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Effects of different salting and smoking processes on the microstructure, the texture and yield of Atlantic salmon (*Salmo salar*) fillets

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Abstract

The effect of different conditions during the salting and smoking process on the microstructure and the texture of salmon fillets was studied in interaction with different raw salmon material; ocean-ranched Atlantic salmon (*Salmo salar*) from Iceland and two groups of farmed Atlantic salmon (*Salmo salar*) from Norway, one from Northern Norway and one from Western Norway. The ocean-ranched salmon was found to have significantly smaller fiber diameters and higher shear force compared to the farmed fish. The cross-sectional area of the muscle fibers decreased during the salting and smoking process. Small differences were noted in the cross-sectional area between smoked fillets processed by different salting and smoking methods. However, the cross-sectional area of fibers in dry salted fish fillets from the farmed groups were significantly smaller than in the brine salted fillets, as the fibers shrunk more during dry salting than brine salting. The force required to shear the smoked fillets was significantly higher than for the unprocessed fillets, but was not found to be related to the different salting and smoking processes. Yield during smoking was not related to the initial cross-sectional area or the shear force of the unprocessed muscle.

Keywords: Salmon; Smoking; Microstructure; Shear force

1. Introduction

The main quality parameters for fresh salmon are fat, color, texture and freshness. Other quality parameters commonly cited are white stripes (myocommata), bloodstains, marbling and melanin spots (Koteng, 1992; Sigurgisladottir, Torrissen, Lie, Thomassen & Hafsteinsson, 1997; Torrissen, Sigurgisladottir & Slinde, in press). Atlantic salmon is often cold smoked or marinated and cut in thin slices and consumed without any further heat treatment. The cold smoking process includes three stages, each of which is important to the product's potential shelf-life: salting, drying and smoking all at temperatures below 30°C. Cold-smoked salmon is a lightly preserved fish product with salt content ranging between 2.0 and 3.9% or 3.5 and 6.0% in the water phase, water content between 65 and 70% and pH between 5.8 and 6.3 (Hansen, Gill & Huss, 1995; Hansen, Gill, Rontved & Huss, 1996; Hansen, Rontved & Huss, 1998). The smoking process brings about changes in quality parameters such as flavor, color and texture.

The ionic strength and pH are the important factors that influence water binding of muscle proteins (Acton, Henna & Satterless, 1981; Gill, Chan, Phonchareon & Paulson, 1992; Hamm, 1986; Offer & Trinick, 1983; Trout & Schmidt, 1986). Low content of salt (1–2%) is known to improve the yield and liquid holding capacity of fish muscle (Regenstein, Jauregui & Baker, 1984). Duerr and Dyer (1952) described that as the salt penetrates the cod muscle it dissolves in the water associated with the proteins. In solutions of about 2–5% NaCl concentration, myosin swells very strongly and the water in the tissues

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becomes more firmly bound to the myosin. Duerr and Dyer reported that 9% NaCl is a critical concentration regarding the uptake of both salt and water, and further salt uptake leads to a process of water removal in cod where the protein suddenly denatures, loses its gel structure rapidly and releases a large part of the solution formerly held by the myosin gel. Ofstad, Kidman, Myklebust, Olsen and Hermansson (1995) showed that liquid loss in minced salmon fillet during heating decreased with increasing salt concentration from 1 to 2%. Shomer, Weinberg and Vasiliver (1987) reported swelling and fusion of the myofibrils and loss of arrayed structure using NaCl at 0.3–1.5% but at 12% NaCl there was a compaction of myofibrillar structure in silvercarp muscle. Rao, Gault and Kennedy (1989) reported that swelling of muscle was highly positively correlated with the fiber diameters. This emphasis that increases in muscle fibre diameter are much more important for total muscle swelling than increases in sarcomere length.

The commonly observed loss in weight of fillets during the process is both due to dehydration of the muscle, and lipids leaching from the muscle (personal communication, smoking industry). According to a review by Howgate (1979) the loss of weight due to dehydration in the smoking process is around 10–25% depending upon the origin of the raw material, the final product characteristics and the process parameters such as time and temperature during smoking. The raw material characteristics are of great importance for the yield and final product quality. The relationship between increased dietary lipid level from 31 up to 48% and the processing yields during the cold smoking process of Atlantic salmon were studied by Torrissen, Hemre and Sandnes (in press). They found that the total yield was highest in the groups fed the highest dietary lipid level. Einen and Roem (1997) and Rora, Kvale, Morkore, Rorvik, Steien and Thomassen (1998) present similar results. The decreased loss during salting and smoking can be explained by less dehydration in fat fish compared to leaner fish. Sheehan, O'Connor, Sheehy, Buckley and Fitzgerald (1996) reported pronounced gaping in smoked flesh during storage of salmon fed diets containing 30% lipid. However, Torrissen, Hemre et al., in press did not find gaping a significant problem, but their experiment was terminated the day after smoking.

