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Effects of type and concentration of salts on physicochemical properties in fish mince

Kirsti Greiff [a, c, *], Ida G. Aursand [a], Ulf Erikson [a], Kjell D. Josefsen [b], Turid Rustad [c]

[a] SINTEF Fisheries and Aquaculture, Brattørkaia 17C, N-7465 Trondheim, Norway
[b] SINTEF Materials and Chemistry, R. Birkelandsvei 2B, N-7465 Trondheim, Norway
[c] Department of Biotechnology, Norwegian University of Science and Technology, Sem Sælandsv. 6/8, N-7491 Trondheim, Norway

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ABSTRACT

Cooked minces made from both fresh and frozen haddock with NaCl, KCl, or $MgCl_2$ at concentrations from 0.07 to 0.34 mol/kg fish mince were prepared and analysed for physicochemical properties. The properties of the minces varied both with the type and amount of added salt. Minces added the same molar amount of NaCl or KCl had fairly similar properties, but pH in minces made with KCl was slightly higher. Minces made with $MgCl_2$ had lower pH than the corresponding minces made with NaCl. Minces made from fresh raw material with 0.07 mol/kg $MgCl_2$ had significantly lower WHC than the rest of the minces, while minces made with 0.34 mol $MgCl_2$/kg had lower moisture and breaking force than the corresponding minces with KCl or NaCl. Low field NMR T_2 relaxation data indicated differences in the protein structure as an effect of addition of small amounts of salt. Cooking loss decreased with increasing salt content both when fresh and frozen raw materials were employed, and the results indicate that this could be due to the increased ionic strength. WHC for minces made with NaCl decreased significantly, whereas WHC did not change much for minces made with KCl or $MgCl_2$.

1. Introduction

A high intake of sodium (Na) is associated with an increased risk of high blood pressure, which is a significant risk factor in the development of cardiovascular disease (CVD) and stroke (Cook et al., 2007; He & MacGregor, 2002). The daily Na-intake in Europe and USA is estimated to 4–5 g/day (The Norwegian Directorate of Health, 2011), and salt (NaCl) added to food products during production, preparation and at the table is the main source of this Na. Guidelines published by public health and regulatory authorities (FSA, 2004; The Norwegian Directorate of Health, 2011; WHO, 2006) recommend a reduction of Na intake to 2 g/day or less. Salt is commonly employed in fish processing, due to its preservative effects, taste, positive technological effects and low cost (Fuentes, Fernández-Segovia, Serra, & Barat, 2010; Martínez-Alvarez & Gómez-Guillén, 2006).

The development of safe high quality low-sodium fish products is of interest, especially considering the good nutritional characteristics of fish. It is often possible to reduce the addition of salt in "traditional" recipes to some extent, but further reduction then requires the addition of salt substitutes to maintain palatability, texture, processing yield and shelf-life (Kilcast & Angus, 2007). Salt contributes to formation of a viscous protein paste, that creates a dense protein network, a gel, by solubilising the myofibrillar proteins (Kilcast & Angus, 2007). Several authors have reported that when NaCl is partially replaced with other salts like KCl, $MgCl_2$ or $CaCl_2$ this will affect the enzyme activity, protein matrix and texture (Andreetta-Gorelkina, Greiff, Rustad, & Aursand, 2015; Barat, Pérez-Esteve, Aritoy, & Toldra, 2012; Martínez-Alvarez & Gómez-Guillén, 2013). Partial substitution of NaCl by KCl is one of the best alternatives for reducing sodium content (Aliño, Fuentes, Fernández-Segovia, & Barat, 2011; Fuentes et al., 2010; Toldrá & Barat, 2012). Mg-salts are used in low concentrations in commercial "low-sodium" salts on the market (Barat et al., 2012). Most of the studies on the effect of salt and "low-sodium" salts on physicochemical properties have focused on meat and meat batters (Barat et al., 2012; Nayak, Kenney, Slider, Head, & Killefer, 1998; Offer & Trinick, 1983; Ruusunen & Puolanne, 2005; Toldrá & Barat, 2012) or heavily salted cod (Aliño et al., 2011; Martínez-Alvarez, Borderías, & Gómez-Guillén, 2005; Martínez-Alvarez & Gómez-Guillén, 2005). In a study of salt substitution in surimi

* Corresponding author. SINTEF Fisheries and Aquaculture, Brattørkaia 17C, 7465 Trondheim, Norway. Tel.: +47 47903891; fax: +47 93 27 07 01.
E-mail address: kirsti.greiff@sintef.no (K. Greiff).

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gels, Tahergorabi, Beamer, Matak, and Jaczynski (2012) found that hardness increased when NaCl or KCl was added to the gel, but there are limited results available on cooked fish mince. Low-field ^1H NMR (LF-NMR) has been used to indirectly determine the effect of salting by monitoring the changes in proton relaxation behaviour as a result of the salting process (reviewed by Erikson, Standal, Aursand, Veliyulin, & Aursand, 2012), However, none of these studies dealt with salt replacers such as $MgCl_2$ and it was therefore of interest to explore the LF-NMR method further as a tool for measuring proton relaxation behaviour in low-salt applications.

The aim of this study was to investigate the effect of different concentrations of cations (Na^+, K^+, Mg^{2+}) and fresh and frozen raw material on cooking loss, Water Holding Capacity (WHC), pH and proton exchange measured by LF-NMR of raw and cooked sodium reduced haddock mince.

