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Physicochemical changes induced in carp (*Cyprinus carpio*) fillets by high pressure processing at low temperature

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Abstract

Raw carp fillets (*Cyprinus carpio*) were vacuum packed and pressurized at 100, 140, 180 and 200 MPa at 4 °C for 15 and 20 min, and then monitored for changes in the lipid fraction, color and electrophoretic profiles. The values of thiobarbituric acid (TBA) reactive substances in the samples increased with pressure and pressurization time. Similar results were obtained for free fatty acids (FFA) levels formed as a result of pressure treatment. The CIE color values, i.e., L^* (lightness), a^* (redness) and b^* (yellowness) of the carp fish fillets also increased with pressure and pressurization time, and the results obtained attest to the importance of establishing treatment conditions for various fish species when processing these food products in order to minimize changes in their appearance and flavor characteristics.

Keywords: High-pressure processing; TBA values; Color and lipid changes; Myofibrillar proteins; Carp (*Cyprinus carpio*) fish fillets

Industrial relevance: High pressure processing is finding increasing use in the food industry because of its relative advantages versus other food processing methods in eliciting minimal changes in the flavor and nutritional qualities of the final product. High pressure treatment is able to achieve this via its effects on the two causative agents of food spoilage, namely autolysis as well as microbial growth and metabolism. High pressure processing has been used commercially to produce food products such as raw oysters, guacamole, and ham and fruit juices in the US; and to produce jams, jellies, fish and meat products, salad dressing, ham, fruit juices and yogurt in Europe and Japan. However, in spite of the notion that high pressure processing results in minimal changes in food products, it is also common knowledge that the technology induces important changes in the texture and appearance of raw fish would be influenced by temperature at which the pressurize treatment was conducted. This paper illustrates the changes induced in raw carp flesh by pressurization at different temperatures.

1. Introduction

Although initial attempts to apply high pressure (HP) technology to food processing dates back to the late 19th century, the true potential of HP technology for the food industry was recognized only recently in the 1980s. HP technology has since become one of the most popular subjects of study in food engineering and technology. The engineering aspects of HP applications in the context of food processing, safety and quality, and the effects of high pressure on ice-water transitions was recently reviewed (Balny & Masson, 1993; Knorr, 1993; Kalichevsky, Knorr, & Lillford, 1995; Messens, Van Camp, & Huyghebaert, 1997; Sanz, Otero, de Elvira, & Carrasco, 1997; Thakur and Nelson, 1998).

Pressure can be effective for low-temperature pasteurization, meat tenderization or inactivation of endogenous enzymes because it alters the intramolecular interactions that stabilize the higher orders of structure of native protein molecules, probably by disrupting or forming hydrophobic interactions, hydrogen bonds, electrostatic interactions and disulfides linkages (Balny & Masson, 1993). In the particular case of ice–water transition, HP processing offers potential application as in pressure-shift freezing, pressure-assisted thawing, non-frozen storage under pressure at subzero

Abbreviations: EDTA, ethylenediamine tetra acetic acid; HP, high pressure; FFA, free fatty acids; TBA, thiobarbituric acid; TCA, trichloroacetic acid; SDS-PAGE, sodium dodecylsulfate-polyacrylamide gel electrophoresis.

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temperature and the formation of different ice polymorphs (Kalichevsky et al., 1995; Torres & Velazquez, 2005).