The main goal in this study was to investigate the effects of different parameters in the smoking process on the microstructure and texture of salmon fillets. The parameters selected were brine and dry salting prior to smoking and two different temperatures in the smoking process, 20 and 30°C. Electrostatic smoking (Bardin, Desportes, Knockaert & Vallet, 1997; Collignan, Knockaert, Raoult & Vallet, 1993) was used for comparison to the traditional cold smoking process. Three types of salmon material were used; ocean-ranched fish from Iceland and farmed fish from Norway slaughtered in autumn and spring. The ocean ranched salmon from Iceland is in this context regarded as a wild salmon.

2. Materials and methods

2.1. Fish samples

Three groups of fish of different origin were used with 75 salmon in each origin group.

1. (Farmed Oct 1998) Fish harvested in October 1998 from the commercial fish farm Torris Product Ltd A/S, Nordland (67° N). Samples of 75 salmon (4 kg±150 g) were used for the study. The fish were fed with Bio optimal® and Ecolite TT® (Biomar, Bergen) the last 12 months. The fish density in the sea cages was at maximum 30–35 kg/m^3 and the annual average temperature was 8.3°C.
2. (Farmed April 1998) Fish harvested in April 1999 from the commercial fish farm Kvernsmolt A/S, Hordaland (60°). Samples of 75 salmon (3.7 kg±500 g) were used for the study. The fish were fed with Bio optimal 7 mm/TT-9® the last 12 months (Biomar, Bergen). The density in the sea cages was at maximum 10 kg/m^3. The annual average temperature was 9.0°C and the salinity 26–30 ppt.
3. (Ocean-ranched) ocean-ranched salmon harvested in July 1999 from Hraunsfjordur in Iceland. Samples of 75 salmon (2.6 kg±300 g). The salmon had been living wild in the sea for 1 year.

The fish were harvested by netting, and bled by cutting the gill arches on one side. The fish were allowed to bleed in cold sea water. The dead fish were gutted, cleaned and each individual fish was weighed and tagged. All the fish were transported by courier to Institut Francais de Recherche pour Iéxploitation de la Mer (IFREMER) in Nantes, France. During the transport the fish were stored on ice in sealed boxes.

2.2. Salting and smoking processes

At IFREMER the fish was filleted and trimmed. The trimming removed the rib bones and visible adipose tissue. Yield was calculated for each step in the process. The filleting was done at day six after slaughter. The right fillet was utilized for the smoking experiment and the left fillet was used as samples of the raw material.

Five different processing methods (15 salmon in each treatment group) were used with variation in salting method and temperature during smoking. In addition, one group was smoked by a new electrostatic smoking process:

a. Brine salted — traditional smoking at 20°C
b. Brine salted — traditional smoking at 30°C
c. Dry salted — traditional smoking at 20°C
d. Dry salted — traditional smoking at 30°C
e. Dry salted — electrostatic smoking at 12°C (room temperature)

Fish from the three samplings (1, 2, and 3) were processed using the same processing methods (detailed below).

2.2.1. Dry salting

Pure refined dry salt was sprinkled on one side of the fillets to cover the surface. Salting was carried out at 12°C, for 6 h. Then the fillets were shortly rinsed and kept in a cold room at 2°C for 12 h. Weight of each fillet was recorded, just before smoking.

2.2.2. Brine salting

Saturated (360 g of NaCl/l) brine, at temperature 12°C, for 6 h. The fillets were put in the saturated brine, which was continuously circulated. The fillets were loaded in bulk in the brine. The fillets were withdrawn from the brine, loaded on the trolleys, roughly rinsed and kept overnight in a cold room at 2°C. Weight of each fillet was recorded, just before smoking.

2.2.3. Traditional smoking

Smoking temperature 20 or 30°C: Wood chips of beech were used for smoke generation. The smoking process started with drying in the smoking oven for 30 min at 20°C. Smoking was carried out at 20°C, a humidity of 65% and air velocity 2 m/s for 5 h. Control of smoke density was done with opacimeter 0–100%, smoke extraction cycle was 10 min. After smoking the trolleys were stored at 2°C until packing the next day. Weight of each fillet was recorded, just before vacuum packaging (INV 40 Boulanger, Vaiges, France).

2.2.4. Electrostatic smoking

Dry salting was used, but no drying was applied. Smoking carried out in a tunnel for 15 min at a temperature 20°C, tension 40 KV, oak beam used for smoking and pyrolysis 350°C (Bardin et al., 1997). Electrostatic equipment: A continous tunnel capacity 125 kg per hour (Arbor Technologie Landevant, France). Weight of each fillet was recorded, just before vacuum packaging (INV 40 Boulanger, Vaiges, France).

