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Influencing factors on yield, gaping, bruises and nematodes in cod (*Gadus morhua*) fillets

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Abstract

The influence of factors in catching and processing of cod on fillet yield, gaping, number of nematodes and prevalence of bruises was studied in close cooperation with an Icelandic fisheries company. Data was collected onboard fishing vessels and in a fish processing plant in N-Iceland, for 29 months. Conditions during trawling and storing were recorded. Fishing ground had significant effect (95% significance limit) on fillet yield, gaping and number of parasites. Time of year had significant effect on all variables. The time-lag from catch to processing (age of the raw material) affected both gaping and bruises significantly. Fillet yield was closely correlated to both condition factor and head proportion. The results can be used for decision-making on where to direct the fishing boats and what to do with the catch after unloading it.

Keywords: Cod; Processing; Fillet yield; Parasites; Gaping and bruises

1. Introduction

The return from cod catching and processing depends on variables like fillet yield, gaping, parasites and bruises (Birgisson, 1995). Information on the relationship between these variables and e.g. catching ground, season and the time-lag from catch to processing may improve management in the fish industry, by using them to organize fishing tours with the aim to increase yield and decrease defects. Better understanding of the factors controlling condition and quality of the raw material will result in better production management, better production plans and supply management (Nahmias, 2000, chapter 2–9). Previous results indicate that the return of the Icelandic fishing industry can be increased considerably by managing catching and processing simultaneously (Eyjolfsson, Arason, Þorkelsson, & Stefánsson, 2001, Teitsson, 1990). Managing catching and processing unabridged and use of prior knowledge along with the use of previous data to synchronize fisheries and processing can simplify planning for both fisheries and processing managers (Bjarnason, 1997). Trawlers provide over 40% of the annual catch of cod in Iceland (Fiskistofa, 2004). One haul is the process of dropping a trawl, towing it by the trawler and hauling it in again. Length of haul is the time-lag from when the trawl is dropped until it is towed in again. The size of the haul is the weight of the catch. It has long been suspected that both length and size of the haul could affect the quality of the catch, but this has not been confirmed scientifically.

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Most of the variables in this study have been studied earlier by Icelandic and foreign scientists. Love (1975) found that gaping was less in large cod than small. This was contradicted by Birgisson (1995) who found that gaping was more in larger cod. Rikhardsson and Birgisson (1996) concluded that gaping correlated with condition factor[3] and proportion of viscera. The methods for measuring gaping have long been open for discussion and debate. Grading scales, often accompanied with pictures of cod with different amount of gaping have traditionally been used (Love, 1988). The disadvantage of this method is that it is dependent on the person who does the measurements. This might be prevented with more mechanical (objective) methods. Electrophoresis has been used for measuring gaping with good results (Bragadottir & Bjarnason, 1996), but it is not applicable to the conditions on board fishing vessels and in the fish filleting factories.

One of the most expensive factors for cod processing are parasites. Parasitic nematodes or seal worms are a problem in cod fisheries. They are one of the most expensive quality defects both because of the cost of cleaning the fillets and the decrease in yield and value (Dagbjartsson, 1973). Their spread and frequency in Icelandic waters have been studied systematically since 1979, but studies on parasitic nematodes around Iceland range back to 1939 (Hauksson, 1992). Dagbjartsson (1973) mapped the frequency of infection in cod. He found higher frequency of infections off the coast of W-Iceland than E-Iceland, but declining with increasing distance from shore.

The non-existence of bruises in the fish flesh has become more important as more of the cod is produced fresh and quality requirements have increased. The reason why bruises appear in the flesh can e.g. be attributed to pressure in the trawl (Hansen, 2004) and to various, different impacts the fish undergoes until it is bled.

Fillet yield is probably the single most important factor influencing the return of cod processing. Finding out which variables affect fillet yield is therefore of importance. Morphology of the fish is related to fillet yield (Cibert, Fermon, Vallod, & Meunier, 1999) and it is likely that condition factor can be used as an indicator for fillet yield. Eyjolfsson et al. (2001) found a significant correlation between fillet yield and condition factor and stated that there was a considerable difference in condition factor and fillet yield between catching areas.

Number of means to improve fillet yield have been studied around the world, the latest research focusing on genetic improvement. Factors such as time of year, diet and age of the fish have also been under investigation (Bosworth & Walters, 2004).

The aim of this study was to find which factors influence fillet yield, gaping, bruises and nematodes in cod. The study was carried out in close cooperation with an Icelandic fisheries company.

