Application of Quality Index Method (QIM) Scheme in Shelf-life Study of Farmed Atlantic Salmon (Salmo salar)

K. Sveinsdottir, E. Martinsdottir, G. Hyldig, B. Jørgensen, and K. Kristbergsson

ABSTRACT: Salmon (Salmo salar) was stored in ice up to 24 d, and changes during storage were observed with sensory evaluation using the Quality Index Method (QIM), and Quantitative Descriptive Analysis (QDA), total viable counts (TVC), hydrogen sulfide (H$_2$S)-producing bacteria, and instrumental texture measurements (compression test). Maximum storage time in ice was determined with QDA and fat content by Soxhlet extraction. A high correlation between QIM and storage time in ice was found. Storage time could be predicted with ± 2 d. TVC increased exponentially with storage and was dominated by H$_2$S-producing bacteria after 20 d in ice, which was the maximum storage time. Texture measurements indicated softening of salmon flesh with storage.

Keywords: sensory evaluation, quality of salmon, fish freshness, shelf life

Introduction

Freshness is one of the most important aspects of fish, and because of consumer preferences, there is a strong tendency to select very fresh fish (Luten and Martinsdottir 1997). Sensory evaluation is the most important method for freshness and quality assessment in the fish sector (Hootman 1992). The world's production of farmed salmon increased between 1990 and 1997, from 540,000 tons to almost 1,400,000 tons per year (FAO 2000). In 1997, 38% of the salmon produced in the world was Atlantic salmon (Salmo salar). Because of the increased trade between countries, purchases are often performed on unseen lots, and there is a need for a good freshness grading system for salmon, such as the Quality Index Method (QIM). This method is a seafood freshness quality grading system, which is used to assess fish freshness in a rapid and reliable way. QIM is based upon a scheme originally developed by the Tasmanian Food Research Unit (Bremner 1985). The method has to be adapted to each fish species. To date, the system incorporates fresh herring (Clupea harengus) and cod (Gadus morhua) (Jonsdottir 1992; Larsen and others 1992), red fish (Sebastes mentella/marinus) (Martinsdottir and Arnason 1992), Atlantic mackerel (Scomber scombrus), horse mackerel (Trachurus trachurus), and eel (Sardina pilchardus) (Andrade and others 1997), bril (Rhombus laevis), dab (Limanda limanda), haddock (Melanogrammus aeglefinus), pollock (Pollachius virens), sole (Solea vulgaris), turbot (Scophthalmus maximus) and shrimp (Pandalus borealis) (Luten 2000), gilt-head seabream (Sparus aurata) (Húdóbo and others 2001), and farmed salmon (Salmo salar) (Sveinsdottir and others 2001). QIM has several unique advantages, including estimation of past and remaining storage time in ice (Botta 1995; Hyldig and Nielsen 1997; Luten and Martinsdottir 1997).

The maximum storage time of fish can be determined by sensory evaluation of cooked samples. The Quantitative Descriptive Analysis (QDA) (Stone and Sidel 1985) is a sensory method, which may be used for the determination of maximum shelf life in addition to a detailed description of the sensory profile for a product. With the QDA, all detectable aspects of a product are described and listed by a trained panel. The list is then used to evaluate the product, and the panelists quantify the sensory aspects of the product using an unstructured scale. The end of shelf life is the result of unpleasant sensory characteristics mostly due to bacterial growth. The amount of bacteria on newly caught fish can vary greatly, normally ranging from $10^2$ to $10^7$ cfu/cm$^2$ (Liston 1980). The most important seafood spoilage bacteria are characterized by their ability to produce H$_2$S and reduce trimethylamine oxide (TMAO), which has been used for their specific determination. Capell and others (1997) found counts of H$_2$S-producing bacteria closely associated with the rejection of several fish species, irrespective of the temperature and atmosphere. Microbial metabolites have low odor thresholds, and during fish spoilage, the concentrations of sulfur compounds, short-chain acids, alcohols, sulfur compounds, and amines increase (Olafsdottir and Fleurence 1997).

