Effects of catching methods on quality changes during storage of cod (Gadus morhua)

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Abstract

The catching method, storage time and composition of fish are factors that influence the quality of fish. Different opinions have been expressed concerning the effect of catching methods on the fish quality. In this work cod caught at the same time and location, using different catching methods (gillnet and longline) has been stored for up to 16 days. The same soaking time was used for both fishing gears. No differences due to fishing gear was observed in the quality attributes QIM score, water content, TVN, DMA, TMA, TMAO, Freshmeter-readings, total viable count, sulphide producing bacteria and \textit{P. phosphoreum} during storage. The catching method had significant influence on pH only. It is shown that the pH of the fish caught by gillnet is lower than pH of fish caught by longline. It is also shown that fish caught by gillnet have higher \textit{K}-factor than fish caught by longline. The pH of the fish muscle is closely correlated to \textit{K}-factor; higher \textit{K}-factor supports lower pH.

It is also shown that by using the quality parameters water content, TVN, DMA, QIM score, Freshmeter-readings, TVC, sulphide producing bacteria, and \textit{P. phosphoreum}, the storage time in ice can be predicted with a correlation of 0.99 and a prediction error of 0.8 day.

Keywords: Cod; Catching method; Storage quality; Gillnet; Longline

1. Introduction

It is well known that catching procedure and post-harvest treatment affect the quality of fish. Different opinions have however been expressed concerning the effect of catching methods on the fish quality. The quality of cod caught by gillnet and longline has been compared in a few studies. Botta, Bonnell, and Squires (1987a) reported that colour grades, discoulouration/bruising grades and final overall grades of cod caught by gillnet were significantly lower than cod caught by longline. On the other hand, fillet odour and texture grades were not significantly different. It is also reported that cod caught by gillnet had higher calorific content, higher protein content, as well as lower moisture content than cod caught by longline (Botta, Kennedy, \& Squires, 1987b). In these studies, the soaking time for the fishing gears were different; the longlines were hauled within 4 h of being set, while gillnets were hauled after 3 to 7 days. Significant differences in fish quality due to soaking time using trawl and gillnet have been reported by Auclair (1984); the longer soaking time the lower quality. Hattula et al. (1995) studied the effect of gillnetting, poundnetting and trawling on mortality and quality of herring. The soaking time of the trawling and gillnetting were relatively similar; 2–6 and 10 h, respectively. No statistical differences in quality between herring caught by gillnet, trawl or poundnet were found.

Selectivity studies have shown that longline select cod with lower condition (\textit{K}-factor) than both trawl and gillnet operating in the same fishing grounds under normal, and close to commercial, operation (Huse, Løkkeborg, \& Soldal, 2000).

Fulton’s \textit{K} condition factor, $K = 100\times(W/L^3)$, where $W$ is the total or gutted weight (g) and $L$ is the fork
length (cm), is one of various formulas used to evaluate the weight–length relationship in fish, and have been demonstrated to be a measure of the energy reserves of fish, e.g. Atlantic cod (Lambert & Dutil, 1997). In aquacultured salmon, the $K$-factor is shown to reduce when the feeding reduce (Einen, Morkø, Røra, & Thomassen, 1999). It is also reported that pH increase at the same time, and that several changes in sensory texture characteristics occur.

Storage time and storage conditions have also great impact on the quality of fish and fish products, and the storage stability of fish depends on the composition of the fish (Ashie, Smith, & Simpson, 1996). Since the composition of the fish varies when the $K$-factor varies, and different catching gears select fish with different $K$-factor, it is relevant to study if the quality changes during storage is affected by catching methods. In order to reveal which factors affect the quality changes the most, multivariate analyses like principal component analyses (PCA) and partial least squares regression (PLSR) have proven to be useful tools. Such techniques have been used by Boknaes et al. (2002) in order to select key parameters in good manufacturing practice for production of a thawed cod product.

The main objective of the present work was to study and compare several quality parameters during storage of cod caught at the same time and location, using different commercial catching methods (gillnet and longline) operated at comparable conditions. It was also of interest to evaluate quality parameters that could be used for assessing the freshness, as storage time in ice, of the fish.

