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Quality changes in high pressure processed cod, salmon and mackerel during storage

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ABSTRACT

High pressure (HP) treatments inhibit spoilage and thereby increase the shelf life of fresh fish. However, studies comparing the effect on the biochemical changes in different fish species are lacking. The current study investigated the effect of HP treatments at 200 and 500 MPa for 120 sec. (8-days on texture, liquid loss, water holding capacity and protein denaturation in cod, mackerel and salmon. At 500 MPa hardness increased,and the fish became lighter and less red in all species. Severe protein denaturation was induced by HP treatment in all species. It was concluded that the effect on the measured quality parameters were not much affected by fish species, which suggests that HP induced changes in structural proteins and thereby affects only parameters like texture, lightness and water holding capacity, and do not depend on amounts of fat or the muscle composition.

1. Introduction

In recent years, high pressure (HP) treatment has been increasingly implemented in the meat industry as a post processing method applied to extend the microbiological shelf life of processed meat. The effects of HP on fish and seafood have not been as intensively studied, thus the industrial use is limited. The shelf life of fresh fish and seafood is short, and processing methods to inhibit spoilage and thereby increase shelf life would be an advantage. Although a range of studies on the effects of HP on appearance, texture and sensory properties have been conducted in mackerel (Aubourg, Torres, Saraiva, Guerra-Rodríguez, & Vázquez, 2013; Fidalgo, Saraiva, Aubourg, Vázquez, & Torres, 2014; Vázquez, Torres, Gallardo, Saraiva, & Aubourg, 2013), salmon (Lakshmanan, Parkinson, & Piggott, 2007; Yagiz et al., 2009) and cod (Angsupanich & Ledward, 1998; Angsupanich, Edde, & Ledward, 1999), the results are difficult to compare since different equipment, pressure level, holding time, temperature and storage times and conditions are applied.

It is known that HP treatment affects the microstructure of fish by increasing hardness at pressure between 200 and 400 MPa, depending on the species (Murchie et al., 2005). Different fish species may react differently on HP treatment. Studies of salmon and cod, have shown significantly increased hardness after HP treatment at 200 MPa for 60 min (Amanatidou et al., 2000) and 400 MPa for 20 min (Angsupanich & Ledward, 1998), respectively. Another study showed similar results for mackerel, that hardness gradually increased with pressures (150–450 MPa) and holding time (0–5 min) (Aubourg et al., 2013).

Visual changes in HP treated fish have been reported in white fish species, salmon, tuna, mackerel, shellfish and octopus and the results were reviewed by Murchie et al. (2005). In general, at pressures below 300 MPa and up to 30 min holding time the fish muscle has a cooked appearance similar to that obtained by very light cooking. At pressures above 300 MPa cod and mackerel muscle had a lighter (increased *L*-value) and opaque appearance (Ohshima, Ushio, & Koizumi, 1993). This is in agreement with Angsupanich and Ledward (1998) who found that when cod was treated at 200 MPa it lost some translucency and at higher pressures it became white and opaque with a cooked appearance. Amanatidou et al. (2000) investigated the effects of HP treatment and storage on colour and hardness of salmon fillets. They found that lightness (L* values) increased with increasing pressure (0.1–200 MPa) and holding time (0–60 min). At 150 MPa (60 min)

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and 200 MPa (10 min) the product became opaque (defined as an L* value above 70).

Liquid loss during processing and following storage of processed seafood is a very important issue both economically as loss of product yield and regarding reduced quality. Pressures of 200 MPa may not induce severe protein denaturation and thus leading to only minor liquid losses. At pressures above 400 MPa severe protein denaturation have been reported (Angsupanich et al., 1999; Angsupanich & Ledward, 1998). This may lead to severe liquid loss, or possibly a solubilisation of sarcoplasmic and myofibrillar proteins setting a gel, thus resulting in increased water holding capacity and decreased liquid loss (Tornberg, 2005a). In mackerel, Aubourg et al. (2013) reported that the amount of expressible water increased with increased pressure. However, systematic studies investigating liquid loss and water holding capacity of HP treated mackerel, cod and salmon during storage are lacking in the literature.

The aim of the current study was to elucidate the biophysical quality changes during high pressure processing (200 and 500 MPa, 2 min, 8–9 °C) and following storage time (up to 25 days) in mackerel, cod and salmon fillets, by investigating texture, liquid loss, water holding capacity, colour changes and protein denaturation profiles. The current study investigated fish processed at low temperature, which reduced the potential for protein denaturation in the fish caused by adiabatic heating. To the authors knowledge this is the first study to compare the effect of high pressure and storage on a range of quality parameters in three different fish species.

