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Water uptake, drip losses and retention of free amino acids and minerals in cod (*Gadus morhua*) fillet immersed in NaCl or KCl

Rune Larsen *, Edel O. Elvevoll

Department of Marine Biotechnology, Norwegian College of Fishery Science, University of Tromsø, 9037 Tromsø, Norway

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Abstract

The aim of this work was to study differences in water uptake, drip losses and retention of low molecular components of cod fillets immersed in relatively weak NaCl or KCl solutions. Fillet pieces were excised from post rigor cod, immersed 12 h and stored 5 days at 4 °C, and further analysed for contents of chloride, minerals and free amino acids. A markedly increased water uptake was registered when concentration of immersion solution was raised from 342 to 513 mM. At chloride concentrations above 800 mg/100 g in cod fillet, both water uptake and drip losses reached a threshold in which increased swelling and reduction of drip loss were minimal. No significant difference was found between NaCl and KCl solutions with equal molar concentration with regard to water uptake, but fillet pieces immersed in 171 mM KCl had a significantly lower drip loss. Losses of free amino acids were up to 50%, but no difference was found among any of the immersion solutions.

Keywords: Potassium chloride; Cod; Muscle; Water uptake; Drip loss; Retention; Free amino acids

1. Introduction

Dietary sodium intake is higher than recommended in developed countries. Elevated levels in blood may lead to hypertension, which is a prominent risk factor for cardiovascular diseases (Chobanian et al., 2003; Whitworth, World Health Organization, & International Society of Hypertension Writing Group, 2003). Common dietary modifications that lower blood pressure are reduced salt intake and increased potassium intake (Appel et al., 2006). Although data on the effect of potassium have been inconsistent, some studies show that potassium has a direct beneficial effect on blood pressure (Brancati, Appel, Seidler, & Whelton, 1996; Naismith & Braschi, 2003). Hyperkalemia rarely occurs solely on the basis of increased potassium intake since kidneys have a high capacity to excrete K^+ (Oh & Uribarri, 2006). However, increased potassium intake may be harmful to individuals with impaired potassium excretion, e.g. diabetics and some with renal diseases (Appel et al., 2006). Nevertheless, US Dietary Guidelines recommend a reduction of sodium consumption and an increased potassium intake (United States. Dept. of Health and Human Services, United States. Dept. of Agriculture, & United States. Dietary Guidelines Advisory Committee, 2005).

In food processing the use of salt is frequent, and approximately 75% of sodium intake is derived from salt added by manufacturers (United States. Dept. of Health and Human Services et al., 2005). The growing awareness of diet related diseases has initiated an interest in producing foods with beneficial health effects. As the consumption of sodium generally is too high, the industry are looking for ways to reduce sodium content of foods, without having an adverse effect on sensory and technological properties. One of the approaches to reduce sodium content in processed foods is the use of salt substitutes, in particular KCl (Desmond, 2006). However, bitter and metallic tastes have been associated with KCl based salt substitutes (Gillette, 1985). Some KCl mixtures have given satisfactory or equivalent sensory properties when used in sausages and hams (Guar-

* Corresponding author. Tel.: +47 776 46311; fax: +47 776 46020.
E-mail address: rune.larsen@nfh.uit.no (R. Larsen).

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dia, Guerrero, Gelabert, Gou, & Arnau, 2006), but perceived bitterness is reported when substitution is above 30–40% (Gelabert, Gou, Guerrero, & Arnau, 2003; Hand, Terrell, & Smith, 1982).

The effects of salt on water uptake and water holding capacity (WHC) of meat, and its interaction with muscles and myofibrils are complex. The water in muscles is primarily held within myofibrils by capillary-like forces, and gains and losses of water are primarily explained by volume changes of myofibrils (Offer & Knight, 1988a). Chloride binds more strongly to proteins than sodium, raising the electrostatic repulsion between myofilaments, thus causing expansion of the filament lattice (Hamm, 1972). Increasing salt concentrations causes myosin depolymerization which leads to an entropically driven swelling (Offer & Trinick, 1983). Further swelling occurs as salt weakens or breaks structural linkages between the filaments, such as m-lines, z-disks and cross-bridges in the actomyosin complex (Offer & Knight, 1988a).