In raw fish, the texture softens during chilled storage (Andersen and others 1995; Einen and Thomassen 1998) because proteolytic enzymes break down the muscle structure (Andersen 1995). The fat content of fish flesh appears to influence the texture. When the fat content is high, the flesh is softer (Andersen and others 1994), and juiciness increases (Einen and Thomassen 1998). The total lipid content of farmed salmon is often up to double the content found in wild salmon (Moe 1990) and has been reported varying from 12% to 19% (Hafsteinsson and others 1998; Refsgaard and others 1998).

The aim of this work was to perform a shelf-life study with farmed Atlantic salmon (Salmo salar) and characterize the changes in freshness with the Quality Index Method (QIM) scheme for raw salmon and the Quantitative Descriptive Analysis (QDA) for cooked salmon. Furthermore, the goal was to compare the sensory analysis to microbial counts (total viable counts and H$_2$S-producing bacteria) and instrumental texture measurements (compression test).

Materials and Methods

Salmon

The salmon was obtained from the fish farm Silungur ehf.
(Vogar, Iceland). The salmon had been fed various types of the feed blend “Gull” (Gull 3, 4, 6, 8, 10, 12, depending on the age of the salmon) from Fodurblandan hf (Reykjavik, Iceland). The blend contained 40% protein, 16% carbohydrates, and 25% to 30% fat. The salmon were starved for 2 wk and then slaughtered with carbonic acid. After slaughtering, the salmon were gutted, bled, gills cut through, and the salmon were then rinsed in running water for 30 min, followed by chilling to 0 °C in slush ice (0 to –1 °C) before icing in boxes. The salmon weighed 3 to 4 kg. The fish were slaughtered before sexual maturity in 8 batches (October/November 1999) and stored up to 24 d at 0 to 2 °C in iced boxes until analyzed. A total of 50 salmon were used in the experiment. Eleven were used for training the sensory panel. Salmon stored 1, 2, 4, 8, 11, 13, 15, 17, 19, 20, 21, 22, and 24 d in ice were analyzed during the shelf-life study. Three salmon from each storage day were analyzed with QIM; thereof 2 were used for QDA, microbial counts, texture measurement, and fat analysis (Figure 1).

Sensory evaluation

Quality Index Method

The QIM scheme for salmon lists quality attributes for appearance/texture, eyes, gills, and abdomen and descriptions of how they change with storage time. Scores were given for each quality attribute according to the descriptions, ranging from 0 to 3. Very fresh fish normally received the score 0, with scores increasing with storage time. The scores given for all the quality attributes are summarized by the Quality Index, which increases linearly with storage time in ice. The sensory evaluation of each attribute was conducted according to Martinsdottir and others (2001).

Prior to the shelf-life study, the QIM scheme for farmed salmon (Sveinsdottir and others 2001) was revised, as it did not include a parameter for the textural state of rigor mortis. Additionally, 1 score was added for color/appearance of the skin. Changes were made in the setup of the scheme and selection of words to describe the parameters in the scheme, mainly to make each description more precise and to facilitate the QIM assessment.

Twelve trained panelists of the Icelandic Fisheries Laboratories sensory panel participated in the sensory evaluation with QIM. Members had several years of experience in evaluating fish freshness. Prior to the shelf-life study, the panel was trained in applying the QIM scheme in 2 sessions. The scheme was explained to the panel while observing salmon of different freshness categories. The panel used the scheme to assess 6 to 9 salmon from 2 to 3 different storage days per session during the shelf-life study. The salmon was placed on a clean table 30 min before the evaluation. The side where the gills had been cut through was facing down. Each salmon was coded with 3 random digit numbers. All observations of the salmon were conducted under standardized conditions, with as little interruption as possible, at room temperature, and under white fluorescent light.

Quantitative Descriptive Analysis

The QDA, introduced by Stone and Sidel (1985), was used to assess cooked samples of salmon. An unstructured scale (0 to 100%) was used on a list of words describing odor, flavor, appearance, and texture.

Twelve panelists of the Icelandic Fisheries Laboratories’ sensory panel participated in the QDA of the cooked salmon. They were all trained according to international standards (ISO 1993), including detection and recognition of tastes and odors, training in the use of scales, and in the development and use of descriptors. The members of the panel were familiar with the QDA method and experienced in sensory analysis of salmon. Two sessions were used for training of the panel using salmon of different freshness categories. Sensory evaluation of the cooked salmon was performed parallel to the QIM assessment. Each panelist evaluated duplicates of samples from 2 to 3 different storage days. The fish was served in a random order during 2 sessions for each day of the sensory evaluation.

