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Quality changes during superchilled storage of cod (*Gadus morhua*) fillets

A.S. Duun *, T. Rustad

Department of Biotechnology, NTNU, NO-7491 Trondheim, Norway

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Abstract

Superchilling is a method with potential for extending the shelf life of food products by partial freezing. For centuries, Atlantic cod (*Gadus morhua*) has been the most important commercial species in the North Atlantic fisheries and is now regarded as a very promising species in cold water fish farming. In the present work, superchilled storage at −2.2 °C of fillet portions of farmed cod was investigated. Superchilled cod showed increased shelf life with respect to reduced growth of sulphide producing bacteria compared to ice chilled. Drip loss was lower in superchilled cod. However, liquid loss by low-speed centrifugation was higher in superchilled cod fillets compared to ice chilled. This can be explained by freeze denaturation of muscle proteins, which is supported by the lower extractability of salt soluble proteins. There is a need for process optimization to minimize protein denaturation.

Keywords: Superchilling; Cod; *Gadus morhua*; Bacterial count; SPB; Drip loss; Liquid loss; Protein extractability; pH; Free amino acid

1. Introduction

For centuries, Atlantic cod (*Gadus morhua*) has been the most important commercial species in the North Atlantic fisheries and is now regarded as a very promising species in cold water fish farming. Fish farming may provide an opportunity to obtain a seasonally independent supply of fresh fish to the market. Norway is one of the largest net exporters of seafood and in recent years the annual harvest has been more than 3 million metric tonnes of fish and seafood. In 2005, fish farming was responsible for almost half the value of Norwegian seafood exports. Cod has traditionally been sold as whole fish, while the tendency now is more toward fillets and prepacked dishes. The demand for fresh cod fillets is rapidly increasing at the expense of frozen fillets (Norwegian Seafood Export Council, 2005). Since the shelf life of fillets are lower than for whole fish, the need to develop methods for maintaining good post mortem quality of the fish on its way to the market increases. Extending the shelf life of fish may also be a way to increase profitability, since product prices in the fresh market are higher than in the frozen market. Potentials for extending shelf life can be found in using hurdle technologies such as different gas mixtures (Sivertsvik, 2007), additives (Boskou & Debevere, 2000) or new temperature regimes.

The most important factor for increasing shelf life is the temperature from catch to consumer. Superchilling (also called partial freezing or deep chilling) is often used to describe a process where food products are stored between the freezing point of the products and 1–2 °C below this. The initial freezing points of most foodstuffs are between −0.5 °C and −2.8 °C (Fennema, Powrie, & Marth, 1973). The surrounding temperature is set below the initial freezing point of the food, and depending on the method used some ice is formed in the outer few millimeters. In this way refrigeration capacity is stored inside the product, making it possible to maintain a low product temperature during storage or in a distribution chain where a considerable

* Corresponding author. Tel.: +47 7359 4070; fax: +47 7359 1283.
E-mail address: anne.sissel.duun@biotech.ntnu.no (A.S. Duun).

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heat load is assumed. In this temperature range, a drop in temperature of about 1 °C will often result in doubling the amount of water frozen out (Power, Morton, & Sinclair, 1969). With the high latent heat of ice (3.65 kJ/kg), this will give a certain degree of aftercooling of the product if the cooling is interrupted. A low product temperature can thereby be ensured even with a short cooling time. Since fish is more highly perishable than meat, the temperature is even more important.

For many food products, superchilling results in better quality compared to conventional chilling. The shelf life of superchilled food can be extended by 1.5–4 times compared to chilled food and should be an attractive alternative to freezing and conventional chilling (Einarsson, 1988). Normal shelf life of good quality ice chilled cod is about 11–14 days (Dalgaard, Gram, & Huss, 1993; Einarsson, 1994). Power et al. (1969) concluded that reducing the storage temperature of round cod to just below the freezing point could approximately double the storage life, as measured by a taste panel. Based on the content of total volatile base nitrogen (TVB-N) and hypoxanthine, Nowlan and co-workers stated that the shelf life of ice chilled or superchilled cod at −1.6 or −4 °C – were 10, 14 and 18–20 days, respectively (Nowlan, Dyer, & Keith, 1975). Mullet (*Mugil* spp.) had a shelf life of 10 days stored at −2 °C compared to 7 days stored in ice (Lee & Toledo, 1984). Extension of shelf life was attributed to delayed microbial growth and reduced rates of biochemical processes.

