Application Note 119. Calibration for Fat and Water Content in Tuna Fish.

Introduction

Tuna fish farming is a major industry in South Australia. Tuna are penned together in large circular nets and fed of bate fish, eg, pilchards. The growth of the tuna is very rapid and the objective is to harvest the tuna when they reach an ideal quality for the Japanese market. The quality is dependent on several factors, however the fat content is the most important chemical parameter. This study attempts to establish the ability to develop a NIR calibration for fat and water content of the tuna using a Fibre Optic Probe NIR Analyser, ie, the FOP-38.

Description:

1) Experiment 1: Analysis of Tuna Flesh

12 whole tuna were selected during the 2003 season. The fish represent the growth period of the tuna while in the pens. The tuna were cut into 5 half moon sections along the fish and the flesh was scanned using the FOP-38 Analyser. 5 spectra were collected for each of three positions in each section, ie, top, mid and bottom. Each piece of flesh was scanned twice. The flesh was cut out of the section, bagged and analysed for fat and water content.

The NIR spectra(figure 1.) were used to develop the following calibrations for fat and water content.

Results:

By examining the fat content of the fifteen pieces from each fish, it was noted that only sections 1 and 2, contained a consistent range of fat. Sections 3, 4 and 5 tended to have far less fat than sections 1 and 2. The variation in fat in sections 3, 4 and 5, did not fit a consistent pattern as did sections 1 and 2. As such only the spectra collected from sections 1 and 2 were used in the calibration. The rationale for using only sections 1 and 2, was to reduce the high degree of scatter that was observed in the calibrations when all sections were used.

The 5 spectra from each section were averaged. NTAS(NIR Technology Australia Software) was used to develop PLS calibrations for fat and water content.

Figure 2. shows the plot of the NIR calibrated fat content versus the reference fat content. The correlation, R2 = .926 and the Standard Error of Calibration (SEC) = 3.6, using 7 Principle Components.

Figure 3. shows the plot of the NIR calibrated water content versus the reference water content. The R2 = .922 and the SEC = 4.1%, using 9 Principle Components.