2.3. Preparation of samples

All fillets were individually tagged with identical numbers for the left and right fillet. Unprocessed left fillets (15 fillets) were compared to salted and smoked right fillets (15 fillets) of the same fish individual. Fifteen fish individuals were in each treatment group (five groups). All samples were collected from the white muscle from the same location on each of the fillets, below the dorsal fin (Sigurgisladottir, Ingvarsdottir, Sigurdardottir, Torrissen & Hafsteinsson, in press). Two samples were collected for the microstructure study using a cork knife and two samples for textural measurements. The samples were embedded in plastic tubes containing O.C.T. compound (embedding medium, Tissue Tek, USA) and frozen in liquid nitrogen. Freezing (below −80°C) occured in approximately 40 s. The frozen specimens were stored at −80°C until sectioning.

2.3.1. Cryosectioning

The specimens were sectioned (10 μm) frozen at −27°C in a cryostat (Leica CM1800, Heidelberg, Germany) for transverse and longitudinal cuts.

2.3.2. Orange G and Methyl blue staining method

Cryo-sections were mounted on slides. The sections were stained for 5 min in Orange G (0.5 g of Orange G, 1 ml acetic acid dissolved in 99 ml distilled water and filtered). The sections were washed with distilled water and stained for 5 min in Methyl blue solution (0.07g Methyl blue, 1 ml acetic acid dissolved in 99 ml distilled water and filtered). The stained samples were washed for 5 min with distilled water before mounting with Mountex (Histolab Products AB). Using this staining method the muscle proteins stain yellow and collagen blue (Sigurgisladottir et al., in press).

2.4. Viewing and image processing by light microscope

The samples were examined in a microscope (Leica DML, Cambridge, UK) at 100×, 200× and 400× magnification. TV camera and LEICA Q500MC image processing analysis software (Cambridge, UK) were used for calculations of diameter, cross-sectional area and number of fibers in the images. Three pictures including 60–100 fibers each were processed and used for calculation.

2.5. Textural measurements

The TA.XT2 Texture Analyzer was used (Stable Micro System, Surrey, UK) with a load cell of 25 kg. Blade (knife-edge, 60°) of a thickness of 3.0 mm and width of 70 mm was used. The shear force was measured according to Sigurgisladottir, Hafsteinsson, Jonsson, Lie, Thomassen and Torrisen (1999). The blade approach was applied by pressing the blade through the muscle vertical to the muscle fibers. Duplicate measurements were performed on each sample. The measurements were carried out 2 days after filleting.

2.6. Fat content

Fat content and fat distribution was analyzed by non-destructive computer-aided X-ray tomography (CT) as described by Rye (1991).

2.7. Salt content

Quantitative determination of chloride from water-soluble chlorides, expressed in NaCl. Chlorides were solubilised in water and titrated by a chlorimeter (Chloride analyser 926 Corning).

2.8. Statistics

Data sets were compared by multiple comparison ANOVA using all pair wise comparison by Sigmastat 2.03 (Jandel Scientific Software, ON, Canada). Tukey test was used for multiple comparison and Pearson correlation coefficients were determined between variables. The difference was found to be significant at $P < 0.05$.

3. Results and discussion

3.1. Raw material characteristics: muscle fibers cross-sectional area and shear force

The ocean-ranched fish were leaner (9.4%) than the farmed fish from Norway harvested both in Oct 1998 (24.0%) and in April 1999 (20.2%) (Fig. 1).

The cross-sectional area of muscle fibers from the unprocessed ocean-ranched fish fillets were significantly ($P < 0.05$) smaller than the muscle fibers from the two groups of farmed fish (see Figs. 1 and 2). The cross-sectional area of muscle fibers from salmon harvested in October 1998 was significantly ($P < 0.05$) smaller than from salmon harvested in April 1999. The differences in the shear force between the groups were less pronounced than the cross-sectional area (Fig. 1). However, the shear force of unprocessed fillets from the ocean-ranched group was higher (31.8 N) than the shear force of farmed fish muscle harvested in October 1998 (28.2 N) and in April 1999 (27.6 N), although the difference was not significant.

Muscle fibers from farmed salmon used in this study both from October 1998 and April 1999 were found to have cross-sectional area in the same range as found in diploid fish in a previous study comparing diploid and triploid salmon (8800–11 100 μm^2) originating from the Institute of Marine Research, Bergen, Norway (Sigurgisladottir et al., in press). The weight of the salmon from October 1998 was approximately 4 kg but the salmon from April 1999 were smaller of average 3.7 kg, although that group of fish had the largest fibers average cross-sectional area of 12 000 μm^2. In contrast to mammals, muscle fiber number in many fish species increases throughout life. This along with other factors in the farming conditions, such as flow rate, temperature, oxygen can influence muscle growth (Johnston, 1999).