2. Materials and methods

2.1. Raw materials and sampling

Cod was caught by commercial fishing gears, gillnet and longline, at Malangsgrunnen off the coast of Kvaløy in Northern Norway the first week of March 2002. Both the gillnet and the longline were soaked overnight. After catch, 45 live cod from gillnet and longline catches respectively, were collected at random, and immediately bled, gutted, cleaned and iced. The weight of the fish caught by gillnets varied between 2.0 and 6.2 kg after gutting, with an average of 3.6 kg. The fish caught by longline was between 1.5 and 4.4 kg after gutting, with an average weight of 2.7 kg. The $K$-factor was calculated using gutted weight. The iced fish were transported to the laboratory and stored in ice in a 2–4°C cold room up to 16 days. From each catch (gillnet and longline), batches of five fish were selected by random and applied for measurements on day 1, 2, 3, 4, 6, 8, 10, 13 and 16, respectively.

On the day of measurement, the Quality Index Method and RT-freshmeter was applied on whole fish. Samples for microbial analyses were cut from the interior of the left fillet, and pH was determined at the cut site. Finally, the right side fillet was cut, skinned, and used for chemical analyses.

2.2. Sensory and physical analyses

The quality index method (QIM) was applied on whole fish to obtain the quality index (QIM-score). Three experts in sensory evaluation, experienced with QIM for cod, examined the five fishes in each batch. Changes observed in appearance, odour and texture during storage were listed in the scheme described by Luten and Martinsdóttir (1997). The freshness of the five fishes in each batch was also assessed by recording electrical properties using the RT-Freshmeter Type RT-2E (Rafagnatakni Electronics, Reykjavik, Iceland). Freshmeter records were taken by pulling the freshmeter thrice on the left side of the fish, from the front of the dorsal fin to the anal opening, as described by the supplier.

2.3. Microbial analyses and pH

Raw material for microbial analyses was cut from the interior of the left fillet using sterile technique. Samples from three of the five fishes in each batch were pooled. Fish muscle (3–10 g) was homogenized with 9 parts of peptone water containing 0.9% NaCl using a stomacher (Lab Blender 400) for approximately 4 min and diluted ten times in peptone water. Sulphide producing bacteria were determined as black colonies on Iron agar Lyngby (Oxoid) after 2–3 days incubation at 22°C. Total viable counts were determined using standard plate count agar (Oxoid CM463) supplemented with 1.5% NaCl, and incubated for 5 days at 12°C. Numbers of Photobacterium phosphoreum were determined by a conductance method as described by Dalgaard, Mejholm, and Huss (1996). pH was determined at the cut site using WTW pH Meter (pH 330, Wissenschaftlich-Technische Werkstatten GmbH, Weilheim, Germany).

2.4. Chemical analyses

200 g were cut from the loin of the right side fillet of each fish. The samples from the same batch (catching method and storage time) were pooled and homogenized for 3 × 1 min in a Hallda Blender. Water content was determined by drying samples of mixed, minced muscle overnight at 103°C, while total volatile nitrogen (TVN) was determined by the Kjeldahl method (Tecator, 1983), and expressed as mg TVN per 100 g fish muscle. The mixed, minced muscle was also used for obtaining perchloric acid-extracts to determine trimethylamine.
oxide (TMAO), trimethylamine (TMA) and dimethylamine (DMA) as described by Oetjen and Karl (1999). The amines were determined in triplicate.

2.5. Statistical analysis of results

The data were analysed by use of multivariate techniques, applying the software Unscrambler version 7.8 (CAMO Process AS, Oslo, Norway). Prior to the analyses, a logarithmic transformation was applied to the microbial counts in order to compare values that range over several orders of magnitude (Martens & Martens, 2001). In addition, the variables were weighted with the inverse of the standard deviation of all objects in order to compensate for the different scales of the variables.

Principal component analysis (PCA) (Martens & Næs, 1989), was used to identify similarities and differences amongst samples on the basis of microbiological, sensory, chemical and physical data. Partial Least Square Regression, PLSR1, (Martens & Næs, 1989), was used to identify similarities and differences amongst samples on the basis of microbiological, sensory, chemical and physical data. Partial Least Square Regression, PLSR1, (Martens & Næs, 1989), was used to identify similarities and differences amongst samples on the basis of microbiological, sensory, chemical and physical data. Partial Least Square Regression, PLSR1, (Martens & Næs, 1989), was used to identify similarities and differences amongst samples on the basis of microbiological, sensory, chemical and physical data. Partial Least Square Regression, PLSR1, (Martens & Næs, 1989), was used to identify similarities and differences amongst samples on the basis of microbiological, sensory, chemical and physical data.