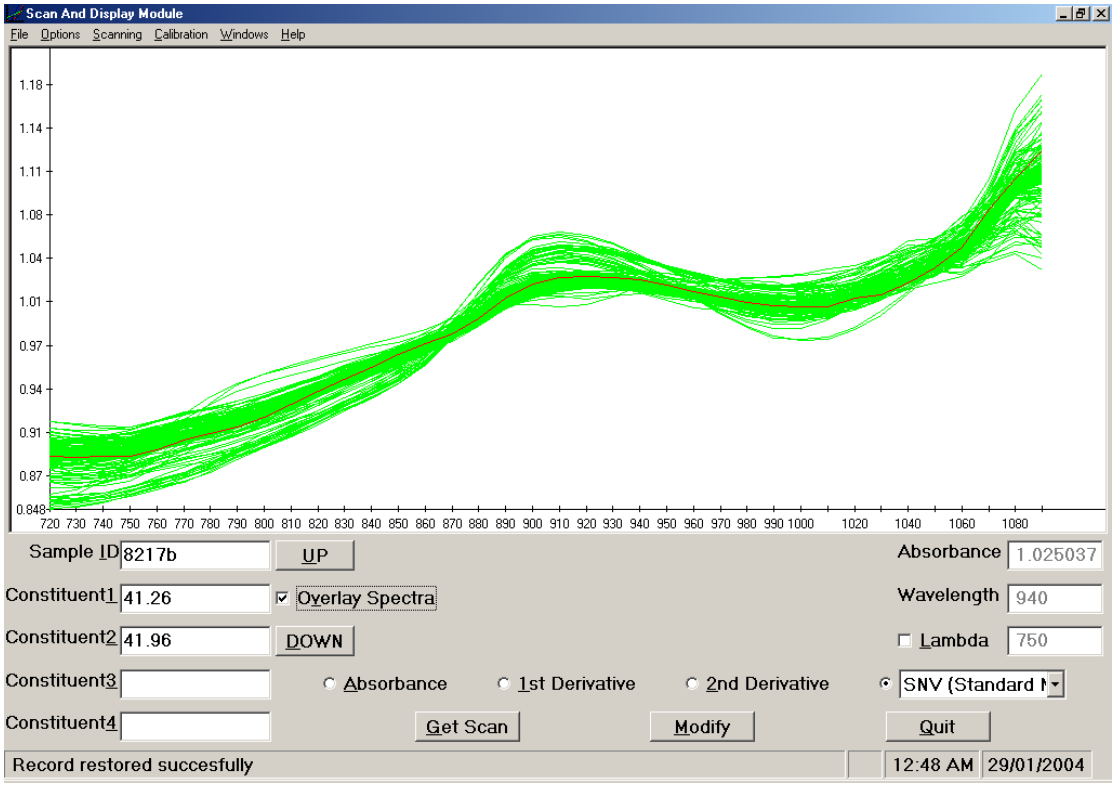

Figure 1. NIR spectra of Tuna Fish, Sections 1 & 2, Positions 1 & 2, SNV applied.