All sample observations were conducted according to international standards (ISO 1988). Twelve samples collected from each salmon with skin came from the loin part, ranging from the spine to 2 cm below the lateral line. The samples were coded with 3 random digit numbers and cooked at 95 to 100 °C for 7 min in a prewarmed oven (Convotherm Elektrogeräté GmbH, Egglting, Germany) with air circulation and steam and then served to the panel.

Microbial counts

Skin samples were collected before all other analysis by cutting 2 x 7.5 cm² skin strips from 1 side of the fish and placed in a Stomacher containing 50 mL Butterfield’s Buffer solution (APHA 1992). Blending was done in a Stomacher 400 for 1 min. Flesh samples were collected after QIM evaluation from the other side of the salmon. The skin was washed with alcohol and removed with a sterilized scalpel. The flesh under the skin was collected, and after mincing, 25 g were weighed into a stomacher bag containing 225 g Butterfield’s Buffer solution to obtain a 10-fold dilution. Blending was done in a Stomacher for 1 min. Further 10-fold dilutions were made as needed. Total viable counts (TVC) and selective counts of H₂S-producing bacteria were done on iron agar (IA) by the pour plate technique with an overlay as described by Gram and others (1987). The plates were incubated at 22 °C for 3 d. Bacteria forming black colonies on this agar produce H₂S from sodium thiousslate and/or cysteine.

Instrumental texture measurements

One sample from each fish was measured in a Texture Analyzer (TA.XT2; Stable Micro System, Surrey, England) using a compression test. The salmon was filleted, skin removed, and samples collected transversely behind the dorsal fin. Samples were cut right above the lateral line, 2.5 cm in length and width, and 2.2 ± 1.4 cm in height. The samples were then covered with plastic and stored in a refrigerator at 4 to 5 °C until measured (within 3 to 5 h) using an aluminum compression plate (SMSP/100). Samples were compressed to 80% of the sample height at a constant speed (0.8 mm/s) with a 100 g constant force. The trigger force was set at 5 g and the registration rate to 200 PPS (registrations per s).

Fat content

Samples were collected according to a method recommended by the Norwegian General Standardizing Body or (1994), the Norwegian Quality Cut (NQC). The samples were vacuum packed and stored at –20 °C until analyzed (within 10 d). The fat content was determined with the Soxhlet method (AOAC 1990) with modification described in the IFL’s method manual for chemical analysis (IFL 1999) using the solvent petroleum ether.

Data analysis

The QI was treated with analysis of variance (ANOVA, 2-factor without replication) to analyze if a difference existed within a group (QI given for each salmon within a storage day and QI given for each salmon within a storage day and QI...
Shelf life of salmon with QIM . . .

Table 1—The QIM scheme for farmed salmon. Revised from Sveinsdottir and others (2001)

<table>
<thead>
<tr>
<th>Quality parameters</th>
<th>Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin: Color/appearance</td>
<td>Pearl-shiny all over the skin</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>The skin is less pearl-shiny</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>The fish is yellowish, mainly near the abdomen</td>
<td>2</td>
</tr>
<tr>
<td>Mucus</td>
<td>Clear, not clotted</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Milky, clotted</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Yellow and clotted</td>
<td>2</td>
</tr>
<tr>
<td>Odor</td>
<td>Fresh seaweed, neutral</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Cucumber, metal, hay</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sour, dish cloth</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Rotten</td>
<td>3</td>
</tr>
<tr>
<td>Texture</td>
<td>In Rigor</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Finger mark disappears rapidly</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Finger leaves mark over 3 s</td>
<td>2</td>
</tr>
<tr>
<td>Eyes: Pupils</td>
<td>Clear and black, metal shiny</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Dark gray</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mat, gray</td>
<td>2</td>
</tr>
<tr>
<td>Form</td>
<td>Convex</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Flat</td>
<td>1</td>
</tr>
<tr>
<td>Gills*: Color/appearance</td>
<td>Red/dark brown</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Pale red, pink/light brown</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Grey-brown, brown, gray, green</td>
<td>2</td>
</tr>
<tr>
<td>Mucus</td>
<td>Transparent</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Milky, clotted</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Brown, clotted</td>
<td>2</td>
</tr>
<tr>
<td>Odor</td>
<td>Fresh, seaweed</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Metal, cucumber</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sour, moldy</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Rotten</td>
<td>3</td>
</tr>
<tr>
<td>Abdomen: Blood in abdomen</td>
<td>Blood red/not present</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Blood more brown, yellowish</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sour, melon</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sour, fermenting</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Rotten/rotten cabbage</td>
<td>3</td>
</tr>
</tbody>
</table>

