In line NIR monitoring of grain into a flour mill.

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Introduction.

Flour milling requires control of the protein and moisture content of wheat. Traditionally samples of wheat are collected from each truck load and decisions are made to segregate the wheat into low, medium and high protein silos. These grab samples do not necessarily reflect the protein variation within the truck or railcar loads. As such a Manildra Flour Mill, Narrandera, NSW installed a CropScan 3000S In Line Whole Grain Analyser (fig 1 and 2) to measure protein and moisture in wheat at the in-take elevator of the mill.

Figure 1. CropScan 3000S In Line Whole Grain Analyser

A calibration was developed by collecting spectral data from daily intake loads over several weeks. Having a good range of samples with low to high protein and moisture values and different varieties helped to develop a robust calibration that predicts accurately in the future. To validate the CropScan 3000S calibration for wheat samples from many weeks were compared to the flour mill's laboratory NIR analyser. This study compares the protein and moisture in wheat as analysed by the CropScan 3000S In Line Whole Grain Analyser with the flour mills' bench top NIR analyser.

Figure 2. CropScan 3000S In Line Whole Grain Analyser

Instrumentation.

The CropScan 3000S In Line Whole Grain Analyser uses a remote sampling head to trap a sample of grain taken from the in-take elevator at approximately 11 second intervals before returning the grain to a conveyer belt. Light from a tungsten halogen reflector lamp is passed through the trapped sample of grain. A fiber optic cable collects the light that passes through the grain sample and transmits the NIR light back to the CropScan 3000S NIT spectrometer located in a Nema IV enclosure that is mounted on the wall near the in-take elevator.

The CropScan 3000S uses a diode array spectrometer (fig 3) to scan the wavelength region 720-1100nm. Within this region of the NIR spectrum, protein (N-H bonds) and water (O-H bonds) absorb NIR light. The amount of light absorbed at the resonant frequencies for protein and moisture are proportional to the concentrations. Calibration models stored in the CropScan

3000S's computer is applied to the NIR spectrum such that the protein and moisture contents are measured every 11 seconds. The results are displayed as the individual and averaged protein and moisture values for each load received by the mill on a PC located in the mill's laboratory.

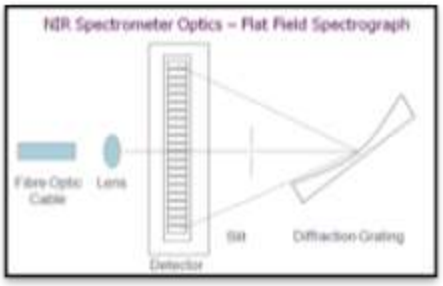


Figure 3. Schematic of the CropScan 3000S Diode Array Detector System

Calibration:

380 truckloads of wheat were speared and a 500ml sub sample was collected and analysed using the Foss Infratec 1214 NIR Analyser. Each truck load of wheat was emptied into the in-take elevator. The CropScan 3000S In Line Whole Grain Analyser scanned sub samples from the in-take elevator every 11 seconds or 0.35 Tonne of grain loaded into the mill. The spectral data from the CropScan 3000S were averaged for each load, Figure 4. The lab data were collected from the Infratec 1241 and combined with the CropScan spectral file. A Partial Least Squares Regression was performed on the combined calibration file using NTAS (NIR Technology Analysis Software) to develop calibration models for protein and moisture. Figures 5 and 6 show the calibration plots and statistics for protein and moisture.

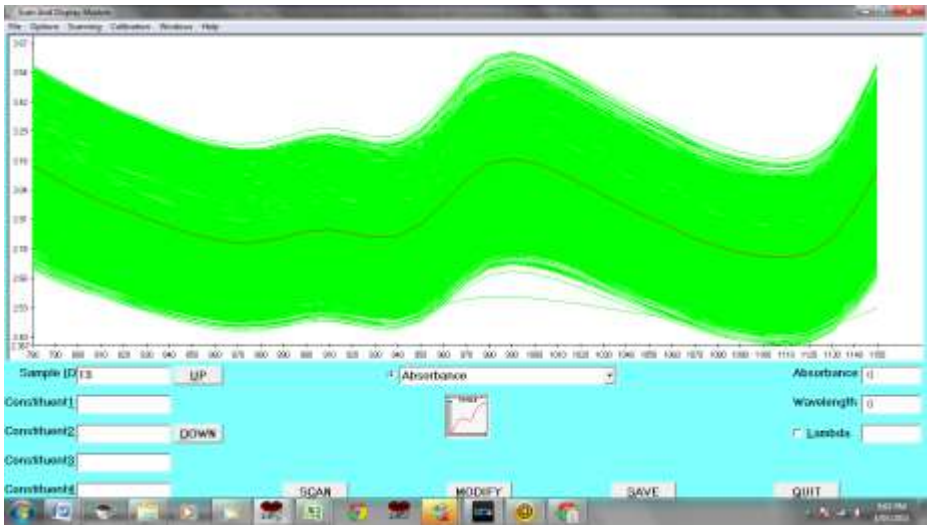


Figure 4: Plot of NIR Spectra for Wheat.