It has been stated in the literature that, in general, cultured fish tend to have softer and less preferable texture than free-living fish (Haard, 1992), e.g. Atlantic salmon (Love, 1988; Sigurgisladottir et al., 1999), Pacific salmon (Cepeda, Chou, Bracho & Haard, 1990). Ocean-ranched fish used in this study was found to have the significantly smallest fiber diameters and also a higher shear force was needed to shear the fillet samples compared to the farmed groups. However, the difference in shear force was not significant. Previously obtained results (Sigurgisladottir et al., 1999) on ocean-ranched salmon indicated that it took higher forces to shear them than samples of farmed salmon.

In a previous study (Sigurgisladottir et al., in press) shear force measurements of raw fresh fillets were not observed to be significantly different between the groups of fish containing triploid and diploid fibers of different cross-sectional area.

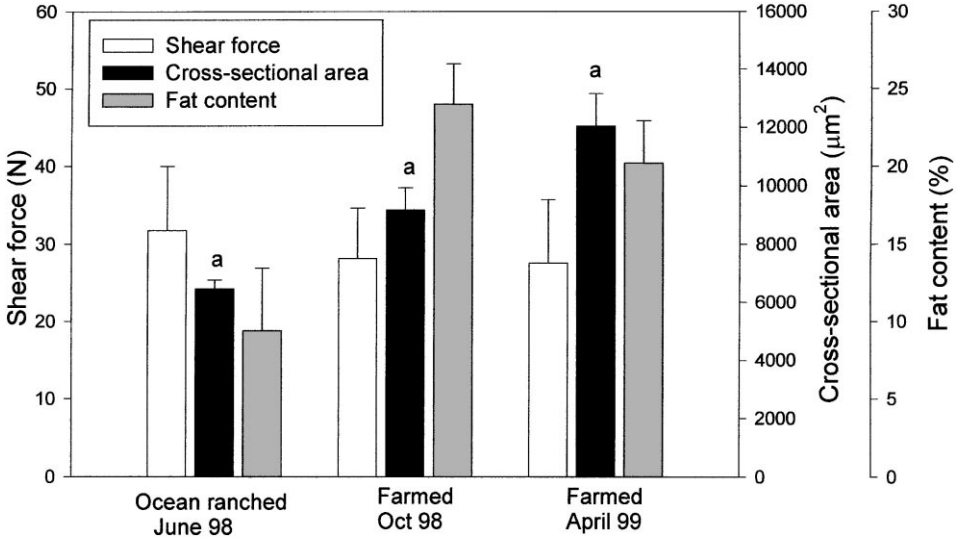
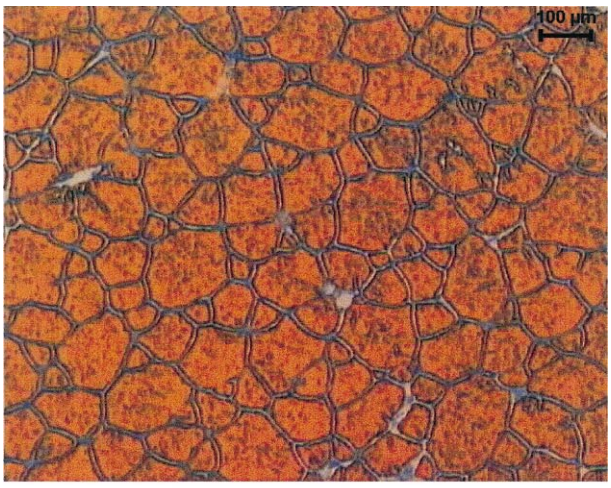
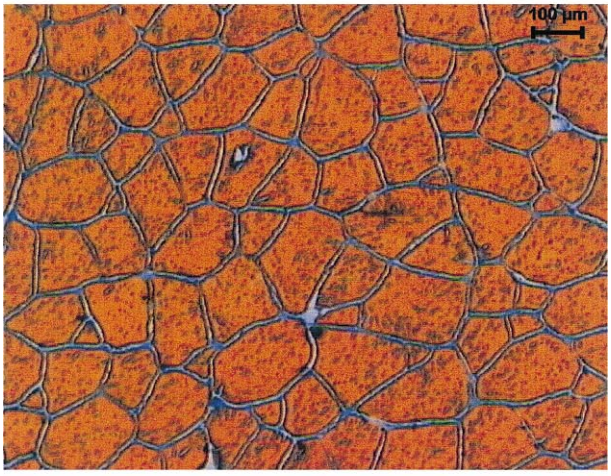


Fig. 1. Shear force, cross-sectional area of fibers and fat content of unprocessed muscle from ocean-ranched salmon and farmed salmon from October 1998 and April 1999. Data are mean and standard deviation of 15 samples [are significantly ($P < 0.05$) different].