Maximum sum (Quality Index): 24

* Examine the side where the gills have not been cut through

en by each judge assessing salmon within a storage day). The equation of best fit and the correlation coefficients (r) of QI, total viable count, H2S-producing microbes on salmon skin and flesh, and instrumental texture parameters against storage time in ice were calculated using Microsoft® Excel 2000 (Microsoft Corporation, Redmond, Wash., U.S.A.).

Data from QDA was treated in HyperSense® (Version 1.6; 1996 Icelandic Fisheries Laboratories, Reykjavik, Iceland). Interaction of panelists and samples was assumed, and statistical analysis was performed using 2-factor design with interaction in the analysis of variance (ANOVA). The program calculates multiple comparison using Tukey’s test. Multivariate comparison of different attributes in QIM and QDA was conducted in the statistical program Unscrambler® (Version 6.1; CAMO, Trondheim, Norway) with principal component analysis (PCA). Predictability of QI was analyzed using partial least square regression (PLS) with full cross validation. The average QI for each storage day, including assessment of 3 salmon, was used for this analysis. The root mean square error of prediction (RMSEP) was calculated for the model (the prediction error in original units). Bias is the averaged difference between predicted and measured Y-values for all samples in the validation set. The standard error of performance (SEP) is the precision of results corrected for the bias. From a PLS2 model, the initial variance (signal) at zero PCs and the residuals variance (noise) after optimal PCs were plotted as a signal to noise (S/N) ratio for each panelist and for each word (Martens and Martens 2000). The significance level was set at 5%, if

Figure 1—Sampling plan for measurements in the shelf-life study of salmon at the Icelandic Fisheries Laboratories in November 1999

1. QDA
2. Texture
3. Microbial counts - side A = skin samples, side B = flesh samples
4. Fat content
5. Whole salmon QIM

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Results and Discussion

Sensory analysis

Quality Index Method

The sum of scores evaluated according to the QIM scheme (Table 1) was presented as the Quality Index (QI). The QI was calculated for each storage day of sampling and formed a linear relationship with time (Figure 2).

High correlation between the average QI and days in ice was obtained with a slope of 0.692. The slope was different from the slope observed by Sveinsdottir and others (2001) using the QIM scheme for salmon, presumably because of the revision of the scheme prior to this shelf-life study, including the addition of 2 score attributes. The aim when developing QIM scheme for fish is to have the regression line begin at the origin (0,0), which was not reached here, since the intercept was at 1.568. If the line was forced through the origin, the correlation between the average QI and days in ice became lower ($R^2 = 0.933$). The QIM scheme gave the assessors the opportunity to choose between scores ranging from 0 to 3 but never a negative number, therefore, allowing for residuals above zero but not below.

The difference between salmon of the same storage time in ice was in some cases significant. The results were analyzed with partial least square regression (PLS) to examine how well the QI could predict the storage time in ice (Figure 3).

The standard error of performance (SEP) value for the QI was 2.0 (Figure 3). The SEP may be used to evaluate the precision of the predictability of the QI. Since the QI was the sum of 11 attributes evaluated in the QIM scheme, a normal distribution could be assumed (O’Mahony 1986). Esbensen and others (1998) stated that $2 \times$ SEP could be regarded as a 95% confidence interval assuming normal distribution. Therefore, it can be assumed that the QI of a batch (if 3 salmon were assessed) could be used to predict the storage time with ±2.0 d. It could be assumed that including more salmon in the assessment of each batch might reduce this interval, as observed by Sveinsdottir and others (2001), where including 5 salmon per storage day gave a SEP value of 1.4.