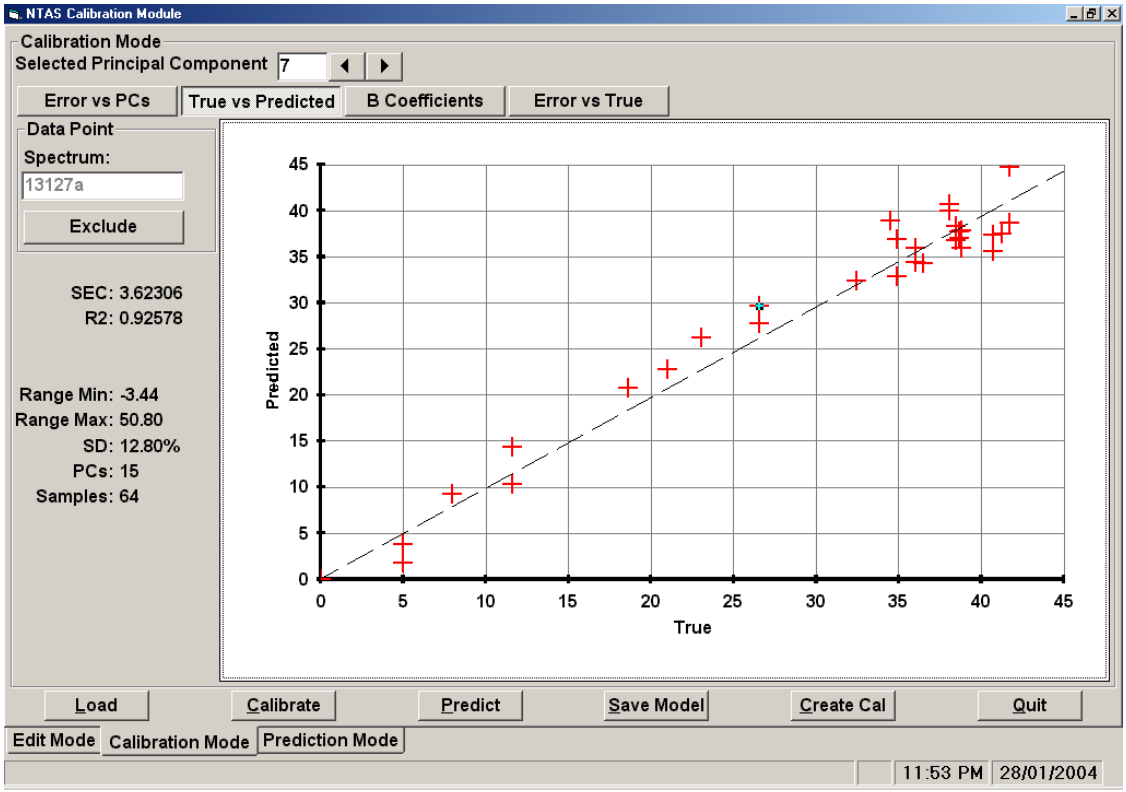

Figure 2. Plot of NIR calibration for fat content in tuna,

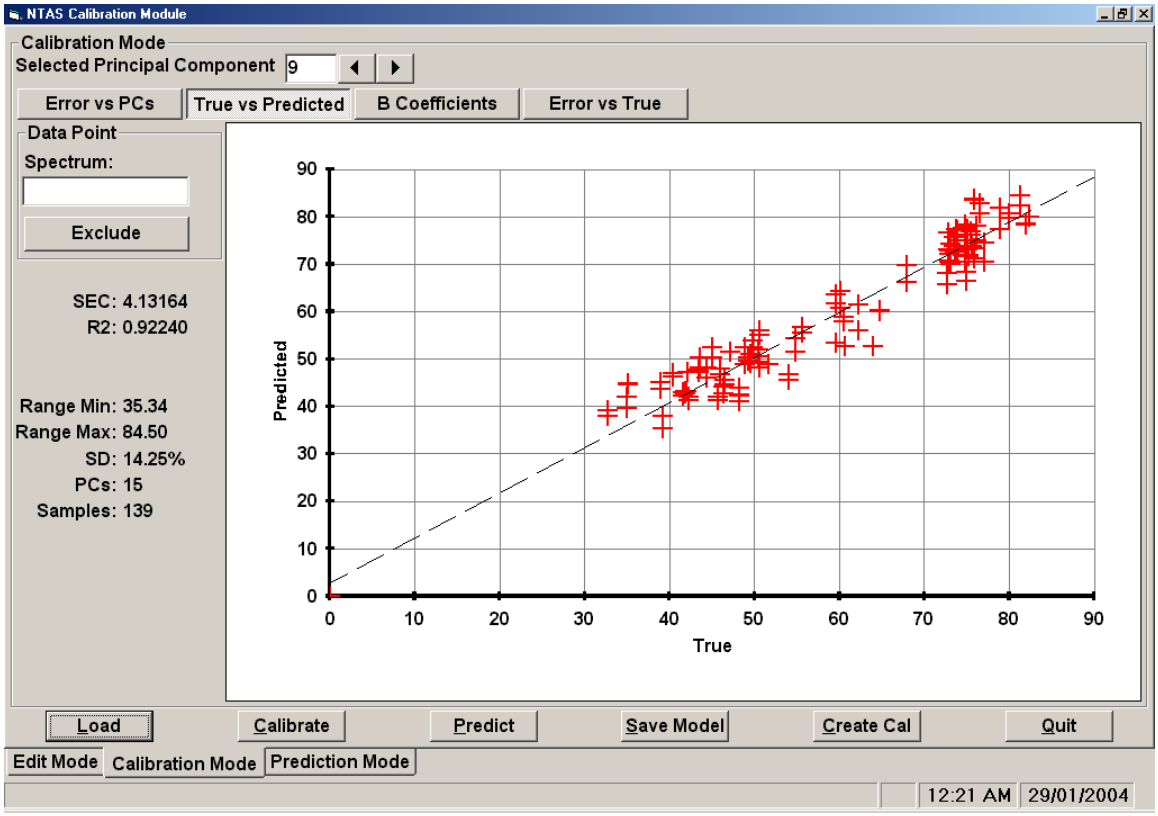

Figure 3. Plot of NIR calibration for water content in tuna,

2) Experiment 2: Analysis of Tuna Fish with Outside Skin Removed

The next phase is to see if spectra collected off the skin of the tuna can provide similar calibrations. Spectra were collected from the whole tuna after scraping away the outside skin of the fish. The scales were left intact.

Figure 4. shows the spectra of the surface of the tuna. Only section 1, positions 1 and 2, are included in these spectral plots. Each set of 5 scans were averaged and a Standard Normal Variant(SNV) spectral conversion algorithm has been used to normalise these spectra.

