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Effect of superchilling on Atlantic salmon quality through the value chain

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Results show improved water holding and other quality attributes

This study concluded that superchilling whole Atlantic salmon using refrigerated sea water resulted in lower drip loss and bacterial counts than traditional methods using wet ice. Photo by Darryl Jory.

Water holding capacity (WHC) – the ability for raw meat to retain moisture – is known as an important quality parameter of raw and cold-smoked Atlantic salmon (*Salmo salar*). A high WHC is one of the major goals in food processing because it is related to the yield, quality and sensory attributes of a product. And it can affect weight changes during storage and transport, weight loss during thawing and cooking, and meat texture.

After the animal's death, some of the free water in muscle tissue is lost as drip loss. It represents liquid loss during processing, storage or thawing, and is due to extrusion of tissue juices from the structural change of muscle. Water soluble compounds are also lost as drip and are a nutritious substrate for microbial growth and can directly influence product profitability and consumers' perception related to product appearance and texture. Therefore, it is important to minimize the rapid onset of rigor through controllable methods such as rapid cooling, gentle handling and proper processing.

Superchilling is a preservation method where temperature is kept between conventional chilling and freezing to prolong shelf life of foods. Traditional chilling on ice represents 20 to 30 percent of the total weight of a box of fish, and directly results in additional costs to both producers and consumers. Superchilling reduces the need for ice during transportation and storage, effectively utilizing the fish itself as a cooling medium, which prevents microbial activity and helps maintain food freshness and quality.

Superchilling can be done by several methods, including refrigerated sea water (RSW) slurry. RSW uses water with microscopic ice crystals commonly used in fishing vessels for holding and cooling fish to minus-1 degrees-C in large seawater tanks until processing. Storing fish in RSW has proven to be rapid and easy, and slurries have better heat exchange rates and causes less fish damage in contrast to flaked ice. To our knowledge, superchilling during initial storage of whole salmon in RSW and its effect on water holding properties and other quality parameters in the whole value chain has not been explored.

This article – adapted and summarized from the **original publication** (https://doi.org/10.1016/j.aquaculture.2020.735381) [S.S. Chan et al. 2020. Effect of chilling technologies on water holding properties and other quality parameters throughout the whole value chain: From whole fish to cold-smoked fillets of Atlantic salmon (*Salmo salar*). *Aquaculture* 526, 15 September 2020, 735381] – reports on a study to superchill whole Atlantic salmon and then follow the entire value chain process until resulting fillets were dry salted and cold-smoked; and to assess water holding properties and other quality attributes throughout the process.

Study setup

In collaboration with Hav Line AS, we carried out our experiment onboard their fish slaughtering vessel, which directly harvests fish at fish farms, slaughters them and immediately superchills the fish in RSW tanks onboard. By doing so, the temperature of salmon is already kept at superchilled conditions during the early stages of the value chain. About 210 tons of Atlantic salmon (*Salmo salar*) were pumped onboard the slaughter vessel. The fish were not fed for five days, then sacrificed according to protocol, and 82 of these fish were used for quality analysis.

The experimental design included whole fish (chilled on wet ice versus RSW); fillet (stored on wet ice/superchilled with liquid nitrogen, N_2); and processed (raw/cold-smoked), resulting in eight different groups. First, a group of head-on-gutted (HOG) salmon (n = 36) was stored in wet ice for four days until before filleting as control in expanded polystyrene (EPS) boxes. Another group (n = 36) was immediately superchilled in RSW with ice slurry to minus-0.7 degrees-C in storage tanks onboard for around 12 hours. Commercial temperature loggers were inserted in the abdomen of iced fish, and at the gut area towards the tail for RSW fish. The superchilled fish were transported to Nofima AS in Stavanger (Norway), and fish stored in ice and superchilled fish (RSW) were kept at 0 and minus-1 degrees-C, respectively, until filleting on day 4.

For detailed information on the experimental design; fish filleting, salting and smoking; quality analyses; drip loss and yield; water holding capacity and water content; analyses for color, texture and other parameters; and microbiological and statistical analyses, refer to the original publication.

Results and discussion

Our results demonstrated that superchilling whole fish in RSW, followed by storage on ice after filleting, resulted in lesser drip loss as compared to the traditional storage method on ice. In addition, superchilling resulted in better gaping scores (the splitting of connective tissue between muscle layers, creating slits and holes in the fish fillet), lower blood-spot counts and higher firmness and toughness after smoking.

Superchilling whole fish improved gaping scores in processed fillets.
Photo by Darryl Jory.