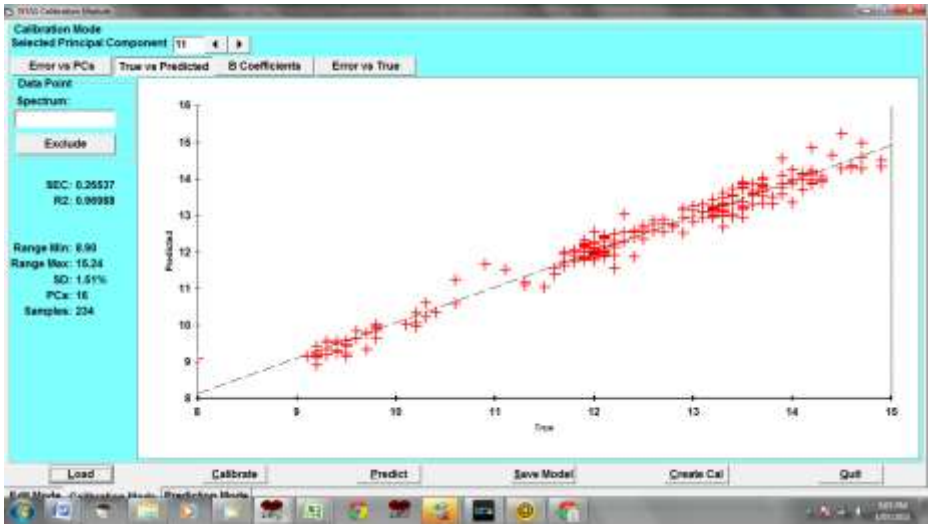


Figure 5 Calibration plot for protein. The Standard Error of Calibration (SEC) was 0.25% with a correlation (R^2) of 0.97.

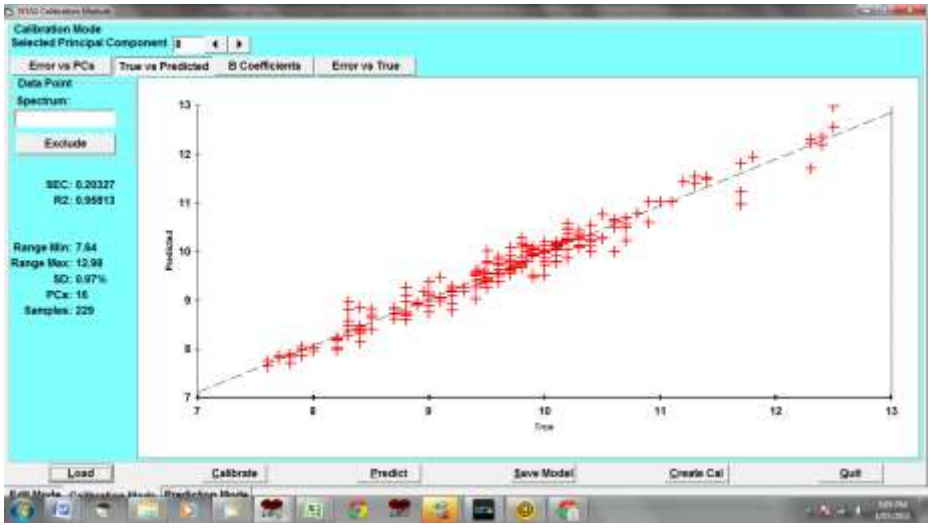
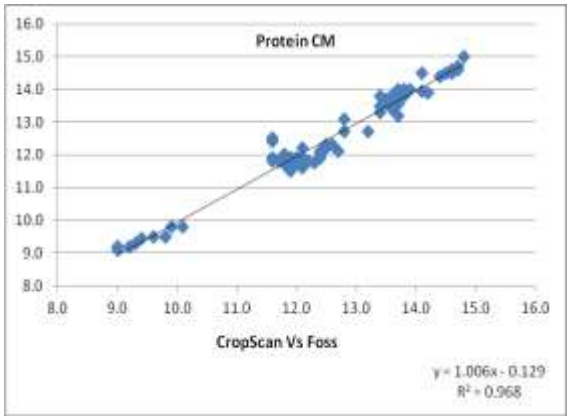


Figure 6: Calibration plot for moisture. The Standard Error of Calibration (SEC) was 0.2% with a correlation (R2) of 0.96.