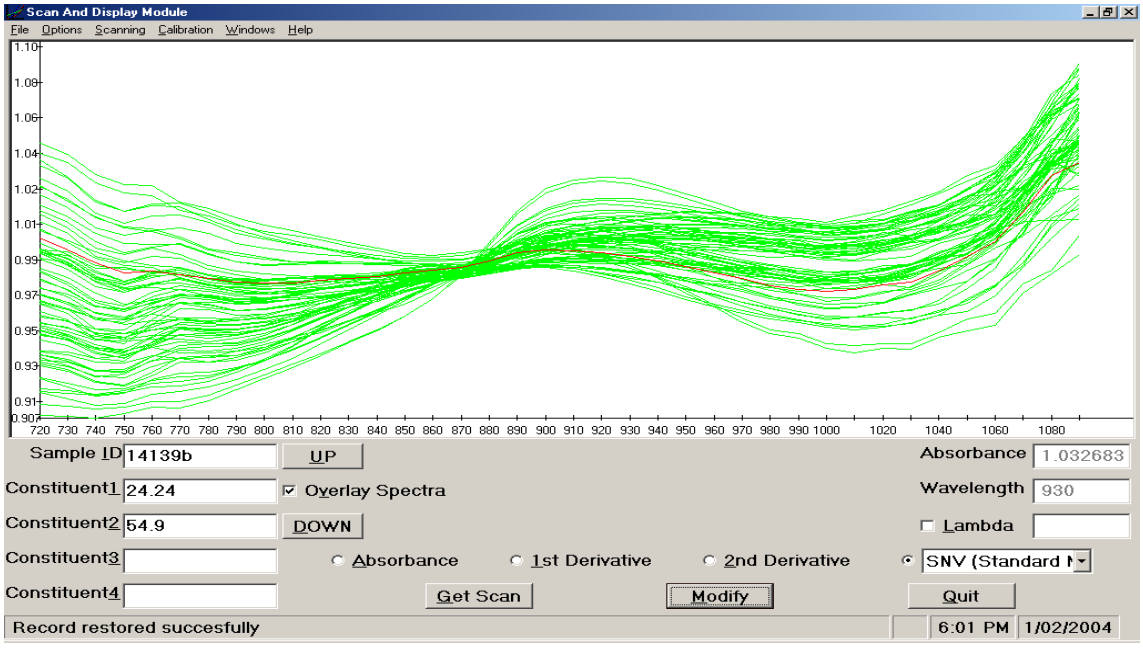

Figure 4.NIR spectra of Tuna Fish with Skin Off, Section 1, Positions 1 & 2, SNV applied.

Results:

Figure 5. shows a plot of NIR Fat vs Ref Fat calibration. Samples with fat content less than 2% were excluded from the calibration set. The data shows a SEC = 4.3% and R2 = 0.879. Figure 6. Shows the calibration data for water content. The SEC = 4.3 and R2 = .873.

