Food Chemistry 141 (2013) 201–208

Contents lists available at SciVerse ScienceDirect

Food Chemistry

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

Interactions of dietary fibre and omega-3-rich oil with protein in surimi gels developed with salt substitute

Alicia Debusca [a], Reza Tahergorabi [b], Sarah K. Beamer [a], Susan Partington [a], Jacek Jaczynski [a,*]

[a] West Virginia University, Division of Animal and Nutritional Sciences, P.O. Box 6108, Morgantown, WV 26506, USA
[b] Oregon State University, Seafood Research and Education Center, 2001 Marine Dr., Astoria, OR 97103, USA

ARTICLE INFO

Article history:
Received 26 September 2012
Received in revised form 7 January 2013
Accepted 26 February 2013
Available online 7 March 2013

Keywords:
Surimi
Gelation
Endothermic transitions
Ingredient interactions
Dietary fibre
Salt substitute
Fish oil
Algal oil
Flaxseed oil
Omega-3 fatty acids
Functional food
Nutraceutical food
Food product development

ABSTRACT

Most Western populations have insufficient intake of fibre and ω-3 polyunsaturated fatty acids (PUFAs), while sodium intake greatly exceeds the recommended maximum. Surimi seafood is not currently fortified with these nutraceutical ingredients. Alaska pollock surimi seafood was developed with salt substitute and fortified with either 6 g/100 g of fibre or 10 g/100 g of ω-3 oil (flax:algae:menhaden, 8:1:1) or fibre + ω-3 oil (6 g/100 g of fibre + 10 g/100 g of ω-3 oil). The objective was to determine effects of the dietary fortification on physicochemical properties of surimi. Fortification with either dietary fibre or ω-3 oil alone or in combination enhanced ($P < 0.05$) rheological and textural characteristics. The combined fortification had a synergistic effect on rheological properties. This indicates greater gelation of surimi in the presence of fibre + ω-3 oil, suggesting their interaction with surimi myofibrillar proteins. Fibre results in protein dehydration increasing protein concentration; while oil is immobilised by protein filling void spaces in the gel matrix. Differential scanning calorimetry showed that fibre and ω-3 oil did not interfere with normal denaturation of surimi proteins. Colour properties were only slightly affected ($P < 0.05$). Fortification of surimi with fibre and ω-3 oil resulted in a quality product that could be useful in developing surimi products with nutritional benefits.

1. Introduction

Heart disease is a number one cause of death in the United States. As of 2006, mortality from cardiovascular disease (CVD) and coronary heart disease (CHD) accounted for 1 of every 2.9 and 6.0 deaths, respectively (Lloyd-Jones et al., 2010). The American Heart Association (AHA) recommends limiting saturated fat, cholesterol, and sodium as well as increasing fibre and unsaturated fats (Krauss et al., 2000).

Dietary fibre has cardiovascular benefits (Anderson et al., 2009). The American diet is deficient in fibre with the average intake of only 15 g/day (Dietary Guidelines Advisory Committee, 2010). The Institute of Medicine recommends fibre intake to be 25–38 g/day. Dietary fibre has been defined as remnants of plant edible parts and analogous carbohydrates that are resistant to digestion and absorption in humans. It includes polysaccharides, oligosaccharides, lignin and associated plant substances that benefit human health (Bodner & Sieg, 2009; Prosky, 2000).

Similar to fibre, omega-3 polyunsaturated fatty acids (ω-3 PUFAs) have cardiovascular benefits (Psota, Gebauer, & Kris-Etherton, 2006). α-linolenic acid (ALA, 18:3n3) decreases C-reactive protein (CRP), an indicator of inflammation associated with CVD (Zhao et al., 2004). Eicosapentaenoic (EPA, 20:5n3) and docosahexaenoic acids (DHA, 22:6n3) decrease triglycerides, total and LDL cholesterol, and increase HDL cholesterol (Juturu, 2008; Nair, Leitch, Falconer, & Garg, 1997; Narayan, Miyashita, & Hosakawa, 2006). Adequate intake of EPA and DHA may reduce CVD mortality by 30–60% (Psota et al., 2006). The cardiovascular benefits of ω-3 PUFAs have been discussed elsewhere (Anderson & Ma, 2009; Mozaffarian & Wu, 2011; Psota et al., 2006). Plant sources such as flaxseed oil are abundant in ALA, although algal oils are rich in DHA (Arterburn et al., 2008; Calder & Yaqoob, 2009; Gogus & Smith, 2010). Marine sources are abundant in EPA and DHA (Narayan et al., 2006). Dietary intake of ALA in Western populations is 0.5–2 g/day and EPA + DHA is as low as <0.1 g/day. Although currently there are no official recommendations, the suggested intake of ALA is 1.1–1.6 g/day and EPA + DHA is 0.3–0.4 g/day. Some sources suggest >0.5 g of EPA + DHA per day (Calder & Yaqoob, 2009; Institute of Medicine, 2005; Juturu, 2008; Kris-Etherton, Grieger, & Etherton, 2009).

