On line near infrared analysis of whole salmon fillets

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Introduction

Salmon farming is growing in importance in Norway and the value of the export is now considerable (nearly ten billion NOK in 1998). The need for efficient tools for quality control has greatly increased with the volume of production. It appears that the demand for fish of different fatness varies between the specific markets in the world. In order to optimise the demands of consumers in different markets, especially for smoked salmon, a rapid and non-destructive method for estimating and classifying fat content is highly desirable. The wide variation of fat and moisture content in the raw material has obvious consequences for the quality of the processed products.[1] It is known that within industrial processing of smoked salmon, it is important to have a known and stabile quality. For the European market, a fat content no higher than 15% is preferred.[2]

The aim of this present study is to classify salmon into two classes according to fat content, higher and lower than 15% fat, by using near infrared (NIR) on-line measurements.

Materials and methods

In this preliminary study, 45 skinless fillets of farmed Atlantic salmon (*Salmo salar*) was used to study the possibility of classifying fish according to the fat content in the fillets. Salmon of different commercial quality classes and from different fish farming plants were randomly selected.[3] The salmon weighted between 4–5 kg (without their heads) and the fat content varied between 9–21%. The data were divided into two classes; the "lean" class contained fillets with less than 15% fat and the "fat" class contained fillets with a fat content of 15% or higher.

For the NIR on-line analysis, fillets were placed on a manually movable table, Figure 1, 20 cm from the 5-filter on-line instrument (MM55, NDC, InfraRed Engineering Ltd). The instrument had a quartz halogen lamp, a rotating filter wheel, a mirror, lenses, a concave light collecting mirror (diameter 85 mm) and two lead sulphide detectors. The filter wheel rotated at 50 Hz and data output was produced every four rotations. The gauge was connected to a remote data processing control unit (InfraRed Engineering Ltd).

The NIR filters had centre wavelength specifications at 1441, 1510, 1655, 1728 and 1810 nm, each with a bandwidth of about 25 nm.

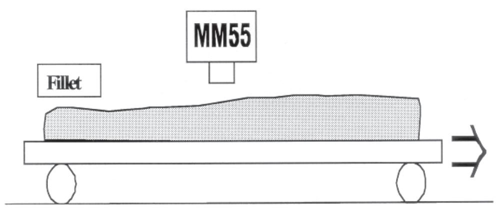

Figure 1. A rolling table was used to perform the analysis in the longitudinal direction of the fillets.

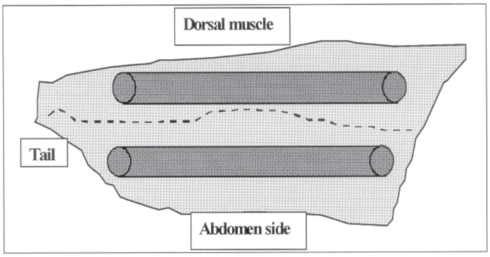

Figure 2. Illustration of the area for continuous on-line analysis of the dorsal muscle and the abdomen side of a salmon fillet.

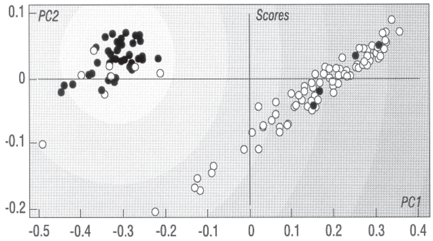

Figure 3. PCA analysis of the dorsal muscle (●) and the abdomen side (❍) of the fillets. Except for a few samples, the lean and the fat part of the fillets are separated into two classes.