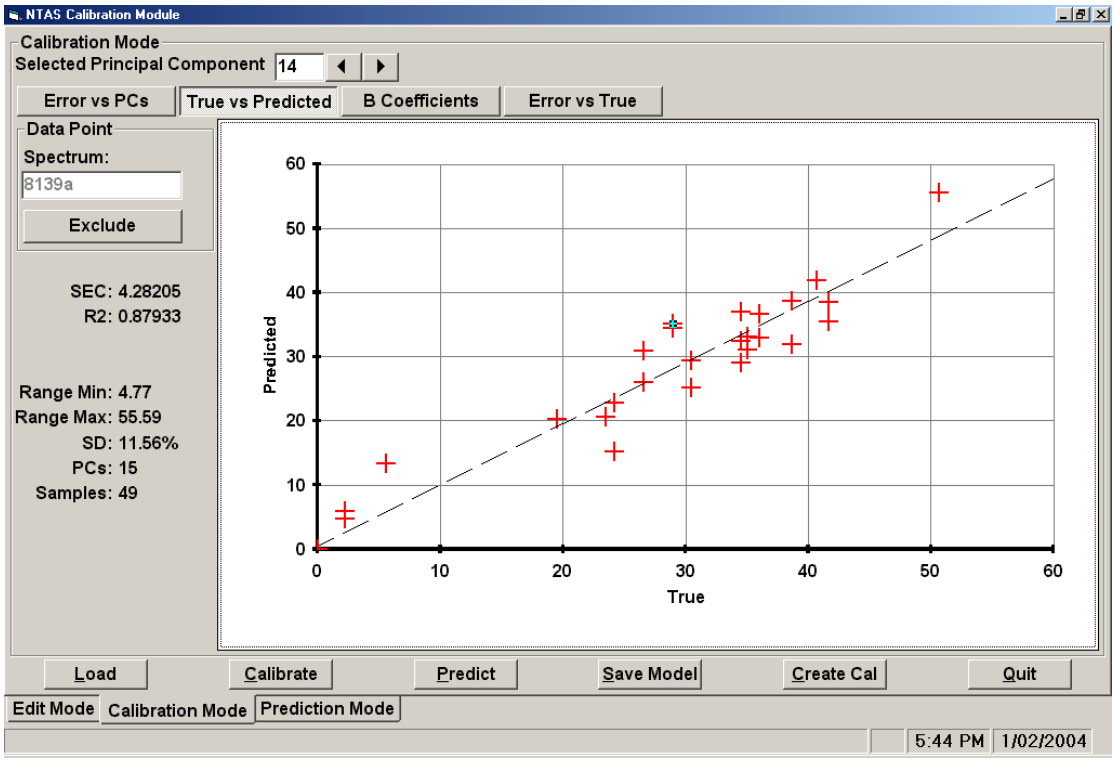

Figure 5. Plot of NIR calibration data for fat content in tuna.

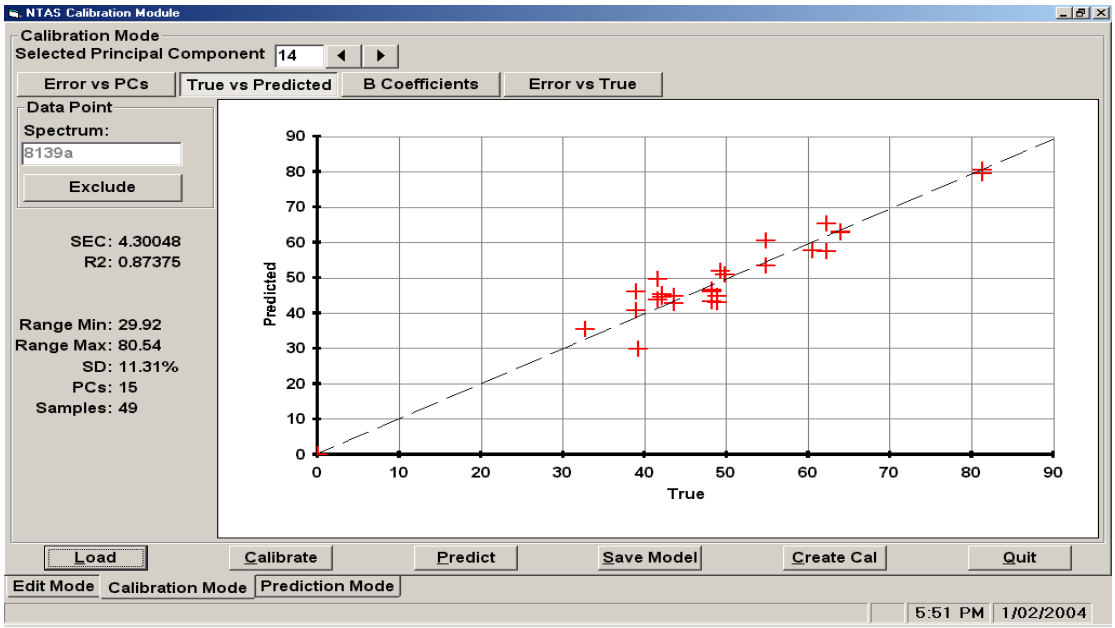

Figure 6. Plot of NIR calibration data for water content in tuna.

3) Experiment 3: Analysis of Tuna Fish through the external skin.

Figure 7. shows the plot of the NIR spectra of the tuna fish through the external skin. Only sections 1 and 2, positions 1 and 2 are included. The spectra are the average of 5 scans and with SNV applied.