(a)



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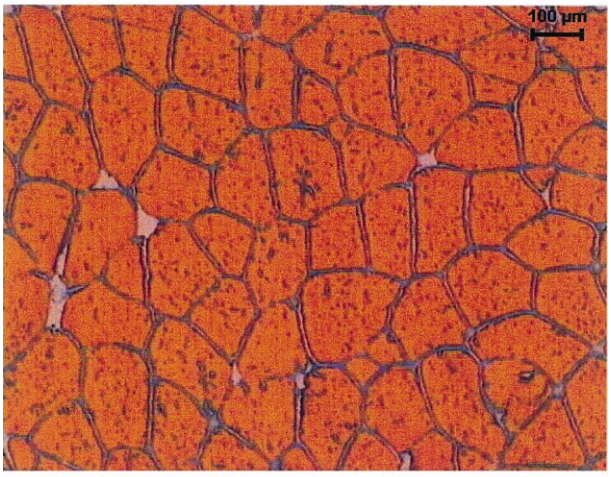
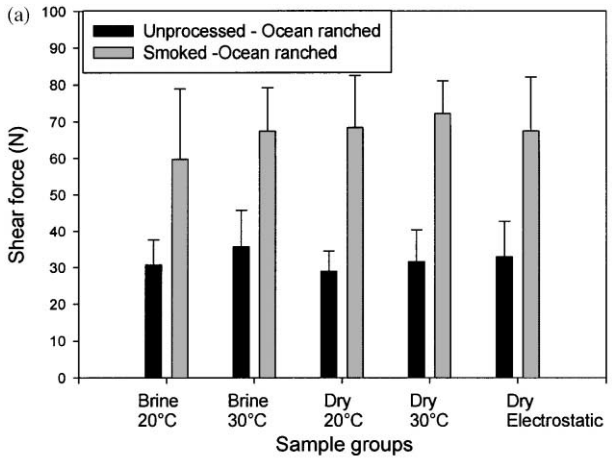
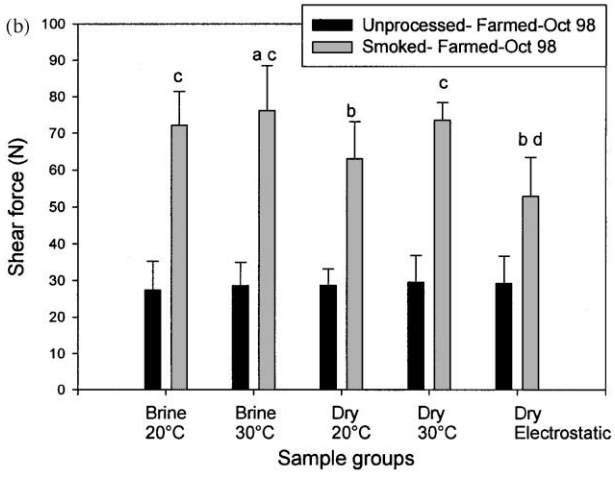


(c)

Fig. 2. Transverse sections of muscle from unprocessed salmon fillets: (a) ocean-ranched salmon slaughtered in July 1998; (b) farmed salmon slaughtered in October 1998; (c) farmed salmon slaughtered April 1999. The samples were stained by using Orange G and Methylene blue. Muscle protein stains yellow and collagen blue.





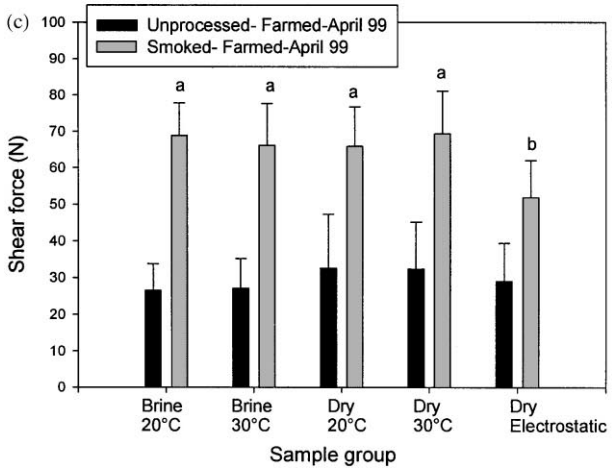


Fig. 3. Force required to shear smoked Atlantic salmon fillets after different processing methods applying both brine and dry salting, smoking at 20 and 30°C and electrostatic smoking: (a) ocean-ranched salmon slaughtered in July 1998; (b) farmed salmon slaughtered in October 1998; (c) farmed salmon slaughtered in April 1999. Data are mean and standard deviation of 15 samples [a,b are significantly ($P < 0.05$) different; c,d are significantly ($P < 0.05$) different].