Prediction.

82 truckloads of wheat were measured over two weeks to check for accuracy and stability of the calibration models developed above. The table below shows the average protein and moisture results from the CropScan 3000S versus the average results from the laboratory NIR analyser.

Figures 7 and 8 show plots and graphs comparing the results from the CropScan 3000S In Line Whole Grain Analyser vs. the flour mill's laboratory analyser. The correlation between the CropScan 3000S and the laboratory NIR analyser is R^2 = 0.968 for Protein and R^2 = 0.929 for Moisture. Figures 9 and 10 show the Trend Plots for Protein and Moisture. The Trend Plots demonstrate how consistent the data is between the in line analyser and the laboratory analyser.



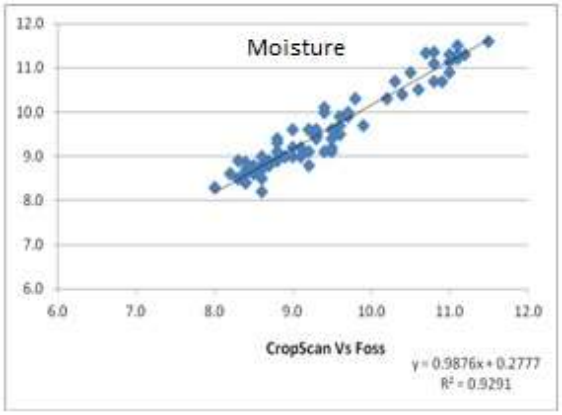
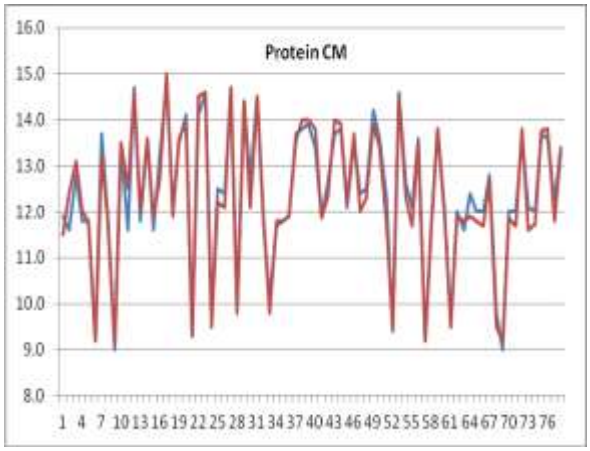


Figure 7 and 8 Protein and Moisture Plots: CropScan 3000S vs Lab NIR



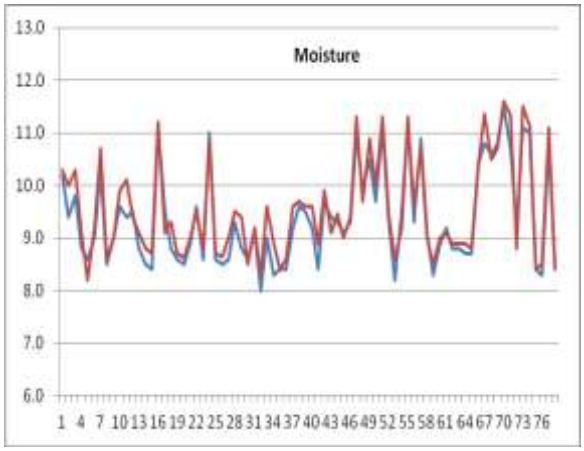


Figure 9 and 10. Protein and Moisture Trend Plots: CropScan 3000S vs Lab NIR

Daily Data:

Having established that the CropScan 3000S provide consistent and reliable measurements for protein and moisture for the incoming wheat, the system was then used continuously for 6 months to monitor the intake wheat stream. A typical daily wheat intake record is shown in Figure 11. These trend plot for protein and moisture show the measurement of approximately 19 truck loads across a day, ie, April 14th, 2015. The range of proteins across the 19 truck loads varied from 9% to 14.5% and the moisture varied from 8% to 11%.