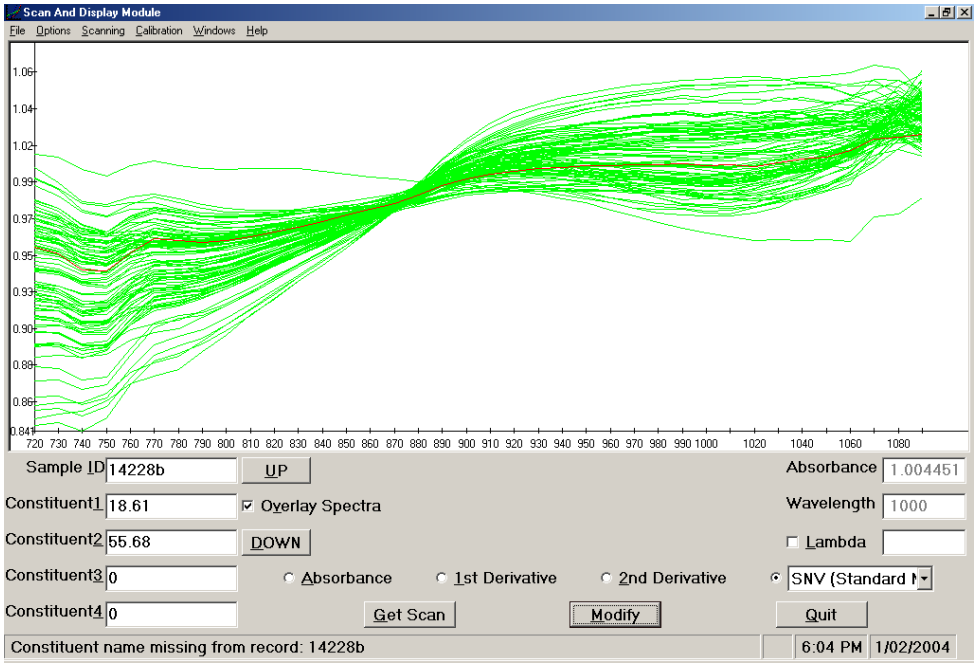

Figure 7. Plot of NIR Spectra of Tuna Fish through the skin, Sections 1 and 2, Positions 1 and 2., Average of 5 scans, SNV applied.

Results:

Figure 8. shows a plot of NIR Fat vs Ref Fat calibration. Samples with fat content less than 2% were excluded from the calibration set. The data shows a SEC = 6.0% and R2 = 0.787. Figure 9. Shows the calibration data for water content. The SEC = 6.0 and R2 = 0.793.