Table 1
Yield after salting and smoking of trimmed salmon fillets compared to unprocessed fillets and salt content in the smoked fillets[a]

	Ocean-ranched June 1998		Farmed October 1998		Farmed April 1999	
Process	Yield %	Salt content %	Yield %	Salt content %	Yield %	Salt content %
Brine salted, temperature 20°C	90.9±1.7	3.9±0.8	94.6±0.7	2.8±0.5	94.2±0.5	3.2±0.4
Brine salted, temperature 30°C	91.3±1.4	3.6±0.6	95.0±0.6	2.7±0.5	95.0±0.7	3.4±0.4
Dry salted, temperature 20°C	88.8±1.3	3.3±0.4	92.2±0.7	2.4±0.3	91.1±0.8	3.1±0.3
Dry salted, temperature 30°C	89.2±0.8	3.4±0.4	92.7±0.4	2.3±0.2	93.1±0.9	2.7±0.3
Dry salted, electrostatic smoking	89.1±0.5	3.5±0.4	94.1±0.8	2.6±0.4	93.6±0.9	2.7±0.4

[a] Data are mean±standard deviation of 15 fillets.

3.2. Effect of different processing methods and raw material on shear force and yield of the smoked fillets

The force required to shear the smoked fillet samples was significantly higher than for the unprocessed fillet samples for the three origin-groups when comparing unprocessed and smoked fillets from the same fish individual (see Fig. 3). This agrees with results reported by Sigurgisladottir et al. (in press) who studied the structural properties and shear force of diploid and triploid salmon fillets smoked, using only one salting and smoking method.

The force required to shear the salted and smoked ocean-ranched salmon fillets was found to be not significantly different between the processing treatments; brine and dry salting and smoked at different temperature (20 and 30°C) as well as electrostatic smoking (see Fig. 3a).

The force required to shear salted and smoked fillets from the two farmed salmon groups (slaughtered in October 1998 and April 1999) was significantly different between the processing treatments. The shear force required for the dry salted fillets, smoked both at 20°C and by electrostatic smoking from the farmed group slaughtered in October 1998 was lower than for fillets processed by the other processing methods (see Fig. 3b). Shear force of fillets (group April 1999) processed by dry salting and electrostatic smoking was also significantly lower than for fillets processed by the other processing methods (see Fig. 3c).

Significantly lower yield was obtained for smoked samples treated with dry salting than the brine salted fillets. Higher yield was also obtained for samples smoked at 30°C as compared to 20°C. The smoked samples that were brine salted and smoked at 30°C gave the highest yield (see Table 1). A possible explanation could be that the high temperature made a "film" on the top of the fillets preventing fat leakage and/or evaporation.

Lower yield through the salting and smoking process was obtained for the ocean-ranched group than the farmed groups. There was not a significant difference in yield between the farmed groups although there was a difference in the cross-sectional area and fat content in the starting material. Torrissen, Hemre et al. (in press) and Torrissen, Sigurgisladottir et al. (in press) found less yield in the smoking process due lower fat content but during gutting and trimming the yield was higher than for high fat salmon. This is in agreement with Einen and Roem (1977) and Rora et al. (1998). The decreased loss during salting and smoking can be explained by less dehydration in fat fish compared to leaner fish.

The salt content in the smoked product was highest in the ocean-ranched samples in the range of 3.3–3.9% (see Table 1). The salt levels were lowest in the farmed fish samples from October 1998 at 2.3–2.8%. The brine-salted samples were higher in salt content than the dry salted samples in all the three sample groups.

3.3. Effects of different processing methods and raw material on microstructural properties of smoked fillets

The cross-sectional area of the muscle fibers decreased during the salting and smoking process in the three fish origin-groups (see Fig. 4). There was little difference in the cross-sectional area between smoked fillets processed by the different salting and smoking methods. Limited information is available in the literature on the effect of different smoking processes on fillet properties, especially the microstructure of fish muscle. The cross-sectional area of muscle fibers from the smoked fillets of the ocean-ranched fish were not related to the different processes, even though the yield was lower after dry salting than brine salting. However, the cross-sectional area of muscle fibers in smoked fillets from the group of farmed fish slaughtered in October 1998 was smallest in fillets salted by dry salting and smoked at 30°C. In farmed fish from April 1999, the cross-sectional area of muscle fibers were smaller in smoked fillets that were dry salted and smoked at 20 and 30°C than in the brine salted fillets smoked at 20 and 30°C (see Fig. 4). In spite of the significantly different initial cross-sectional fiber area of the farmed groups, the yield after smoking was not different between the groups (Fig. 5). However, the ocean-ranched group with smaller cross-sectional area

than both the farmed groups showed lower yield after smoking (Fig. 5). The interpretation of effects within individual techniques should therefore be cautiously predicted by characteristics of the flesh between fish of very different culture types (wild vs. farmed).