[3] Condition factor: $c = \frac{w}{l^3} = \frac{\text{weight}}{\text{length}^3}$.

2. Materials and methods

Data was collected from February 2001–August 2003. Collection of data was done in cooperation with Samherji[4] hf, a fisheries company in N-Iceland. The date and location of each haul were registered, along with the length and size of the haul. The location registration was twofold: the number of the square (see Fig. 3) and GPS (global positioning system) coordinates, at the time the trawl was dropped. After hauling the trawl in and measuring the size of the haul, the fish was gutted, put in tubs and iced for storing.

After unloading the catch, but before processing, samples of four cods were taken from all tubs that were reweighed.[5] The total weight of cod in the tubs and the length and weight of the sampled cod was measured and registered. Marel PV 1740 ($d_T = 20$ g) was used for weighing and the length of the fish was measured with a steel yardstick (Fig. 1). The fish was headed, weighed (using Marel PV 1740), filleted and skinned. Heading was done in Baader 434 and filleting in Baader 189. The skinning machine was Baader 51. The fillets were weighed (using Marel PL 2010; $d = 1$ g) and all visual parasites counted. Gaping was measured by putting a transparent plastic card with a grid on the fillets (Fig. 2). The grids were 4×4 cm. If a gaping area on the fillet was as big as one grid, it counted as one gaping unit. One unit was also counted if the aggregated area of two or more gaping areas was as big as one grid. The same measurement was used for bruises. After the measurements had been done, the fillets were processed normally. Multivariate regression analysis was used to find a functional relationship (multivariate linear model) between the response variables and the independent variables after a thorough outlier detection of all variables. The SPSS® (www.spss.com) statistical program was used for statistical analysis along with MATLAB® (www.mathworks.com).

3. Results and discussion

As stated earlier, multivariate regression analysis was used to find a model for the response variables. Eq. (1) shows how the model was for bruises (using only variables with $p < 0.05$).

$$y = 1.3 - 0.8x_1 + 0.4x_2 + 0.4x_3 - 0.3x_4 - 0.3x_5 - 0.5x_6 - 0.5x_7 + 0.1x_8 + 0.01x_9 - x_{10} \quad (1)$$

where y = number of bruises, x_1 = January [0/1], x_2 = May [0/1], x_3 = July [0/1], x_4 = August [0/1], x_5 = September [0/1], x_6 = October [0/1], x_7 = November [0/1], x_8 = age of

[4] Samherji hf was founded in 1972. It is an international company and one of Iceland's largest fishing enterprices. Samherji's operation is based on four main pillars of support – freezing at sea, the land-based processing of groundfish, shrimp processing and the processing of pelagic fish products (Samherji, 2005).

[5] Reweighing a certain proportion of tubs is obligatory for all fish processing companies in Iceland.

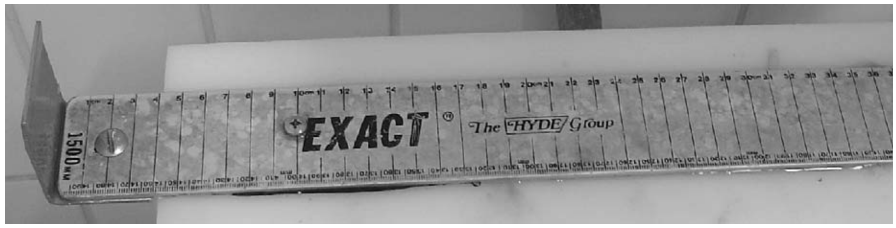

Fig. 1. Steel yardstick used for measuring length of the cod.

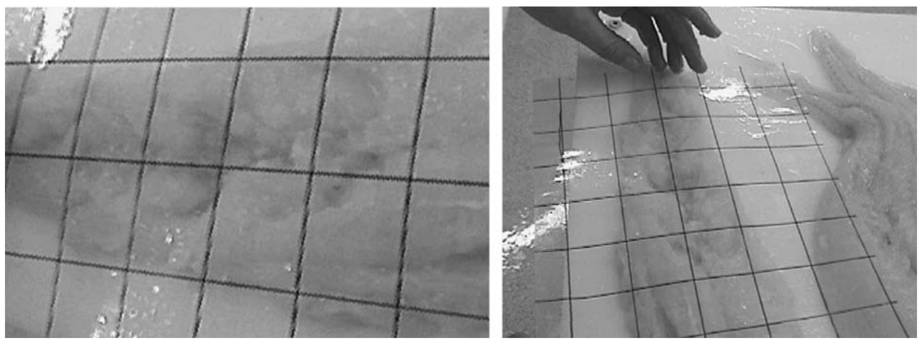

Fig. 2. A plastic card with a grid that was used for measurements on bruises and gaping.