There was a variation in the QI obtained by different panelists (Figure 4). The variation increased with storage time, indicating that the panelists were in better agreement when analyzing very fresh salmon with the QIM scheme at the beginning of storage compared to the not-so-fresh salmon at later stages. There was a tendency for some of the panelists to score either higher or lower than the average score obtained throughout the storage time. The variation between the panelists in this study, which were trained during 2 1-h sessions, was comparable to the variation between panelists trained during 6 1-h sessions (Sveinsdotir and others 2001) in a similar study. This indicated that the 2
Shelf life of salmon with QIM . . .

sessions were sufficient training for the panel.

QIM assumes the scores for all quality attributes increase with storage time in ice (Figure 5).

The average texture score was determined by pressing a finger on the spine muscle and observing how the flesh recovered according to Martinsdottir and others (2001). The scores were around 0 at storage day 1, as the salmon was in rigor. Propagation of rigor caused the muscle to relax again, and through storage in ice, the flesh became soft due to autolysis influenced by both fish muscle enzymes and microbial enzymes (Gill 1995; Nielsen 1995). The skin became softer or less springy after 17 to 20 d, where the average score increased from 1 to 1.5. The average score of skin odor reached only 2 at the end of the storage time. The score 3 (rotten) was used rarely by panelists. At the begin-

Figure 5—Average scores of each quality attribute assessed with QIM scheme for salmon stored in ice against days in ice

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Figure 6—Changes in flavor attributes of cooked salmon (average scores) against storage of the raw salmon in ice observed by a trained QDA panel

Figure 7—Loadings in PCA of salmon data including all quality parameters assessed in QDA of cooked salmon and storage time in ice. f = flavor, o = odor

Ranging from 0 to 100%. Average scores for most positive flavor attributes did not change for the first 17 to 19 d of storage but decreased thereafter (Figure 6). The average scores of sweet and metallic were between 20 and 50 through the storage time, but for salmon stored 21 d, it went below 20. For characteristic salmon flavor and oily flavor, the difference was clearer. The scores were between 50 and 70 until 22 d, when they dropped below 40. Scores for the negative attributes, sour, rancid, and musty/earthy (Figure 6) were low, approximately 0 to 20 for the first 17 to 20 d of storage. Thereafter, the scores increased, especially sour flavor scores, which were around 50 after 22 d. Rancid and musty/earthy flavor reached only 30 after 22 d. The feed of farmed salmon often contains carotenoids (Moe 1990), which have been considered to play an important role in protecting lipid tissues from oxidation (Burton and Ingold 1984). This may have been the reason for the low rancidity scores. The increasing rancid flavor observed during the last storage day might correspond to a train-oily flavor reported by Milo and Grosch (1996), who found their nonfresh cooked salmon samples to be fatty and train-oily smelling. According to their findings, the rancid flavor in salmon was caused by formation of volatile oxidation products such as aldehydes and ketones. They analyzed various odorants in salmon of different freshness (stored 26 wk at -60°C (fresh) and -13°C (not fresh)). They found propionaldehyde and (Z)-1,5-octadien-3-one as the most potent high-volatile odorants in cooked fresh salmon samples. The odor of those compounds was described as sweet and metallic, respectively. Odor is a part of the overall flavor, and those compounds may therefore have been responsible for the sweet and metallic flavor of the cooked salmon in this study. A mixture of odorants in the cooked salmon might be responsible for the characteristic salmon flavor. Milo and Grosch (1996) detected various odorants from cooked salmon (fresh), and the characteristic salmon odor was caused by compounds like propionaldehyde and acetaldehyde (sweet), hexanal and (Z)-3-hexenal (green), methional (boiled potato-like), dimethyl trisulfide (cabbage-like), and 1-octen-3-one (musty-like). The oily flavor and odor might have been due to (Z,Z)-3,6-nonadienal as it was described as fatty and green.

Difference for most QDA attributes was generally only observed after 20 d in ice (Table 2). Data from day 24 was kept out.