2. Material and methods

2.1. Raw material

Skinned and *pre-rigor* filleted back loin from farmed salmon (*Salmo salar*) and cod (*Gadus morhua*) were obtained 2 and 3 days after slaughter, respectively. Fresh wild caught mackerel (*Scomber scombrus*) (caught in the North Sea, June 2013) was filleted, skinned and deboned. Loins for HPP and controls were cut into samples of approx. 6 × 4 cm (LxW), weighed and vacuum packed individually and stored at 0 °C on ice overnight until HP treatment. Samples weighed approximately 105 g ± 15 g, 90 g ± 15 g and 45 g ± 10 g for salmon, cod and mackerel, respectively.

2.2. Experimental design

A full factorial design with 3 pressure levels and 3 storage times was used for cod and salmon, where the storage time was set based on the expected shelf life of fresh fish. In mackerel 4 storage times were employed due to an expected shorter shelf life of this species compared with salmon and cod. The HP treatments were assigned to samples from different fish and different locations on the loin in an incomplete block design. Each HP treatment was repeated 5 times.

2.3. High pressure treatment and storage

HP treatment was carried out in a high hydrostatic pressure (HP) machine QFP 2L-700 (Avure Technologies Inc., Columbus, USA). The pressure medium of the HP machine is water. The HP machine was cooled to 8–9 °C prior to the treatments. Samples were placed in the high pressure vessel and pressurized for 120 s at either 200 MPa or 500 MPa. Control samples were non-pressurized samples. Immediately after HP treatment (day 0) liquid loss, water holding capacity (WHC), texture, colour and denaturation enthalpy (DSC) were analysed for all samples.

2.4. Liquid loss

Control and HP treated samples were weighed before and after treatment and storage. Liquid losses were calculated as the difference in weight before and after HP treatment divided by the weight before HP treatment. Liquid losses are expressed as percentage liquid lost during processing and/or storage.

2.5. Water holding capacity

Control and HP treated samples were analysed according to the method described by Skipnes, Østby, and Hendrickx (2007) and was made in 5 replicates per treatment. Five samples from each treatment were centrifuged at 2000 × *g* for 15 min at 4 °C and the centrifuge loss calculated. Dry matter contents of the samples were determined by drying samples at 105 °C for 16 h. WHC was then calculated as the centrifugation loss divided by the dry matter content in grams. Results are given as percentage water after centrifugation of initial water in samples.

2.6. Kramer shear test

Control and HP treated samples were tempered at room temperature for 1 h prior to analysis. Shear force was measured at a Texture Analyzer TA-XT plus (Stable Micro Systems, UK) equipped with a 5-bladed Kramer cell adapted to a 50 kg load cell at a cross-head speed of 1 mm/s. Shear force measurements were carried out perpendicular to the muscle fibers as this has been shown to result in higher repeatability and reduced variability between individual fish (Taylor, Fjaera, & Skjervold, 2002). The height was registered and multiplied with the sample width (6 cm), and then divided with the total shear force. Thus, results are given in N/cm^2. Eight replicates from each treatment were analysed.

Table 1
LS means of water holding capacity (WHC) in % and liquid loss (Loss) in % of control and HPP cod, mackerel and salmon during storage. Letters in superscript a-d refer to significance between treatments and storage time within each measured parameter and within each fish species ($P < 0.05$).

Type	Storage time (days)	0.1 MPa (control)		200 MPa		500 MPa	
		WHC	Loss	WHC	Loss	WHC	Loss
Cod	0	92.5^{a}	0.7^{d}	89.7^{a}	2.6^{cd}	91.5^{a}	2.2^{cd}
	11	93.6^{a}	2.2^{cd}	91.9^{a}	6.7^{ab}	93.4^{a}	4.9^{abc}
	18	93.0^{a}	4.2^{bc}	76.4^{b}	7.4^{a}	78.0^{b}	7.1^{a}
Mackerel	0	85.7^{abc}	3.0^{d}	80.5^{c}	7.2^{c}	90.3^{a}	6.9^{c}
	4	86.8^{abc}	7.6^{bc}	87.9^{a}	10.7^{ab}	87.7^{ab}	9.1^{bc}
	18	79.1^{c}	6.2^{c}	81.7^{bc}	11.2^{ab}	85.1^{abc}	10.0^{b}
Salmon	0	93.5^{a}	ND	83.1^{abc}	1.5^{bc}	84.2^{abc}	0.6^{c}
	11	90.8^{ab}	3.3^{abc}	72.2^{d}	3.8^{ab}	77.0^{cd}	1.7^{bc}
	25	ND	5.2^{a}	73.2^{d}	5.7^{a}	80.2^{bcd}	3.1^{abc}

ND – not determined.