negatively, there are good enzymes affecting gelation positively. They are endogenous transglutaminase (ETG) and microbial transglutaminase (MTG) which catalyze the formation of ε-(γ-

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http://dx.doi.org/10.1016/j.lwt.2015.02.033
0023-6438/

glutamyl) lysine cross-links between myofibrillar proteins, leading to improvement of surimi gel texture after setting (Lanier, Carvajal, & Yongsawatdigul, 2005). As ETG is a Ca^{2+}-dependent enzyme, calcium compounds added optimally to surimi paste have been reported to activate transglutaminase and thus increase gel texture values (Lee & Park, 1998). We hypothesized that if two opposite enzymes (proteases and transglutaminase) are effectively controlled, Pacific whiting surimi may be used for slowly heated products such as fish balls. However, no reports on the use of Pacific whiting surimi for fish balls processing are made.

Our objectives were to investigate how to overcome proteolytic enzyme activity while enhancing the activity of endogenous transglutaminase (ETG) and to determine optimum processing conditions for slowly heated surimi seafood like fish balls using Pacific whiting surimi.

2. Material and methods

2.1. Materials

Pacific whiting surimi, approximately 1 mo frozen, was obtained from American Seafoods (Seattle, WA, USA). Surimi was cut into about 500 g blocks, individually vacuum-packaged, and stored in a freezer (−18 °C) throughout the experiments. Dried egg white (EW) as an enzyme inhibitor was obtained from Henningsen Foods (K-200, Omaha, NE, USA). Calcium lactate as endogenous transglutaminase (ETG) activator was obtained from PURAC America (Lincolnshire, IL, USA). Native corn starch was obtained from Cerestar USA, Inc. (Hammond, IN, USA). Microbial transglutaminase (MTG) with an enzyme activity of 100 units per g powder was provided by Ajinomoto Co., Inc. (Tokyo, Japan). Monosodium glutamate (MSG) was obtained from Firmenich Inc. (Princeton, NJ, USA). Total protein contents of Pacific whiting surimi and EW were 16.15% and 78.44%, respectively, which were measured using microKjeldahl method (AOAC, 1990).

Reagents used for gel electrophoresis were obtained from Bio-Rad (Hercules, CA, USA). All other chemicals were of analytical grade.

2.2. Gel preparation

Sample preparation was based on test formulation (Table 1). Frozen surimi was partially thawed at room temperature for 1 h before being cut into about 3 cm cubes. Surimi cubes were chopped at 1800 rpm for 1 min using a silent cutter (UM 5 universal, Stephan Machinery Corp, Columbus, OH, USA). Sodium chloride (2 g/100 g paste) was then added to extract fish myofibrillar protein, and chopping continued at 1800 rpm for 1 min. Corn starch (4 g/100 g paste), MSG (0.1 g/100 g paste) and other functional ingredients were added into the salted surimi. Moisture content was adjusted to 78 g/100 g paste using ice water (0 °C) and sugar before chopping at 1800 rpm for another 1 min. Sugar was added as an inert ingredient to the treatments without or with reduced functional ingredients to substitute EW, calcium lactate or MTG and to maintain moisture content equally. A vacuum was applied (50–60 kPa) and chopping processed at 3600 rpm until temperature reached 15 °C, which was a suggested final chopping temperature for Pacific whiting surimi (Poowakanjana & Park, 2014). The paste prepared above was packed into a polyethylene bag and subjected to a vacuum machine (Reiser VM-4142; Roescher Werke, Osnabrueck, Germany) to eliminate air bubbles. The paste was extruded into a polyethylene sausage casing (3.0 cm diameter) using a sausage stuffer (The Sausage Maker, Buffalo, NY, USA) and both ends were tied. Sample pastes were subjected to 2-step cooking (incubation in water bath, 25 °C for 2 h followed by heating in 90 °C water bath for 30 min). All heated gels were immediately submerged in ice water for approximately 15 min after cooking, and stored overnight in a refrigerator (4 °C). Gels heated in the sausage casing in 3-cm diameter were treated like fish balls with 3-cm diameter.

Table 1
Experimental formula for surimi pastes.

Ingredients	Egg white					Calcium lactate		Setting time	
	A	B	C	D	E	F	G	H	I
Surimi	400	400	400	400	400	400	400	400	400
Corn starch	40	40	40	40	40	40	40	40	40
Salt	20	20	20	20	20	20	20	20	20
Egg white	0	10	20	30	40	30	30	30	30
Calcium lactate	2	2	2	2	2	0	2	2	2
MTG	0	0	0	0	0	0	0	0	5
Sugar	50	40	30	20	10	22	20	20	15
MSG	1	1	1	1	1	1	1	1	1
Ice water	487	487	487	487	487	487	487	487	487
Total	1000	1000	1000	1000	1000	1000	1000	1000	1000

Each formula was based on equal moisture (780 g/kg) and salt (20 g/kg). A–E represents pastes with different egg white (EW) concentration from 0 to 40 g/kg. F and G represent pastes with 0 and 2 g/kg calcium lactate, respectively. H and I represent pastes with 0 and 5 g/kg MTG, respectively.

According to the function of calcium lactate in surimi paste (Lee & Park, 1998), a preliminary test was carried out to determine the combined effects of calcium lactate (0 g/100 g and 0.2 g/100 g) and EW (3 g/100 g) in surimi paste by subjecting to water bath incubation at 25 °C for 2 h followed by water bath heating at 90 °C for 30 min. To investigate effects of EW on gel properties, five concentrations of EW (0, 1, 2, 3 and 4 g/100 g) and 0.2 g/100 g calcium lactate were incorporated as functional ingredients into salted surimi paste, then subjected to water bath incubation at 25 °C for 2 h followed by water bath heating at 90 °C for 30 min. To investigate effects of MTG and setting time on gel properties, two concentrations of MTG (0 g/100 g and 0.5 g/100 g), calcium lactate (0.2 g/100 g) and EW (3 g/100 g) were incorporated as functional ingredients into surimi paste, then subjected to water bath incubation at 25 °C for 0 h, 2 h, 4 h, 6 h and 8 h, followed by water bath heating at 90 °C for 30 min.

2.3. Fracture gel evaluation

Fracture gel evaluation was performed according to the method described by Yin and Park (2014) using a TA-XT texture analyzer (Stable Micro Systems, Surrey, UK). At least 10 measurements were made for each sample.

2.4. Texture profile analysis

Texture profile analysis (TPA) of surimi gel was performed using a TA-XT texture analyzer (Stable Micro Systems, Surrey, UK) equipped with a flat plunger 50 mm in diameter (SMS-P/50). Each cylinder (2.5 cm long) was compressed axially in two consecutive cycles of 50% compression at 5 s apart. The crosshead moved at a constant speed of 1 mm/s. At least 10 measurements were made for each sample.

2.5. Gel colors

Surimi gel color was determined using a CR-300 Minolta colorimeter (Osaka, Japan). At least 12 measurements were made for each sample. L (lightness), a* (redness to greenness) and b* (yellowness to blueness) were measured.