More recently, Olafsdottir, Lauzon, Martinsdottir, Oehlenschlager, and Kristbergsson (2006) investigated superchilling of aerobically packed cod fillets by combined blast and contact (CBC) chilling. They found the shelf life of superchilled cod based on Torry score and TVB-N to be 15 days at −1.5 °C compared to 11 days for ice chilled cod.

Superchilling of fatty fish has shown promising results. Based on both sensory and microbial analyses, superchilled salmon stored at −2 °C had a 21 days sensory shelf life, whereas fillets stored at chilled conditions were spoiled after 7 days (Sivertsvik, Rosnes, & Kleiberg, 2003).

When some of the water freezes out, the concentration of solutes in unfrozen solutions increases. This may lead to denaturation of the muscle proteins as well as structural damage of membranes, which can result in increased drip loss, loss of water holding capacity and textural changes. Increased enzymatic activity has also been suggested during storage at subzero temperatures (Foegeding, Lanier, & Hultin, 1996). The shelf life of superchilled food is far shorter than for frozen food, but could be more attractive since the amount of water frozen out is lower in superchilling compared to freezing. Less water frozen out will lead to less change in microstructure, which in turn may result in a lower degree of freeze denaturation and less drip loss (Einarsson, 1988). Structural changes due to ice crystals at subzero temperature storage have appeared to be minor compared to those which occurred during freezing at −20 °C, as revealed by microscopic examination (Lee & Toledo, 1984). The ice fraction curve is very steep in the superchilling temperature area. Fluctuating temperature may give melting and refreezing of water resulting in larger ice crystals, which can be disruptive to the microstructure (Mackie, 1993).

Superchilling has emerged as a potential method for extending shelf life, but still there is a need to know more about how the degree of superchilling (the amount of water frozen out) affects biochemical changes, such as protein denaturation, enzymatic activity and liquid retention. Most of the studies on superchilling have focused on microbiology, sensory analysis and spoilage indicators such as TVB-N (Olafsdottir et al., 2006; Sivertsvik, Jeksrud, & Rosnes, 2002; Sivertsvik et al., 2003; Zeng, Thorarinsdottir, & Olafsdottir, 2005), and have only to a minor extent studied the effect of superchilling on biochemical processes and how they influence quality parameters, such as loss of juiciness and negative textural changes.

The aim of this study was to investigate the effects of a superchilling process on selected quality parameters of farmed cod in order to extend shelf life without freezing the fish.

2. Materials and methods

2.1. Raw materials and processing

Twenty Atlantic cod (*G. morhua*) from a fish farm in mid-Norway were slaughtered and transported on ice to the laboratory in October 2005. After three days of ice chilled storage, the cod were headed, filleted and deboned. The fish had a weight of 2348 ± 509 g, the length was 53.6 ± 3.5 cm and the hepatosomatic index (HSI), calculated as the ratio of liver weight to ungutted fish weight, was 13.9 ± 1.7%. From the middle of each skin-on fillet with thickness of 15–25 mm, two portions of 158 ± 31 g were vacuum packed and labeled. Samples from the right side of the cod fillets were subsequently cooled down for 14 min in a freezing tunnel at a temperature of −24 °C and air velocity of 4 m/s. The duration of the cooling was based on previous experiments and simulations (Hardarson, 1996). After cooling the surface ice layer was 3–5 mm and the core temperature approximately −1 °C. The samples were immediately transferred to a cold storage room at −2.2 ± 0.2 °C for temperature equalization and storage for up to 34 days. The day of processing was defined as day 0. Samples from the left side of the cod fillets were used as references and kept on ice or frozen at −21 or −40 °C, respectively. Prior to analysis (1–2 h depending on fillet thickness) subzero stored samples were transferred to room temperature for thawing. During the superchilled storage air temperature was logged by logs of the type StowAway-IS Temp with an internal sensor.

2.2. Sampling

Analysis were made on superchilled samples on day 7, 14, 21, 28, 35 and 42 and on ice stored samples on day 1,