The advantages of HP technology include minimal effects on flavor and nutritional attributes of the final products. Some studies done on meat and fish have shown that HP may be a useful processing tool for such products (Ohshima, Nakagawa, & Koizumi, 1992). Recently, Ashie and Simpson (1996) applied HP to control enzyme induced texture deterioration in seafood. Other studies include HP effects on thawing of beef (Zhao, Flores, & Olson, 1998), HP effects on myofibrillar proteins (Angsupanich, Edde, & Ledward, 1999), prevention of HP denaturation of muscle proteins by sugars and polyols (Ashie, Lanier, & MacDonald, 1999), and high pressure processing inactivation of pathogens in raw oysters (An, Calik, He, Adams, & Morrissey, 2000). Studies have also been reported on HP inactivation of enzymes and pathogens in various fruit juices (Bayindirli, Alpas, Bozoglu, & Hizal, 2006), such as HP inactivation of pectinmethylesterase in carrot juice (Balogh, Smout, Nguyen, Van Loey, & Hendrickx, 2004), and HP inactivation of *Escherichia coli* and *Listeria monocytogenes* in alfalfa seeds (Ariefdjohan et al., 2004). More recent studies on the pressure effects on food and related systems include those by Chapleau, Mangavel, Campoint, and de Lamballerie-Anton (2003) that verified how pressure influenced beef myofibrillar protein structure. The influence of pressure on the quality of salmon that had been cold-smoked and vacuum packaged during refrigerated storage has also been investigated (Lakshmann, Miskin, & Piggott, 2005). Chevalier, Le Bail, and Ghoul (2001) studied high pressure effects on the quality of turbot flesh, while Schubring, Meyer, Schluter, Boguslawski, and Knorr (2003) also reported on the use of high pressure to facilitate thawing of frozen fish to assure better quality fish products. The use of high pressure in combination with low temperature on growth and proliferation of *Listeria* in smoked salmon mince has also been described (Picart, Dumay, Guiraud, & Cheftel, 2005). Montero, Giménez, Pérez-Mateos, and Gómez-Guillén (2005) investigated oxidation in pressure and heat induced gels made from minced mackerel, while Linton, McClements, and Patterson (2003) studied high pressure effects on the microbiological quality of selected shellfish (i.e., scallops, prawns, mussels and oysters). In spite of these developments, it is still felt that our understanding of the effects of pressure on muscle tissue characteristics is limited. It is well known that the texture and appearance of fish changes remarkably during heat treatment. These changes have also been observed in fish meat that had been subjected to HP treatment. The response of food products to HP processing is complex, being affected by processing parameters and product characteristics, such as pressure intensity, duration of the pressurization, temperature, product pH, and water activity. The purpose of this study was to verify the combined effects of high pressure (up to 200 MPa), low temperature (4 °C) and pressurization time on the color of carp fillets, as well as on the lipid fraction of fish flesh. This information would be very useful in defining process conditions for HP treatment of seafood.

2. Materials and methods

2.1. Fish samples

Live carp (*Cyprinus carpio*) (weight, ca. 1226±221 g and length 40±7 cm), were obtained from an aquaculture farm (Ferme acquacole d'Anjou, Morannes, France), and immediately transported to the pilot plant (Nantes, France). The fish were held in fish-tanks (10 °C) overnight and then slaughtered, cleaned, skinned and filleted the next morning. The fresh fish fillets were placed in moisture-impermeable polyethylene bags (La Bovida, France), vacuum-packed and then processed between 3–5 h after slaughter.

2.2. Pressure treatment

Pressure treatment was carried out in a 3 L capacity high-pressure vessel (ALSTOM, Nantes, France). The stainless steel vessel (12 cm internal diameter and 30 cm internal height), and the pressure transmitting medium (50/50 v/v ethanol/water solution) were maintained at about 0 °C by circulating the cold ethanol/water solution from an external cryostat through the internal cooling circuit of the high pressure vessel. A high-pressure pump supplied pressure, and a K-type thermocouple was installed at the center of the samples. The maximum temperature of the samples during pressure treatment was 4 °C. Fish samples were placed in the high-pressure vessel, and pressurized at various levels (i.e., 100, 140, 180 and 200 MPa) at a rate of 100 MPa/min. Time treatment refers to the time that the product was subjected to a given pressure (it does not include come up time and release time). After the pressure treatment, pressure was released at a rate of 10 MPa/s. Directly after pressure treatment, the samples were analyzed for changes in TBA values, free fatty acid content, color and electrophoretic profiles. Each experiment was performed in duplicate on 2 different batches of fish.

2.3. Thiobarbituric acid (TBA) values

TBA values were determined using a modified version of the procedure of Vyncke (1970), described in detail by Chevalier et al. (2001) for their studies on high pressure processing of turbot. Thiobarbituric acid (TBA) values were calculated from a standard curve obtained by reacting known amounts of 1,1,3,3 tetraethoxypropane with TBA. Triplicate analyses were performed on all samples and the TBA number was expressed in mg of malonaldehyde equivalents/g fish tissue.

2.4. Free fatty acid (FFA) content

Free fatty acid content of the fish samples was determined as per the method of Kirk and Sawyer, 1991. A mixture of diethylether (25 mL), ethanol (70% v/v) (25 mL) and 1% phenolphthalein solution (1 mL) was prepared then neutralized with 0.1 M NaOH solution. Two gram quantities of fish