Added salt improves texture, enhances taste, prolongs shelf-life and increases the WHC (Ruusunen & Puolanne, 2005). Brining of fish fillets, which can improve fillet palatability and WHC, has recently received more attention (Esaiassen et al., 2004, 2005). Consumer attitudes towards ready-meals are changing, and as a result, the demand for lightly salted fish fillets may grow. These products generally have a salt content of 2–3%. However, soluble components within the fillets, such as free amino acids (FAA), vitamins and proteins, may leach out during brining. Thus, brining has both nutritional and economic implications, because it may increase both yield and palatability, but nutritional components may be lost during the process, and it introduces sodium chloride to a low salt-containing food.

The effect of salt on swelling and drip loss of meat is well documented, but research has primarily been carried out on mammalian meat or isolated myofibrils, and limited results are available on fish muscle. Differences between NaCl and KCl in fish processing have mainly been studied using brines of 18%, in the production of salt-cured fish and salt-cured and dried fish (Martinez-Alvarez, Borderias, & Gomez-Guillen, 2005; Martinez-Alvarez & Gomez-Guillen, 2005; Rodrigues, Ho, Lopez-Caballero, Bandarra, & Nunes, 2005). Thus, information on how lower levels of NaCl and KCl influences different quality parameters of fish fillets are lacking. The aim of the current work was to study the water uptake of cod fillets during immersion in relatively weak KCl and NaCl solutions and the subsequent drip loss during storage. In addition, losses of FAA and minerals during the process were investigated.

2. Materials and methods

2.1. Raw materials

Exsanguinated Atlantic cod ($n = 20$, 4527 ± 432 g round weight) were acquired in February 2004 from a local fishmonger, and the fish were caught by Danish seine the day before purchase. The fish were gutted, wrapped in plastic, and stored in ice for 4 days. After resolution of rigor, the fish were manually filleted, skinned and samples were excised from the loins. From each fillet, two pieces (ca $60 \times 40 \times 30$ mm) were cut and labelled. Adjoining muscle tissues, which served as control, were sampled from left- and right-hand fillets of each individual, pooled and frozen at −30 °C in polyethylene (PE) zip-bags until required for analysis.

2.2. Experimental design

The fillet pieces ($n = 68$, 76 ± 10 g) were randomly distributed between 11 treatment groups with 6 or 7 samples in each group. The samples were immersed in 5 l pre-cooled salt solutions for 12 h at 4 °C. After immersion, samples were gently surface dried with a paper tissue, transferred to reticular plastic plates (mesh size 10 mm), and stored inside boxes for 5 days at 4 °C. The weight of the samples was recorded before immersion, after immersion, and every 24 h during storage. The swelling of muscle samples during immersion were measured as increased weight, and drip loss was quantified as decreased weight during storage. The samples were frozen at −30 °C in PE zip-bags until required for analysis. The immersion solutions were fresh water (FW) and 171, 257, 342, 513 and 856 mM NaCl or KCl. These concentrations correspond approximately to 10, 15, 20, 30 and 50 g NaCl/l or 13, 19, 26, 38 and 64 g KCl/l, respectively. Tap water was used for all immersion solutions.

The samples were thawed at room temperature inside the zip-bags and whole samples, including thaw drip, were chopped with a Braun MR 6000 food processor (Braun, Germany) for 30 s. All samples were analysed for % dry matter, pH, muscle juice osmolality and chloride contents. A selection of treatment groups, i.e. untreated control, FW, 342 and 513 mM NaCl and KCl, was further analysed for mineral content and FAA.

2.3. Chloride

Muscle tissue was homogenised with twice its weight of milliQ-water with an Ultra Turrax T25 basic (Ika Werke GmbH, Staufen, Germany) at 19,000 rpm for 30 s. The suspension was heated at 100 °C for 5 min, and then centrifuged at 10,000*g* for 15 min. Chloride content in the supernatant was determined with a Corning 925 chloride analyser (Corning, Sheffiled, UK). Results (mg/100 g) are the mean of four repeated measurements.

2.4. Osmolality

Muscle juice osmolality was measured with an Osmomat 030 osmometer (Gonotec GmbH, Berlin, Germany), using the principle of freezing point depression. Muscle samples