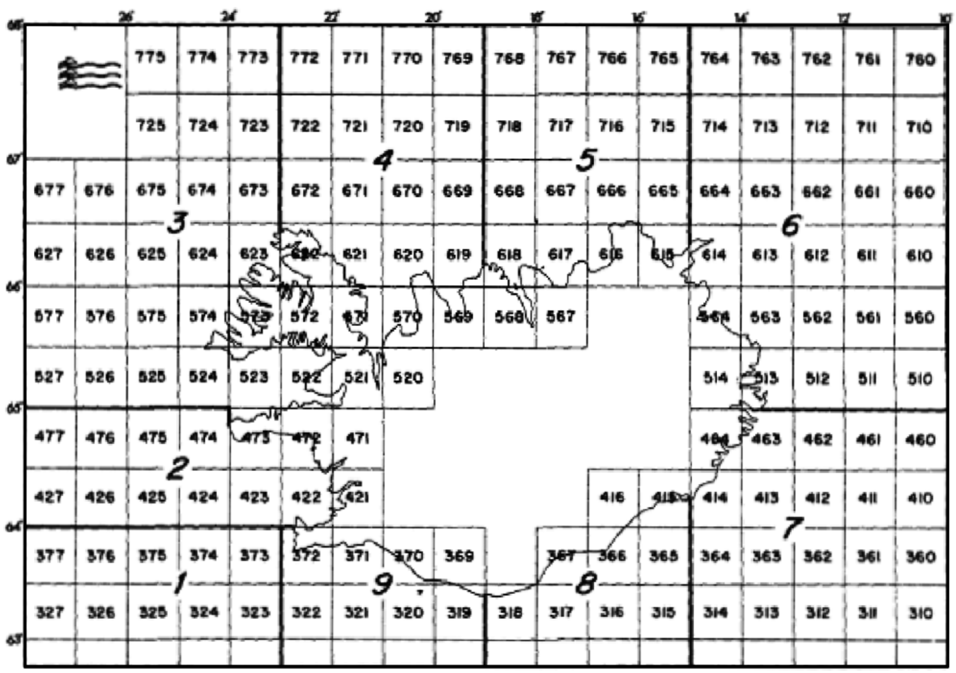

Fig. 3. Squares used for localization in the research. The squares are used traditionally by the Icelandic Marine Institute and the Directorate of Fisheries and are 0.5° by 1.0° wide.

raw material [days], $x_9 =$ size of haul [number of tubs], $x_{10} =$ square 311 [0/1].

Similar equations were made for other response variables. Table 1 shows what variables had significant effect ($p < 0.05$) on gaping, nematodes and fillet yield.

Time of year, age of the raw material and the size of the haul affected bruises significantly. Bruises were fewer in autumn and winter months than other months. Both age of raw material and size of haul had positive effect on bruises ($p > 0.05$). As more time elapses from catch until the fish is processed the longer time natural breakdown processes of the fish have to spoil it. A large haul causes a long waiting time until bleeding. It has been shown that delayed bleeding results in retained blood in beef carcasses (Williams, Vimini, Field, Riley, & Kunsman, 1983). Given that the same applies to cod it is not surprising that the size

Table 1
Variables with significant effect ($p < 0.05$) on gaping, nematodes and fillet yield

Gaping	No. of nematodes	Fillet yield
Time of year	Time of year	Time of year
Age of raw mat.	Weight of cod	Condition factor
Weight in tub	Size of haul	Size of haul
Location of catch	Location of catch	Location of catch
		Head proportion

of the haul correlates to bruises. It has also been noted that contact against the trawl may cause subcutaneous bruises (Hansen, 2004). Increased pressure on the fish in the trawl may therefore also be a reason for positive correlation between haul size and number of bruises. It is not evident why the time of year does affect bruises. Some possible explanations are e.g. the nutritional status of the fish and the temperature of the sea, but more bruises were measured during spring and summer months than autumn and winter months as stated earlier. Love (1988) states that the colour of cod is in general darker in the summer months than winter months, possibly as a result of greater physical activity, but no sources were found on bruises.