Quantitative Descriptive Analysis

The positive attributes for flavor of salmon were described as characteristic salmon, metallic, sweet, and oily flavor on a scale
Shelf life of salmon with QIM . . .

of the analysis because the salmon had utterly exceeded the limits of acceptance. When the salmon had been stored for 21 d in ice, a part of the panel refused to taste the samples after smelling the salmon. This strongly indicated that after 20 d of storage in ice, salmon was—according to sensory evaluation—no longer fit for human consumption. This was in agreement with previous studies. Sveinsdottir and others (2001) concluded that 20 to 21 d was the maximum storage time in ice for salmon. Magnusson and others (1996) observed sensory changes in cooked salmon stored 7, 14, and 21 d and found minor differences between 7 and 14 d, but the overall quality was greatly reduced after 21 d of storage. Lande and Rør (1999) analyzed the flavor, odor, and overall effects in cooked salmon. Minor changes were observed with storage time up to 18 d in ice, however, they did not continue the sensory evaluation of cooked salmon after the 18 d.

Differences were observed among panelists for each QDA attribute. This is a well-known phenomenon in sensory evaluation. The main types of differences among assessors may be caused by confusion about attributes, individual differences in sensitivity to certain sensations, individual differences in the use of the scale, or individual differences in precision (Næs and others 1994). Various ways have been discussed to detect and handle such differences among assessors (Næs 1990; Næs and Solheim 1991; Næs and others 1994). The noise to signal ratio may be observed to decide how to treat the difference among assessors (Sveinsdottir and others 2001).

When the results were analyzed with PCA, the variable d in ice contributed to PC1, and a clear grouping was found between positive and negative sensory attributes on each side of the PC1-axis (Figure 7). Negative parameters became more evident in

![Figure 8](image1.png)
**Figure 8**—Total viable count and H₂S-producing microbes on skin and in flesh of salmon stored in ice

![Figure 9](image2.png)
**Figure 9**—Correlation between bacterial counts on skin and Quality Index of salmon stored in ice
salmon stored longer in ice as they were grouped with the parameter d in ice, while the positive parameters became less evident. The negative attributes described salmon at the end of the storage time similarly. Discoloration appeared to become slightly more evident with storage, but the texture parameters evaluated in cooked salmon contribute very little to PC1 and therefore do not appear to change with storage time, contrary to the texture of raw salmon.

Microbial counts

The total viable counts (TVC) on skin and in flesh increased exponentially with storage time (Figure 8). A similar pattern was noted for bacterial counts on skin and QI with storage time, as salmon of low bacterial counts also received low scores in QIM. A high correlation was established between QI and TVC on skin, and the same was seen for H$_2$S-producing bacteria, which increased proportionally to the TVC at the later stages of storage (Figure 9).

At the beginning of storage, the TVC on skin was approximately $10^3$ cfu/cm$^2$, which is not unusual for newly caught fish (Liston 1980). Very few H$_2$S-producing microbes were a part of the initial microflora (< 10 cfu/cm$^2$), but their proportion of the TVC increased with storage time. The TVC (mainly H$_2$S-producing microbes) on salmon skin was $10^8$ cfu/cm$^2$ after about 20 d of storage. The bacterial counts in salmon flesh were lower than those on the skin. Newly slaughtered salmon contained TVC around $10^5$ cfu/g. The flesh of healthy live or newly caught fish is sterile because the immune system of the fish prevents the bacteria from growing in the flesh, but when the fish dies, the immune system collapses, and during storage, bacteria invade the flesh (Gram 1995). After 20 d of storage in ice, the TVC was $10^6$ cfu/g. As for the microbial growth on salmon skin, the H$_2$S-producing bacteria dominated the bacterial flora at the end of storage. Counts of H$_2$S-producing bacteria were very low (below 10
Shelf life of salmon with QIM...

Table 3—Correlation (r) between evaluated and measured texture parameters of salmon stored in ice

<table>
<thead>
<tr>
<th>Texture parameters</th>
<th>QIM</th>
<th>Dry/Juicy</th>
<th>Tough/Tender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>-0.566*</td>
<td>0.167</td>
<td>-0.110</td>
</tr>
<tr>
<td>Resilience</td>
<td>-0.398*</td>
<td>0.049</td>
<td>-0.032</td>
</tr>
</tbody>
</table>

* Comparisons of significance according to O’Mahony (1986). Significance (p < 0.05)

There was no correlation between texture parameters evaluated in cooked salmon and instrumental texture parameters for raw salmon (Table 3). This was not unexpected for juiciness, as none of the measured texture parameter simulates juiciness. However, tough/tender might have been related to instrumental factors such as the attributes hardness and resilience, expressing how stretchable the samples were. The texture evaluated in QIM (stiffness), on the other hand, was correlated to instrumental texture parameters. Salmon with firm texture according to instrumental texture measurements was assessed firm in QIM.