In order to evaluate quality parameters that could be used for assessing the freshness of the fish, PLSR1 was used to search for possible connections between storage time and measured quality parameters of the different batches.

3. Results and discussion

3.1. Condition factor and pH

Condition factor ($K$-factor = $100 \times \text{weight} \times \text{length}^{-3}$) and pH of cod may vary as a function of both season and catching methods (Botta et al., 1987a; Huse et al., 2000). In addition, pH in fish varies as a function of storage time (Ashie et al., 1996). In order to evaluate which factors mostly affect the pH, and to reveal if there were correlations between $K$-factor, pH and catching methods, a principal component analysis (PCA) was performed on a matrix with 90 objects (cod) and 4 variables ($K$-factor, pH, catching method and storage time for individual fishes). It was found that two principal components (PCs) explained 68% of the total variation, are presented in Fig. 1. The score plot shows a distinction between cod caught by gillnet ($G$) and longline ($L$), and the discrimination is mainly along PC1. The correlation loadings plot shows that the variation in catching method is described by PC1, while the variation in storage time is described in PC2. From the correlation loading plot it is seen that variations in both $K$-factor and pH are mainly described in PC1, and thus correlated to catching method. Cod caught by gillnet have higher $K$-factor than cod caught by longline. This is in agreement with results from Huse et al. (2000).

It is also shown that the variation in the muscle pH is more correlated with catching method than storage time. The pH of fish caught by longline is higher than the pH of fish caught by gillnet. This is in contrast to some previously reported results. Botta et al. (1987a) reported higher muscle pH in fish caught by gillnet than in fish caught by longline. However, the soaking time for the gillnets in the study by Botta et al. (1987a, b) was much longer than for the longline; 3 to 7 days and 4h respectively (Botta et al., 1987b). The soaking time for the gillnets is also much longer than in the present study. The contradictory results are probably explained by the difference in soaking time. Although only live cod were caught in both of the experiments, extensive struggling and stress due to longer soaking time could result in higher post-rigor pH. Such effects have been demonstrated by Skjervold, Fjøra, Østby, and Einen (2001), where long-term stress results in increased post-rigor pH of salmon. Thus, operational conditions such as soaking time is important to consider when effects of different fishing gear are to be compared.
In our experiment, the soaking time for both gillnet and longline was similar, and from the correlation loadings plot (Fig. 1) it is shown that pH and K-factor are negatively correlated; high K-factor supports low pH. The lower pH in fish caught by gillnet could be due to a higher nutritional status, expressed by higher K-factor. The higher nutritional status would probably also account for higher glycogen levels. A higher glycogen reserve in vivo may be responsible for the observed lowered pH in the fish caught by gillnet. This is in accordance with Einen et al. (1999), who reported lower muscle pH in post rigor state of fish that was fed with increased feed ration prior to slaughtering.

3.2. Quality changes during storage

The measured span in the quality parameters for the longline catch and the gillnet catch during storage, is given in Table 2. In order to achieve an overview of the main variations in the quality parameters, a weighted principal component analysis (PCA) was performed on the quality attributes (pH, water content, TVN, DMA, TMA, TMAO, QIM score, Freshmeter-readings, total viable count (TVC), sulphide producing bacteria and P. phosphoreum), as well as K-factor, weight, length, storage time and catching method. All the quality parameters are represented by mean values for the different batches, given catching method and storage time. It was found that three PCs explained 87% of the variations in the data set. The correlation loadings of the first two PCs, representing 54% and 23% of the total variation, are presented in Fig. 2. The correlation loadings plot shows that the variations in QIM score, DMA- and TMA-values, as well as the count of sulphide producing bacteria and P. phosphoreum are mainly described by PC1, and that these parameters are very closely correlated to storage time. TVN and water content are also positively correlated to storage time, while Freshmeter-readings are negatively correlated to storage time. This is in accordance with previously reported results (Oehlenschläger, 1992; Botta, 1995; Gram & Huss, 1996; Luten & Martinsdóttir, 1997; Ólafsdóttir et al., 1997). Interestingly, the variation in TMAO seems not to be correlated to variations in TMA and storage time. The results are indicating that the TMAO levels are closer related to the K-factor, but this has to be confirmed measuring individuals. On the other hand, the pH value is influenced by the catching method rather than the storage time. The score plot in Fig. 2 shows that cod caught by longline appears in the lower part of the plot, and is thus characterized by higher pH, and to some extent also by higher water content than fish caught by gillnet.