Time of year and catching ground affected fillet yield significantly, using 95% confidence limits. Fillet yield was on the average highest in the autumn and early winter months. This indicates that fillet yield might be improved by controlling where and when the cod is caught. Distance from harbour and the expected size of hauls may of course influence such control. The fillet yield was also significantly positively affected by the weight and the length of the cod (condition factor). This is in agreement with Eyjolfsson et al. (2001) who concluded that about 1/3 of the variability in fillet yield of cod was due to condition factor. Fillet yield was negatively affected ($p < 0.05$) by its head proportion. The length of the haul was the last measured variable that had significant effect on the fillet yield (negative effect).

A regression model that was made by using only variables with p-values lower than 0.05 had R^2-value of 0.6, which is considerably higher than obtained by Eyjolfsson et al. (2001). This difference in R^2-values is due to the fact that fewer variables were used by Eyjolfsson et al. (only condition factor was used there). The model was used for forecasting, using (3). Fig. 4 shows a forecast, the actual measurements of the fillet yield and the 95% upper and lower confidence limits. The forecast applies to cod caught in August 2003, but the measurements for these samples were deliberately left out when making the model. The model was able to forecast the fillet yield with good accuracy as Fig. 4 shows. The mean absolute value of the error of prediction was 0.92%.[6] Out of 63 measurements, only 3 fall out of the 95% prediction interval, given with (2) (Montgomery & Runger, 1999).

[6] It shall be emphasised that fillet yield is measured in percents (%). % does therefore mean percentage points when mentioned in connection with fillet yield.

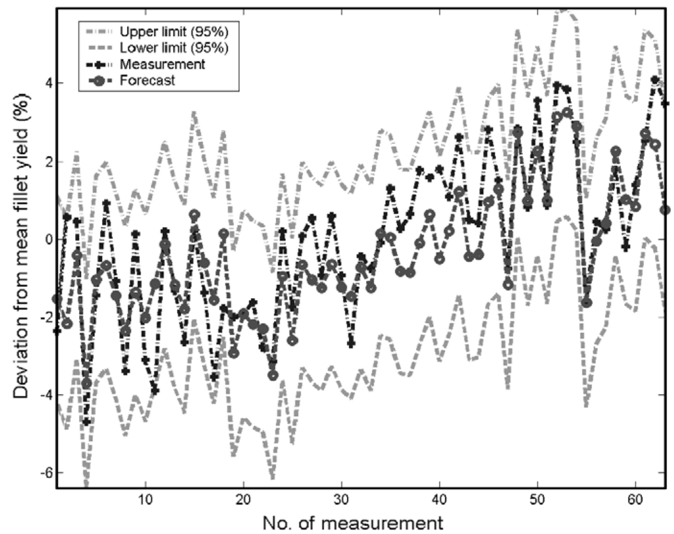

Fig. 4. A forecast and measurements for fillet yield from 63 samples taken in August 2003. The scale is in percentage points and measures the deviation from mean fillet yield for all the measurements.

$$\hat{y}_0 - t_{\alpha/2,n-p}\sqrt{\hat{\sigma}(1 + x_0^{\mathrm{T}}(X^{\mathrm{T}}X)^{-1}x_0)} \leqslant y_0 \leqslant \hat{y}_0 + t_{\alpha/2,n-p}\sqrt{\hat{\sigma}(1 + x_0^{\mathrm{T}}(X^{\mathrm{T}}X)^{-1}x_0)} \quad (2)$$

where

$$\hat{y}_0 = x_0^{\mathrm{T}}\hat{\beta} \quad (3)$$

where $\alpha = 0.05$ (1-significance limit), $n =$ no. of measurements, $p =$ no. of regression coefficients, $\hat{\sigma} =$ estimated variance, $\hat{\beta} =$ vector of regression coefficients, $X =$ measurement matrix (all measurements), $x_0 =$ measurement vector (the incident under inspection).

Fig. 5 shows how the fillet yield varied from one fishing ground to another. The figure shows the results for all months and can be treated as an indication of the difference between catching grounds. It is ill-advised, though to conclude much from the figure, since the time of year and other factors do affect the fillet yield. The difference between fishing grounds is in many ways in agreement with the results of Eyjolfsson et al. (2001), but a precise comparison is not possible since they used other partition of catching grounds.

Fishing ground and time of year were the variables that mostly affected the number of parasites. Parasites were fewer in April–July than in other months. The number of parasites per fish and the geological distribution of fish containing parasites were similar to results obtained by Dagbjartsson (1973), i.e. increasing number of parasites as distance from shore decreased. Dagbjartsson (1973) covered a smaller area than this study, but a comparison of similar areas indicates that the number of parasites in cod caught in Icelandic waters today is similar to 1973. The size of the cod had significant effect on the number of parasites. The bigger the cod was, the more parasites it contained. This is in agreement with Birgisson (1995).