* Corresponding author. Tel.: +1 (304) 293 1893; fax: +1 (304) 293 2232.
E-mail address: Jacek.Jaczynski@mail.wvu.edu (J. Jaczynski).

0308-8146/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.foodchem.2013.02.111

Excessive sodium intake is associated with hypertension, a significant risk factor for CVD. It also contributes to the development of fibrosis in the heart, kidneys, and arteries (Appel et al., 2011). Mainly due to the high sodium content of processed foods, the current dietary sodium intake in the U.S. exceeds 3400 mg/day, which is much higher than the recommended maximum of 2300 mg/day for the general population and <1500 mg/day for those with elevated risks (Dietary Guidelines Advisory Committee, 2010). Potassium chloride (KCl) is commonly used as a salt substitute. Potassium has cardiovascular benefits (Buyck et al., 2009).

The market for functional foods is becoming increasingly popular worldwide. Functional foods are those that contain added, technologically developed ingredients with specific health benefits (Siró, Kápolna, Kápolna, & Lugasi, 2008). Regarding ω-3 PUFAs, the high cost of fish and potential for contamination may drive consumers to choose fortified foods (Candela, López, & Kohen, 2011). Surimi is a commercial preparation of fish myofibrillar protein. Surimi is the main ingredient in a variety of formulated, heat-gelled, flavored seafood products (i.e., surimi seafood, example: crab-flavored seafood). Therefore, surimi seafood is a logical vehicle to provide health benefits of functional additives (Lanier, Martin, & Bimbo, 1988; Park, Kelleher, McClements, & Decker, 2004). Surimi seafood is not currently fortified with fibre or ω-3 PUFAs, nor is salt substitute used. A three-prong strategy (1 – fibre, 2 – ω-3 PUFAs, and 3 – salt substitute) is proposed to address the diet-driven CVD with functional surimi seafood (Tahergorabi, Beamer, Matak, & Jaczynski, 2012d; Tahergorabi, Sivanandan, Beamer, Matak, & Jaczynski, 2012c). This would render a seafood product that aligns with the dietary recommendations posed by the American Heart Association. Research on the individual effects of fibre, ω-3 oils, and salt substitute on the physicochemical properties of surimi is scarce. To our knowledge, the research on the combined effects or ingredient interactions of these functional additives in surimi is absent.

This study hypothesises that addition of dietary fibre (long-chain powdered cellulose), ω-3 oil (flaxseed, algae, and fish), and KCl-based salt substitute to surimi will have a synergistic or additive effect on surimi thermal gelation and gel texture, but will not alter endothermic transitions of surimi proteins or gel colour properties. The objectives of this study were to determine (1) textural (shear stress and strain, Kramer shear force, and texture profile analysis) and colour (L∗a∗b∗ tristimulus colour values) properties; (2) thermal gelation with oscillatory dynamic rheology; and (3) endothermic transitions (i.e., protein thermal denaturation) with differential scanning calorimetry (DSC) of Alaska pollock surimi gels formulated with constant protein concentration, but with added dietary fibre, ω-3 oil, and salt substitute.

2. Materials and methods

2.1. Surimi

Frozen Alaska pollock surimi grade A was obtained from Trident Seafoods Corp. (Seattle, WA). Surimi contained cryoprotectants (4 g/100 g of sorbitol and 4 g/100 g of sucrose), 0.15 g/100 g of sodium tripolyphosphate, and 0.15 g/100 g of tetrasodium pyrophosphate. Frozen surimi blocks (10 kg each) were shipped overnight in heavily insulated industrial strength boxes filled with ice. Upon arrival surimi blocks were cut into approximately 800 g units, vacuum-packed, and stored at −80 °C until needed. The moisture content of surimi was determined as 76.04 g/100 g (Association of Official Analytical Chemists, 1995).