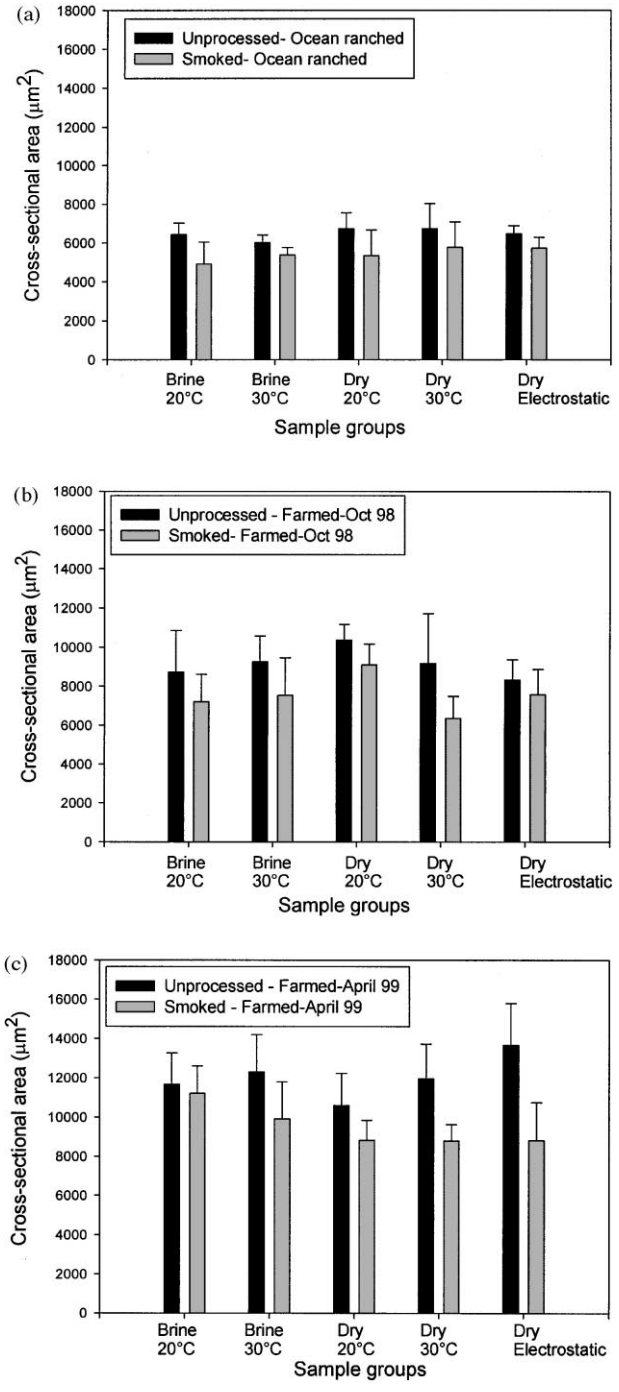


Fig. 4. Average cross-sectional area of muscle fibers from smoked Atlantic salmon fillets after different processing methods applying both brine and dry salting, smoking at 20 and 30°C and electrostatic smoking. Data are mean and standard deviation of five samples: (a) ocean-ranched salmon slaughtered in July 1998; (b) farmed salmon slaughtered in October 1998; (c) farmed salmon slaughtered in April 1999.

3.4. Cross-sectional areas of unprocessed, salted and smoked fillets of the same group after different processing methods

Samples were collected from the same fillets after salting, prior to smoking and after smoking to understand further the effects of the individual process parameters. The same fillets were followed through the process from unprocessed fillet to smoked fillet. Fig. 6 shows the cross-sectional area of muscle fibers from unprocessed, salted and smoked fillets from farmed fish slaughtered in April 1999.

The cross-sectional area of fibers in dry salted fish fillets was significantly smaller due to shrinking compared to the unprocessed fillet. The cross-sectional area of muscle

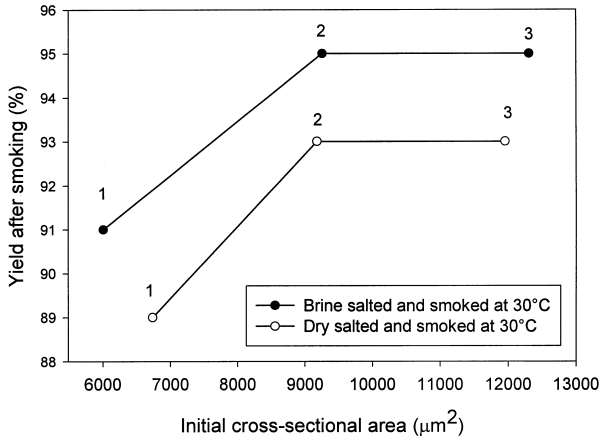


Fig. 5. Yield after smoking plotted versus the initial cross-sectional area of the raw material. Data are mean and standard deviation of five samples. (1) ocean-ranched salmon slaughtered in July 1998; (2) farmed salmon slaughtered in October 1998; (3) farmed salmon slaughtered in April 1999.