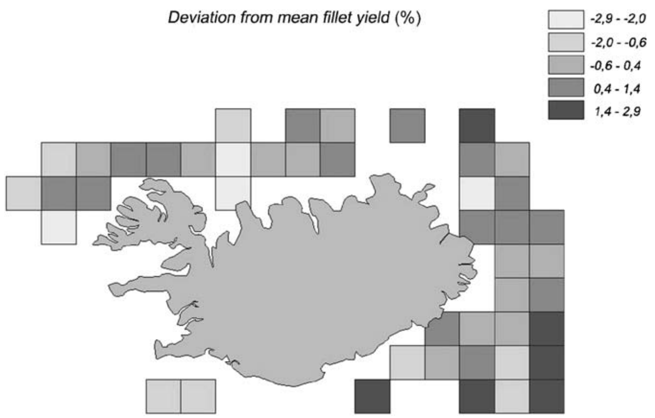

Fig. 5. Deviation from the mean fillet yield (for all measurements). The deviation is shown for different catching grounds and is in percentage points.

Fishing ground, time of year and age of the raw material were the variables that mostly affected gaping. The depth of the trawl may be the reason for the difference between fishing grounds. Air temperature, which has been found to influence gaping (Love, 2001) fluctuates with time of year. So does temperature of the sea. The positive correlation between age of raw material and gaping is consistent with Love (1975), who found that the time-lag from catching until freezing of the cod affected gaping. This is most probably caused by natural breakdown of muscle tissue. The size of the cod did not significantly affect gaping. The correlation between gaping and the size of the cod seems to be rather unclear. Birgisson (1995) found a positive correlation between the size of the fish and gaping, while Love (1975) found negative correlation. Since the method of measuring gaping in cod is not standardized, comparison between these three studies may be difficult.

Are methods used in catching management of economical importance? Two scenarios are worth considering. Let us first take a look at the captain who has found good catching ground and has to make a decision when he will haul the trawl in. A large haul usually results in a longer waiting time until bleeding of the cod. A longer waiting time results in less valuable products (Rikhardsson & Birgisson, 1996) and more bruises according to the results of this research. But a large haul will also decrease oil cost and shorten the length of the fishing tour. Second scenario; let us take a look at the captain who has caught 50 ton of cod in 7 days. By filling up his boat he will come home with 90 ton, but it will probably take him at least 4 days to catch the extra 40 ton. It is considered safe to keep whole, gutted cod in ice for about 15 days (Magnusson & Martinsdottir, 1995). The quality of the cod starts to deteriorate, though, much earlier. A rule of thumb is that the older the cod is the less valuable it is (Wendel, 1995). Keeping cod in ice for about 6–7 days can result in 8–10% less value (Rikhardsson & Birgisson, 1996). What is the right decision for the captain to take? What is the right decision from the processing manager's point of view?

From those scenarios, it is evident that the interests of the catching and the processing links in the catch-processing-market chain do not always go hand in hand. It is better for the trawlers to get big hauls rather than many small, but it may result in a fish of less value. It is also more economical to fill the trawlers up to capacity before sailing to harbour, rather than sailing home with only a half loaded vessel, but doing so may decrease the value of the fish products. It is therefore important to manage the catch and the processing as a whole, in order to optimize the catch-processing chain. The marketing link is also worth considering at later stages.

The first step in such integral management could be sending information about fishing ground, size distribution of the catch and size and length of haul to the production manager after catching the fish. This kind of information makes predisposing of the catch and organizing the production possible. Allocating cod to different products, depending on expected gaping and ensuring sufficient manpower to pluck out parasites if the cod is expected to be rich of them is another advantage of such information usage.

4. Conclusions

Several factors in catching and storing cod affect important variables for processing of cod, such as fillet yield, gaping, parasites and bruises. The most important factors were catching ground, time of catch and age of raw material. The results indicate that integrating cod catch and processing can increase the return of the catch-processing chain.

This project, *Processing forecast of cod*, which started as an M.Sc. project in 2001 and finished in 2003, has since then been continued and expanded into a Ph.D. project. In the last step of the Ph.D. project, the intention is to use the results as well as available data on the price of oil, product prices, wages and other relevant factors to construct an optimization model. The purpose of this model is to help captains, catch- and production managers to make decisions on where to direct the fishing boats and what to do with the catch after unloading it.

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