The selection of the filters was done by analysing a previous data set of homogenised beef, Isaksson *et al*,[4] which was measured by using an off-line full-scanning NIR instrument (InfraAlyzer 500). The five filters were selected to cover the C–H stretch overtone bands dedicated to fat (1728 nm), O–H stretch overtone bands dedicated to water (1441 nm and 1510 nm) and references with low absorbance (1655 nm and 1810 nm). The filter combination was selected primarily for beef application, Isaksson *et al.*[5] To avoid specular reflection of transmitted light from the fillets, the sensing head was mounted at a 20° angle to the salmon's surface. The illuminated circle area and, consequently, the analysis area, was about 40 mm in diameter. Reflectance spectra (Phase Sensitive Detector values) were collected and the signals were averaged over periods of four seconds. The inner side of the dorsal muscle was analysed twice and the inner side of the abdomen side once per fillet, Figure 2. For the data analysis, $\log_{10}$ of the PSD values were calculated. Because of the differences between the fat content in the dorsal muscle and the abdomen side, the PSD values from these measurements were averaged in further analysis, Figure 3.

Each fillet was ground in a mill (Electrolux, model N 10, Sweden) with a 2 mm diameter hole, at 0–4°C and analysed in duplicate for fat (Fosslet, Foss Electric, Hillerød, Denmark), moisture (105°C at 18 h) and protein (Kjeltec Auto 1030, Tecator AB, Höganäs, Sweden). The averages for fat, moisture and protein for each sample were calculated and used in the subsequent calculations.

Regression and discriminant analysis

The classification was performed using three methods, partial least square[6] regression (PLS), linear discriminate analysis (LDA)[7] and quadratic discriminate analysis (QDA).[7] With the LDA method, it is assumed that the observations for the groups are normally distributed with common covariance matrix. The optimal (Bayes rule) is then the LDA.[8] LDA gives linear decision boundaries (in the

Table 1. Overview of the chemical contents of the salmon fillets.

Chemical Component	% Min.value	% Max.value	% Average	Stand. dev.	% *SREF*
Fat	9,1	20,5	14,4	3,47	0.21
Moisture	60,4	70,9	65,6	3,19	0.25
Protein	18,6	20,9	19,6	0,56	0.11

X-space). For QDA, it is assumed that the observations for the groups are generated from normal distributions with possible different covariance matrixes. Then the optimal (Bayes rule) is the QDA.[8] QDA gives quadratic decision boundaries (in the X-space).

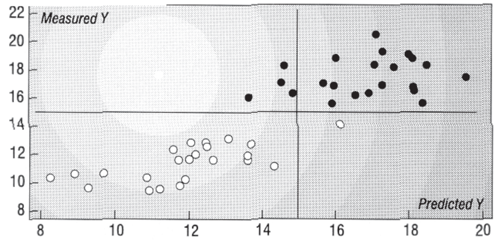

Figure 4. Prediction of fat by PLS yielded a multivariate correlation coefficient of 0.87 and correct classification of 40 out of 45 samples (89%).

Results and discussion

Table 1 gives a survey over chemical composition of the 45 fillets. The standard error of the reference method (*SREF*) is represented as the reproducibility between replicates of a standard product sample. These values give the absolute minimum limits for the NIR prediction error values from the multivariate calibrations.

The PLS method gave a multivariate correlation coefficient of 0.87 for the fat content. The proportion of correct classification in the two classes was 40 out of 45 samples, which gives an 89% correct classification, Figure 4. The *RMSECV* was 1.6%.

LDA gave a correct classification of 93% of the fillets as lean or fat. QDA gave 96% correctly classified samples in the two classes. Because fat is a continuos variable it is impossible and not expected to get all samples correctly classified.

The limited number of samples in this study may have resulted in a somewhat uneven distribution of fat. It should be expected that the population of salmon do have a more or less normal distribution of fat. It may, therefore, be that the classification results in this study are somewhat optimistic. The choice of the five NIR filters was not optimised for classification of salmon. Taking this into account, the classification seems reasonably good. The present results indicate that salmon can be classified by the fat content and should be of interest for the processing industry. However, a further study, using a larger number of samples, is needed before implementation in the industry.

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