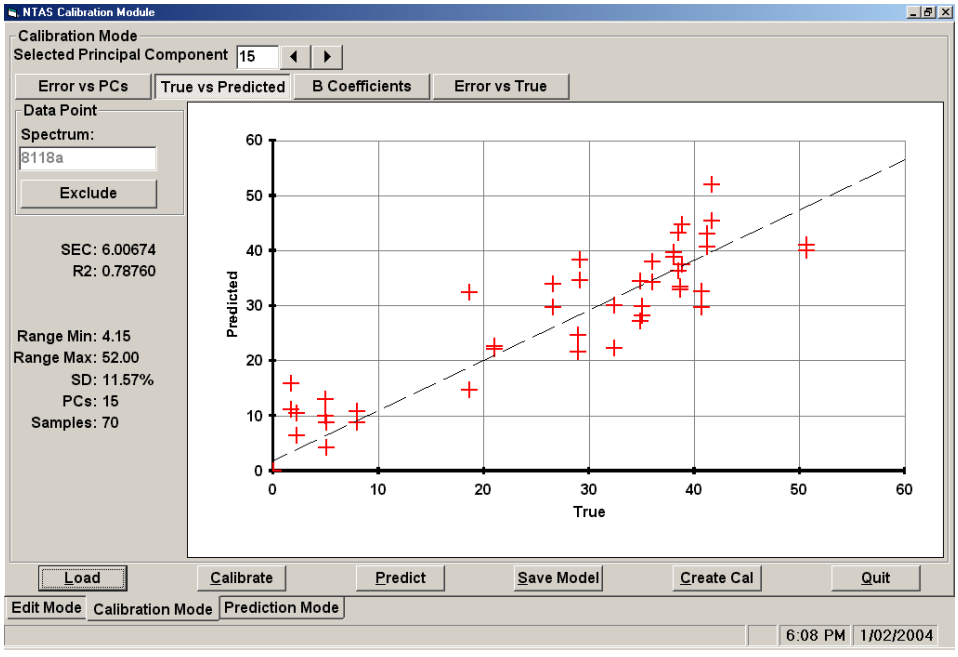

Figure 8. Plot of NIR Fat Calibration vs Ref Fat, Sections 1 and 2, Positions 1 and 2.

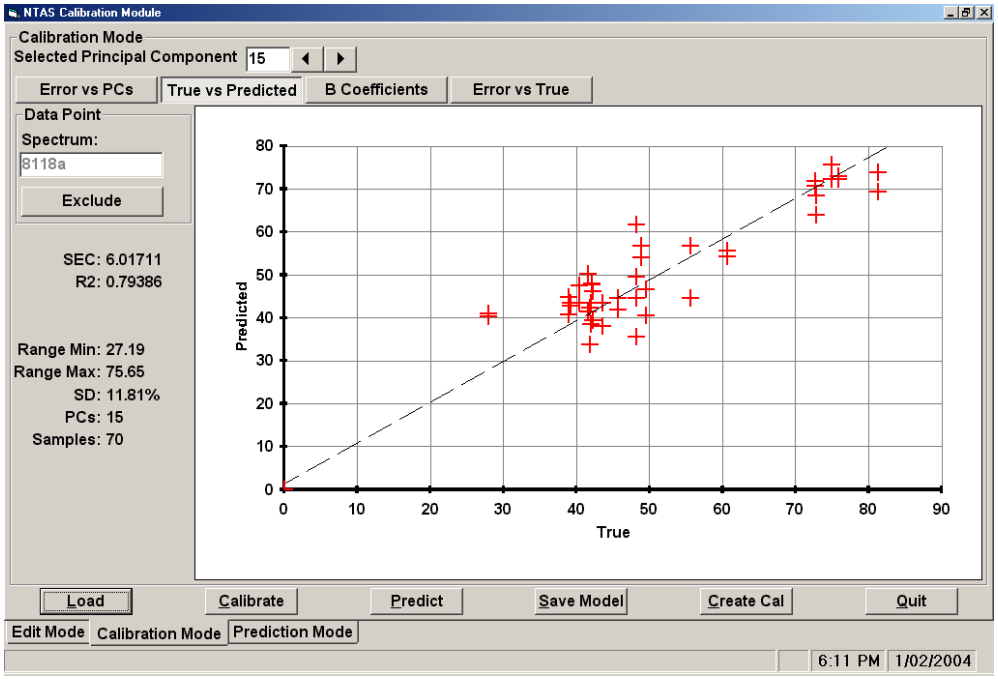

Figure 9. Plot of NIR Water Calibration vs Ref Water, Sections 1 and 2, Positions 1 and 2.

If spectra from Section 1 and 2, buy only Position 1, are used for the calibration for fat, there is a substantial improvement in the calibration statistics. Figure 10 shows the plot for NIR Fat calibration vs Ref Fat for Sections 1 and, Position 1. The SEC = 2.1 and R2 = .982. However there are very few spectra included in this set and the calibration model is an overfit of the data.