2. Materials and methods

Chemical compounds: Ammonium Chloride (PubChem CID:25517), Ammonium Hydroxide (PubChem CID:14923), Ammonium Hydrogen Fluoride ($NH_4FHF < 1\%$, LD_{50} mg/kg not found), Sodium Chloride (PubChem CID:5234), Potassium Chloride (PubChem CID:4873), Potassium Dihydrogen Phosphate (PubChem CID:516951), Magnesium Chloride (PubChem CID:21225507) (Thermo Fisher Scientific, USA, Merck KGaA, Darmstadt, Germany or VWR International BVBA, Leuven, Belgium). All chemicals were of analytical-reagent grades.

2.1. Experimental design

The experiment was carried out as a factorial design, with two factors (concentration and type of salt) at three levels. The compositional model variables were molar concentration of salt and type of salt ($MgCl_2$, NaCl, KCl), giving a total of nine different minces, see Table 1. The salts were analytical-reagent grade; $MgCl_2 * 6H_2O$ (VWR International BVBA, Leuven, Belgium), NaCl (Merck KGaA, Darmstadt, Germany) and KCl (Merck KGaA, Darmstadt, Germany) and added in equimolar concentrations at three levels: 0.07, 0.17 and 0.34 mol/kg mince (corresponding to 0.4, 1.0 and 2.0% NaCl). The content of coarsely ground fillets and added water was 61.7 ± 0.6 and 36.8 ± 0.4 g/100 g mince, respectively. The crystal water in $MgCl_2 * 6H_2O$ was taken into account when calculating the amount of added water. The experiment was repeated with frozen raw material using the same factorial design as described above.

Table 1
Types and concentrations of salt added to haddock mince. The salts (KCl, $MgCl_2$ and NaCl) were added in equimolar amounts at three levels, 0.07, 0.17 and 0.34 mol pr kg mince.

Sample ID	Salt	Molar concentration (mol/kg mince)	Salt concentration (g/100 g)	Estimated ionic strength due to the added salts (mol/kg solute)
0.07 K	KCl	0.07	0.5	0.07
0.07 Mg	$MgCl_2$	0.07	0.7	0.21
0.07 Na	NaCl	0.07	0.4	0.07
0.17 K	KCl	0.17	1.3	0.17
0.17 Mg	$MgCl_2$	0.17	1.6	0.51
0.17 Na	NaCl	0.17	3.2	0.17
0.34 K	KCl	0.34	2.5	0.34
0.34 Mg	$MgCl_2$	0.34	3.2	1.02
0.34 Na	NaCl	0.34	2.0	0.34

2.2. Raw material

Haddock (*Melanogrammus aeglefinus*) was caught by Danish seine on Vesterålsbanken, North-Norway in March 2011. The catch was pumped on board by a vacuum pump and stored alive on-board before electrostunning, bleeding and gutting. The fish were iced in styrofoam boxes and shipped to Trondheim (cold storage). The core temperature in the fish was <4 °C during the experiment. The fish were skinned and filleted six days after catching. Gutted mean weight was 1.8 ± 0.6 kg. Half of the fish were packed in plastic bags and frozen at −28 °C while the other half were filleted and minced the day after filleting. After 67 days, the frozen fish were thawed with drainage in a cold room (+4 °C) for 67 h. The thawed fish were filleted and the minces prepared in the same manner as for fresh fish.

2.3. Process and heat treatment

The fillets were coarsely ground (perforated disc, hole size 5 mm, Hobart A 200 N, Hobart manufacturing, Braunton, UK) and mixed (45 s) with salt before ice water was added. The mixture was homogenized (1.5 min) in a food processor (Braun Multiquick 7, Braun GmbH, Kronberg, Germany), interrupted at one interval to scrape the sides of the bowl. Two parallel minces from each sample were produced and blended into one batch. The fish mince was divided in three plastic trays (~460 g in each tray) and cooked in a convection oven (Rational SCC 61, Rational AG, Landsberg a. Lech, Germany) (100 °C, 100% RH) to a core temperature of 80 °C. After cooling, the minces were packed in plastic bags and stored cool (4 °C) for 24 h before further analysis. The minces ($n = 3$) were subjected to physicochemical and LF-NMR analyses.

The experiment was part of a larger study of minces added different salts with the aim to investigate the effect of cations Na^+, K^+ and Mg^{2+} on physicochemical properties and protein solubility of raw and cooked haddock mince. The protein solubility results are reported by Andreetta-Gorelkina et al. (2015).

2.4. Analytical methods

The **pH** of the raw and cooked minces was measured directly with a pH-meter (WTW PH3110, Weilheim, WTW, Germany) equipped with a glass electrode (SenTix Sp, A, Weilheim, WTW, Germany). Moisture content was determined by drying 5 g cooked fish mince at 105 °C for 24 h to constant weight according to AOAC method (AOAC, 1997). **WHC** of ground fillets and cooked mince was determined by low-speed centrifugation ($210 \times g$) as described by Eide, Børresen, and Strøm (1982). The analyses were run in quadruplicate and WHC expressed as the percentage of water retained in the mince after centrifugation for 5 min. **Cooking loss** was determined by weighing the mince before cooking and 24 h after cooking and chilling. The cooked mince was stored on a grid for 1 min before weighing. Cooking loss was calculated as percent weight difference between the heated and unheated minces ($n = 3$).

The **sodium (Na^+) and chloride (Cl^-)** content of cooked minces were determined in mince extracts. Sodium was determined at ambient temperature with a Na-selective electrode (Ross® Sodium Ion Selective Electrode, Thermo Fisher Scientific, USA) and a Dual Star pH/ISE meter (Thermo Fisher Scientific, Waltman, MA, USA), under constant stirring (Kivikari, 1996) as modified by Greiff et al. (2014). The analytical uncertainty of the method was determined by analysing three extracts from each of three replicates of the same cooked mince. This showed very low variation (1–2%). For the rest of the minces, only one extract from each of three replicates of the same formulation were analysed. The Cl^- content was