Table 4—Correlation (r) between measured fat and some sensory attributes (QDA method) of salmon stored in ice

<table>
<thead>
<tr>
<th>Sensory attribute</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil odor</td>
<td>-0.381*</td>
</tr>
<tr>
<td>Rancid odor</td>
<td>0.444*</td>
</tr>
<tr>
<td>Oil flavor</td>
<td>-0.222</td>
</tr>
<tr>
<td>Rancid flavor</td>
<td>0.537*</td>
</tr>
<tr>
<td>Dry/Juicy</td>
<td>0.223</td>
</tr>
<tr>
<td>Tough/Tender</td>
<td>0.379*</td>
</tr>
</tbody>
</table>

* Comparisons of significance according to O’Mahony (1986). Significance (p < 0.05)

The instrumental hardness (Figure 10) of salmon samples decreased with storage time (Figure 11), indicating softening of the salmon flesh. Similar results were observed by Andersen and others (1995) and Einen and Thomassen (1998). There was no correlation between texture parameters evaluated in cooked salmon and instrumental texture parameters for raw salmon (Table 3). This was not unexpected for juiciness, as none of the measured texture parameter simulates juiciness. However, tough/tender might have been related to instrumental factors such as the attributes hardness and resilience, expressing how stretchable the samples were. The texture evaluated in QIM (stiffness), on the other hand, was correlated to instrumental texture parameters. Salmon with firm texture according to instrumental texture measurements was assessed firm in QIM.

Instrumental texture measurements

The instrumental hardness (Figure 10) of salmon samples increased with storage time (Figure 11), indicating softening of the salmon flesh. Similar results were observed by Andersen and others (1995) and Einen and Thomassen (1998). This was comparable to previously reported instrumental hardness and resilience (Mahony 1986). Significance (p < 0.05) was determined as 20 d in ice. The quality of the cooked salmon did not change much through ice storage until 17 to 20 d. Then the scores for positive attributes decreased, while the scores for negative attributes increased. Differences among panelists were evident for all evaluated attributes in QDA and the QI. The high correlation between QI and storage time in ice made it possible to predict the past storage time in ice. As the maximum storage time of salmon in ice was determined as 20 d, this information may be utilized directly for assessment with the QIM for farmed salmon to predict remaining storage time in ice assuming optimum storage conditions and used in production and quality management.

Fat content

The average fat content of the salmon was 15.1 ± 2.1% (95% confidence interval) and ranged from approximately 10% to 19%. This was comparable to previously reported fat content of farmed salmon (Hafsteinsson and others 1998; Refsgaard and others 1998).

Tenderness, rancid odor, and flavor increased with increased fat content of the salmon (Table 4). Tenderness has previously been reported to increase with increased fat content in salmon (Andersen and others 1994). Juiciness did not correlate with fat content.

Conclusions

The scores for quality attributes included in the QIM scheme increased differently with storage time in ice, but a linear relationship with high correlation was found between QI and storage time in ice. Individual salmon spoil at different rates. A minimum of 3 salmon should be included in the assessment of each batch of salmon. The storage time of the salmon may be predicted within ± 2.0 d at the 95% significance level, but examining a greater number of salmon per batch might increase the precision. Based on the sensory evaluation of cooked salmon, the maximum storage life of salmon has been determined as 20 d in ice. The quality of the cooked salmon did not change much through ice storage until 17 to 20 d. Then the scores for positive attributes decreased, while the scores for negative attributes increased. Differences among panelists were evident for all evaluated attributes in QDA and the QI. The high correlation between QI and storage time in ice made it possible to predict the past storage time in ice. As the maximum storage time of salmon in ice was determined as 20 d, this information may be utilized directly for assessment with the QIM for farmed salmon to predict remaining storage time in ice assuming optimum storage conditions and used in production and quality management.

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