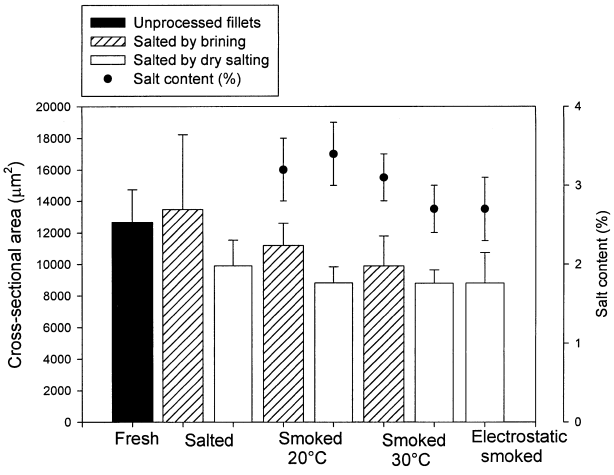


Fig. 6. Average cross-sectional area of muscle fibers from unprocessed, salted and smoked salmon fillets after different processing methods applying both brine and dry salting, smoking at 20 and 30°C and electrostatic smoking. Farmed salmon slaughtered in April 1999. Data are mean and standard deviation of 10 samples.

fibers from salted fillets was found to be smaller after dry salting than after brine salting. After smoking, the cross-sectional area of fibers from the brine salted samples was still bigger than from the dry salted samples (see Fig. 6) and similar compared to the unprocessed fillet. However, a high variation occurred in the cross-sectional area of fibers in the brine salted fillets, i.e. some fibers had expanded, others had shrunk or did not change. Less variation was observed in the cross-sectional area of the muscle fibers from the brine-salted samples after smoking. The high variation in the cross-sectional area after salting in brine is possibly based on uneven salt concentration distribution within the muscle. The brine applied was a saturated brine and can therefore cause an uneven salt distribution in the muscle. That is in agreement with results by Graham, Hamilton and Pierson (1986) who observed more uniform salt content in the water phase of chub muscle using lower concentration of brine mixtures and longer processing time.

Numerous papers have been published on the effects of salts on water retention and/or structural properties of either minced or intact muscle from fish or mammalian meat (Bakir, Hultin & Kelleher, 1994; Gill et al., 1992; Katsaras & Budras, 1993; Kenney & Hunt, 1990; Lemos, Nunes & Viana, 1999; Ofstad et al., 1995; Rao et al., 1989; Regenstein et al., 1984; Richardson & Jones, 1987; Shomer et al., 1987; Velinov, Zhikov & Cassens, 1990; Wilding, Hedges & Lillford, 1986). Wilding et al., 1986 observed that rabbit *m. longissimus dorsi* fibres swelled in hypertonic salt solutions such as 0.6 M KCl 2 times their original cross-sectional diameter. Shomer et al., 1987 reported swelling and fusion of the myofibrils and loss of arrayed structure using NaCl at 0.3–1.5%, but at 12% NaCl there was a compaction of myofibrillar structure. Ofstad et al., 1995 showed that liquid loss (fat and water) during heating decreased with increasing salt concentration from 1 to 2% salt content in minced salmon fillet.

Swelling or shrinkage of the myofibres occurs via an increase/decrease in the fibre transverse axis either by an electrostatically or entropically driven mechanism. Both the ionic strength and the specific ion affects the extent of swelling and hence the liquid holding ability of minced fish muscle (Regenstein et al., 1984; Weinberg, 1983). The relative effects of different factors such as salting on water holding capacity and swelling have been speculated to be similar for comminuted meat and the intact muscle but after comminution, the swelling capacity of the myofibrillar system is much less limited and the water-imbibing power of the thick filaments or myosin primarily determines the water holding capacity of meat (Hamm, 1986).

The final salt content in the smoked samples was found to vary from 2.7 to 3.4% (see Table 1 and Fig. 6). The salt concentrations in the salted fillets are within the limits known to increase the solubility of the muscle proteins (1 M NaCl). The difference between the fibers cross-sectional area of the brine salted and dry salted fillets is most likely due to different salting methods. Using dry salt instead of brine is expected to induce the effects of the salt on interaction of water with proteins such as higher osmotic pressure leading to more fibers shrinking in the dry salted samples than the brine salted samples.

4. Conclusion

The different processing methods used in this study showed similar effects on the muscle fibers diameters as compared to the unprocessed muscle. However, a trend was detected where the dry salting method lead to more fiber shrinkage than the brine salting method. The muscle fiber initial cross-sectional area and yield after smoking was not found to be related. However, these results could not be extrapolated to the wild salmon (ocean-ranched) group. The force required to shear the smoked fillets was not found to be related to the different processing methods or the starting material.

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