Rigor mortis in unstressed salmon normally reaches a maximum between 24 and 30 hours after sacrifice. In our study, fish stored both in ice and in RSW went into maximum rigor at about the same time. This shows that superchilling of whole fish in RSW did not accelerate the progression of the rigor process, as seen in cold shortening on winter acclimatized salmon due to rapid chilling immediately after slaughter.

Temperature variations during storage should be minimal, as this can affect ice melting and recrystallisation, which changes the ice distribution and size within the fish. In this experiment, the temperature was kept rather stable during transportation of whole fish. Fish in RSW cooled down at a faster rate than in ice, which was expected since the recirculating water has a higher convective heat transfer coefficient, and consequently a better heat exchange rate compared to ice. A greater surface area of fish is also exposed to seawater, providing a more even temperature distribution.

Regarding drip loss and yield, there was a steady increase in drip loss for all groups of raw fillets. A rapid increase in drip loss for all smoked fillets was observed after smoking on day 11, before it becomes relatively constant through storage. There was a significant effect for raw fillets on how the whole fish (ice versus RSW) and fillets (ice versus superchilled with N_2) were treated. Drip loss may be attributed to various factors such as fat content, starvation stress prior to slaughtering and storage conditions.

Drip loss of the groups of smoked salmon were affected by storage duration and how the whole fish was treated. All groups of smoked salmon had a weight reduction of 4.2 to 4.7 percent after dry salting, in agreement with other studies reporting a 3.6 to 7.4 percent decrease in fillet weight. The product yields obtained after smoking for all groups were slightly higher than the values reported of 86 to 92 percent reported in other studies. This is economically beneficial but may be due to biological variations such as differences in fat content, as a higher fat content is known to produce better yield after processing.

The water holding capacity (WHC) of raw fillets observed in this study (82.1 to 87.4 percent) was found to be comparable to those from other previous studies. The WHC values of smoked fillets were significantly higher, while water content (WC) lower, than their raw counterparts. Weight loss and lower WC of smoked fillets were mainly due to the salting-out process from drying during the process and lipids leaching out from the muscle, causing muscle shrinkage. We found no WHC differences between the smoked groups, which may be due to variation in the salt and lipid contents of samples. However, WHC in all group of smoked fillets significantly decreased through time in all groups, probably caused by the denaturation of muscle proteins through storage especially with the influence of low thermal processing and salt.

Results from fillet index scores showed that the sensory quality of raw fillets is acceptable for 16 days, regardless of treatment method. Color relates to consumers' perception and is a key parameter on both raw and smoked salmon products, but information on how superchilling affects fillet color is still limited. We observed a darker, lesser red but more yellowish color in all groups of raw fillets until day 16. One factor that could have contributed to the darker color we observed may be the pH increase during fillet storage from day 9 to 16. The observed increase in lightness and decrease in yellowness we noted after day 16 could be an indication of spoilage for the raw fillets.

The firmness levels of fillets from whole fish in RSW and stored in ice or superchilled and fillets superchilled after filleting were higher than smoked fillets from whole fish on ice and stored in ice and smoked fillets superchilled after filleting on day 24. This suggests that the connective tissues for smoked fillets are more intact. Blood counts and gaping score were also found lower in RSW smoked fillets.

A total microbiological concentration over 106 CFU (colony forming units) per gram is considered spoiled, and the product is sensory rejected by consumers. Based on our data, all smoked fillets were still consumable after 31 days while all groups of raw fillets were spoiled after 23 days of storage. So, superchilling whole fish in RSW and storing them on ice after filleting can potentially prolong shelf life, but more research is needed for confirmation.

Minimizing drip loss in fish is important, and the commercial use of RSW superchilling supports storing fish in bulk and the delivery of already superchilled fish to customers, greatly lessening ice demand and providing a better quality than the traditional method on ice. Storing the fish on ice after filleting from RSW fish also lessens drip loss and the need to monitor factors that can affect superchilling, like the formation of ice crystals in fillets. Temperature is a critical aspect in superchilling in RSW and must be monitored closely and kept constant throughout the whole storage period. Adequate cleaning and proper recirculation of RSW systems is also necessary for good hygiene and prevention of microbial growth.

Perspectives

Results of this study showed that superchilling by RSW of whole fish leads to lower drip loss and H_2S-producing bacterial counts than traditional methods using wet-ice, along with better blood-spot counts and gaping after cold-smoking. Compared to superchilling fillets in liquid N_2, it is more feasible to store fillets from RSW fish chilled on ice due to lesser drip loss and better WHC. Smoking of fillets significantly changed WHC, water content (WC), texture and color of all raw fillets.

We did not examine the uptake of water and salt from whole fish, and how this affects water holding properties through the whole value chain. This could be an interesting aspect for further research, in addition to shelf life and sensory studies including a taste panel.

References available in the original publication.

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