2.2. Preparation of surimi paste

Surimi pastes were made using the procedure described by Jaczynski and Park (2003a, 2003b, 2004). Briefly, frozen surimi was thawed in a refrigerator (4 °C) for 1 day. Surimi was chopped in a universal food processor (Model UMC5, Stephan Machinery Corp., Columbus, OH) at low speed for 1 min. A surimi paste was obtained by extracting surimi myofibrillar proteins with 2.8 g/100 g of KCl-based salt substitute (AlsoSalt® sodium-free salt substitute, AlsoSalt, Maple Valley, WA) (hereafter called salt substitute) and chopping at low speed for 0.5 min. This level of salt substitute was found optimal and similar to salt (NaCl) in terms of texture and colour development as well as gelation of surimi protein and reduction of water activity in surimi gels (Tahergorabi, Beamer, Matak, & Jaczynski, 2012a; Tahergorabi & Jaczynski, 2012). The salt substitute contained 68 g/100 g of KCl and L-lysine mono-hydrochloride and calcium stearate. According to the manufacturer, the patented L-lysine derivative masks the metallic-bitter aftertaste of KCl. The concentration of 2.8 g/100 g of the salt substitute corresponds to the concentration of KCl that is equivalent to 1.5 g/100 g of NaCl on equal molar basis.

Final moisture content of the surimi paste was adjusted to 79 g/100 g by adding chilled water (4 °C). Either dietary fibre (Solka Floc® powdered cellulose 900FCC, International Fiber Corporation, Urbana, OH) or SiO_2 (silicon dioxide crystalline 325 mesh, Spectrum Chemical, Gardena, CA) was added to the surimi paste for a final concentration of 6 g/100 g. Solka Floc® Powdered Cellulose 900FCC was used in the present study due to its high water retention ability (9.5 g of H_2O/g of fibre). SiO_2 was added to the surimi paste as inert filler to replace fibre in order to maintain the same protein (i.e., surimi) concentration for all treatment groups (Tahergorabi & Jaczynski, 2012; Tahergorabi et al., 2012a). Fish myofibrillar proteins are a gelling agent in surimi. Therefore, the concentration of myofibrillar proteins is responsible for surimi gelation characteristics; and consequently, final texture and colour properties of surimi gels (Kim, Park, & Yoon, 2005). Replacing fibre with SiO_2 allowed determination of fibre contribution to surimi gelation characteristics and final texture/colour of surimi gels without confounding factors associated with different protein concentration. The ω-3 PUFAs-rich oil (see below) was also added to the surimi paste for a final concentration of 10 g/100 g by replacing chilled water (1:1, wt:wt) that is normally added during formulation of surimi paste (Park, 2005; Pérez-Mateos, Boyd, & Lanier, 2004, 2006). Thus, the final moisture content of the treatments that contained the ω-3 oil was 69 g/100 g (i.e., not 79 g/100 g). One treatment without added dietary fibre or ω-3 PUFAs-rich oil was a control. To mix all of the ingredients with surimi paste, chopping was applied at low speed for 1 min. Additional chopping was performed at high speed under vacuum (50 kPa) for the last 3 min. The paste temperature was controlled between 1–4 °C during chopping. Surimi pastes were prepared in 1 kg batches. Final formulations are listed in Table 1.

A blend of the following ω-3 PUFAs-rich oils was added to the surimi paste: flaxseed oil obtained from Jedwards International, Inc. (Quincy, MA); algae oil (DHAS) obtained from Martek Biosciences (Columbia, MD); and menhaden oil (Omega Pure 8042TE) obtained from Omega Pure (Reedsville, VA). The blend consisted of 8:1:1 weight parts of flaxseed:algae:menhaden oils.

The experimental treatments consisted of (1) control with 0 g/100 g of dietary fibre and 0 g/100 g of ω-3 oil, (2) fibre treatment with 6 g/100 g of dietary fibre and 0 g/100 g of ω-3 oil, (3) oil treatment with 0 g/100 g of dietary fibre and 10 g/100 g of ω-3 oil, and (4) fibre + oil treatment with 6 g/100 g of dietary fibre and 10 g/100 g of ω-3 oil. All treatment groups had constant surimi content because SiO_2 was used to replace fibre in the control treatment (1) and treatment (3), while ω-3 oil replaced water in treatments (3)