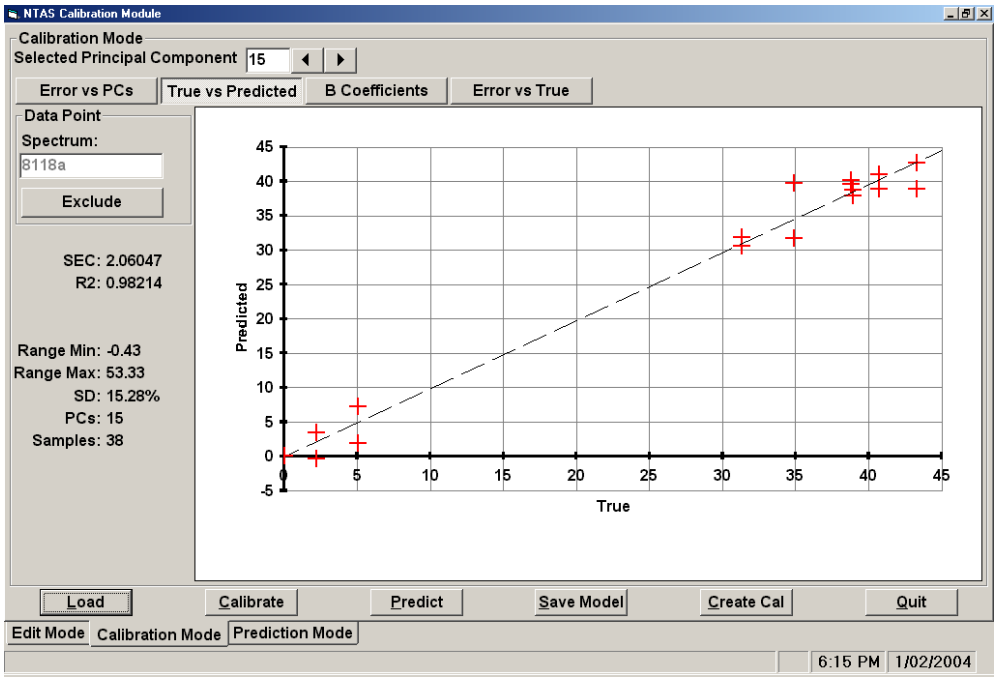

Figure 10. Plot of NIR Fat Calibration vs Ref Fat, Sections 1 and 2, Positions 1 only.

Discussion

1) Experiment 1: Analysis of Tuna Fish Flesh.

The correlations of .92 shows a high degree of linearity between the NIR calibration and the reference method for both fat and water, however the SEC's are considered larger than would be expected. There is obviously a lot of scatter in the data which can be due to poor spectral data or poor reference data. Nonetheless, the data shows there is an excellent potential for the use of NIR to make rapid measurements of fat and water content in tuna by scanning the flesh of the fish.

2) Experiment 2: Analysis of Tuna Fish through the Scales, with the Skin Off.

The correlations of R2 = 0.87 for this experiment still demonstrate a good degree of linearity between the NIR spectra collected through the scales and the fat and water content of the flesh under the scales. The increase in SEC from 3.6% to 4.3% is not that large, however it must be noted that in the data for Experiments 2 and 3, the number of Principle Components is 15 where as for Experiment 1 it was 9. This is significant and may suggest that the data is over fitted. However the data does suggest that fat and water content may be possible to measure through the scales. The best location to make these measurements would be at Position 1, ie, the belly flap. Although there is little difference between calibration data developed using Positions 1 or 2.

3) Experiment 3. Analysis of Tuna Fish through Scales, with Skin On.

The correlations of R2 = 0.79 and the increase in Sec = 6%, for fat and water in this experiment shows the influence outer skin in the spectral data. Figure 7. Shows that the spectra loose the central water peak as compared with spectra of flesh and flesh covered with scales. The data suggests that it may be possible to make fat and water content measurements through the skin, however the errors are starting to become large and the spectral are poorly defined. It may be that by using only spectra collected from Position 1, ie, the belly flap, then the accuracy could be sufficient for making rapid "in vivo" of live fish and thereby having a means of screening fish for fat content and therefore maturity.

Inspection of the NIR spectra collected with the FOP-38 Fibre Optic Probe Analyser show there are many spectra which are of poor quality. This may be due to the probe design, steadiness of the operator's hand while scanning or inconsistent flesh and skin. Significant improvement in the data would be realised if the Fibre Optic Probe design was optimised for this application. A larger probe head, a more powerful lamp and longer scan times would improve the spectral data and therefore the accuracy of the measurements.