In order to identify the effect of catching method, weight, length and storage time on the measured quality attributes, and to reveal which variables significantly effect the quality parameters during storage, PLSR1 models were made. Catching method, weight, length and storage time data were applied as the X-matrix, while the individual quality parameters were used as Y-matrices. By applying the Martens Uncertainty Test, which is based on the jack-knifing principle (CAMO, 2001), the influence of catching method, weight, length and storage time upon every single quality parameter is examined. Table 1 summarizes the results of the analyses. Variables that significantly affect the quality parameters are shown, both when all samples are analysed together, and when fish caught by gillnet or longline are analysed separately. It is noteworthy that the catching method had significant influence on pH only, and not on any other quality parameter during storage. This is in accordance with the results reported by Hattula et al. (1995), but in contrast to the findings by Botta et al. (1987a, b).

To examine whether the quality assessment methods applied in this study can be used as freshness indicators, i.e. if they could be used to predict storage time, partial least squares regression (PLSR1) was used to search for a possible connection between the measured values and elapsed time. The quality parameters are used as X-
matrix and the storage time as Y-matrix. Non-significant variables were removed by applying the Martens Uncertainty Test. The uncertainty test identified water content, TVN, DMA, QIM score, Freshmeter-readings, TVC, sulphide producing bacteria, and P. phosphoreum as the significant variables, in accordance with the results presented in Table 1. Fig. 3 gives a plot of the predicted versus measured storage time for the model. The correlation of prediction was 0.99 and the prediction error, RMSEP, was 0.8 days. The prediction based on these measured parameters has higher correlation and lower prediction error than predicting freshness by use of one method only as described in Jørgensen, Gibson, and Huss (1988), Oehlenschläger (1992), or Luten and Martinsdóttir (1997). From the plot it is seen that the predicted storage time of cod caught by gillnet (G) is slightly lower than the storage time predicted for cod caught by longline (L). Hence, gillnet cod appears fresher than longline cod. This is in contrast to the facts that some methods, like QIM, will assess the freshness of cod caught by gillnet not as good as cod caught by longline since gillnetting causes lower appearance of the skin and more bloodspots in the muscle. Other methods included in this model must therefore assess the freshness of cod caught by gillnet as better than cod caught by longline. It is thus relevant to ask if the cod caught by gillnet, characterized by higher K-factor and lower pH, is better suited for storage than the cod caught by longline. And to ask if the observed differences in storage stability is a function of condition. This has however not been revealed in this study, and has to be put into further investigation.

4. Conclusion

The catching method had significant influence on pH only, no other significant quality differences has been detected during storage of cod caught by gillnet and longline. The fish was caught at the same time and location, and similar soaking time was used for both fishing gears. The pH of the fish muscle is closely

<table>
<thead>
<tr>
<th>Quality parameter</th>
<th>All samples</th>
<th>Gillnet samples</th>
<th>Longline samples</th>
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<tbody>
<tr>
<td>pH</td>
<td>Catching method</td>
<td>None</td>
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</tr>
<tr>
<td></td>
<td>Weight</td>
<td>None</td>
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<td></td>
<td>Length</td>
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<td>Water content</td>
<td>Storage time</td>
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<td>TVN</td>
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<td></td>
<td>Weight</td>
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<tr>
<td>TMA</td>
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<tr>
<td>TMAO</td>
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<td>QIM score</td>
<td>Storage time</td>
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<td>Freshmeter-readings</td>
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<tr>
<td>TVC</td>
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<tr>
<td>Sulph. prod. bact.</td>
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<tr>
<td>P. phosphoreum</td>
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correlated to $K$-factor; higher $K$-factor supports lower pH. The pH of the fish caught by gillnet are lower than pH of fish caught by longline, and the fish caught by gillnet have higher $K$-factor than fish caught by longline. It is also shown that by using the quality parameters water content, TVN, DMA, QIM score, Freshmeter-readings, TVC, sulphide producing bacteria, and $P. phosphoreum$, the freshness of cod, by means of storage time, can be predicted with a correlation of 0.99 and a prediction error of 0.8 day.

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