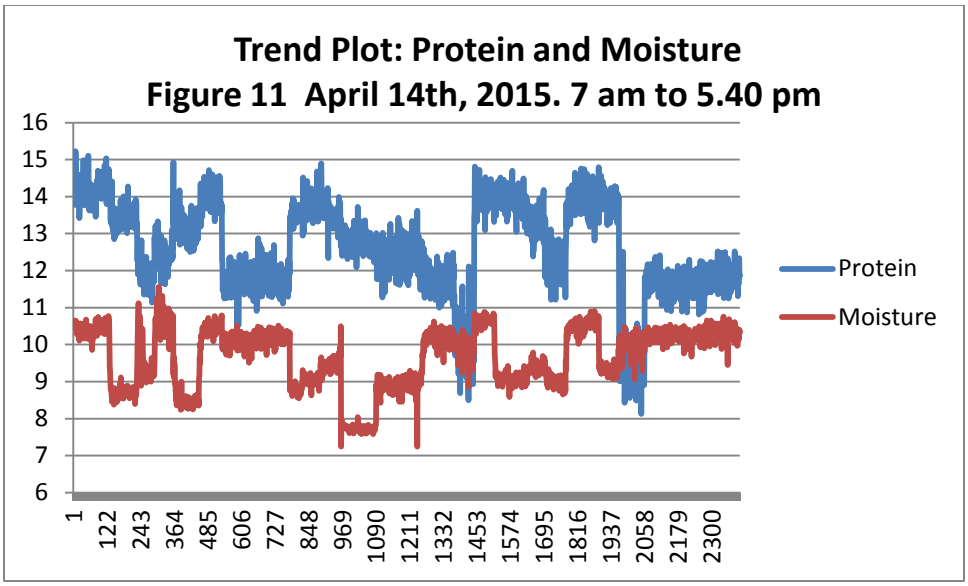
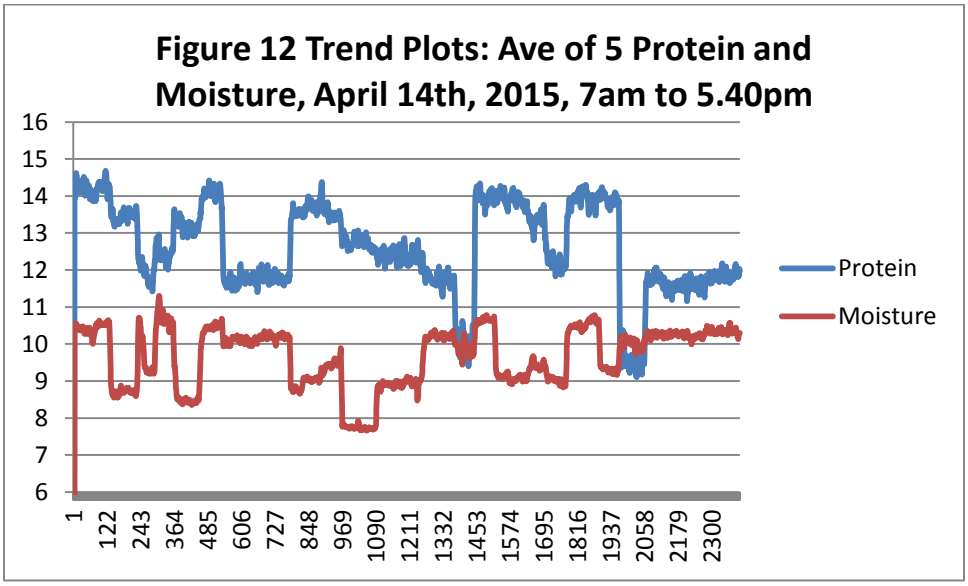
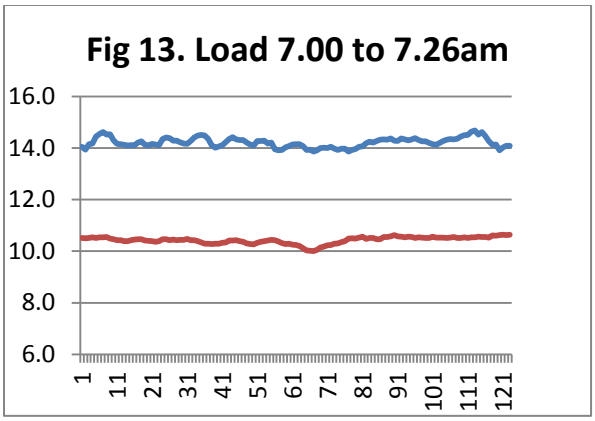
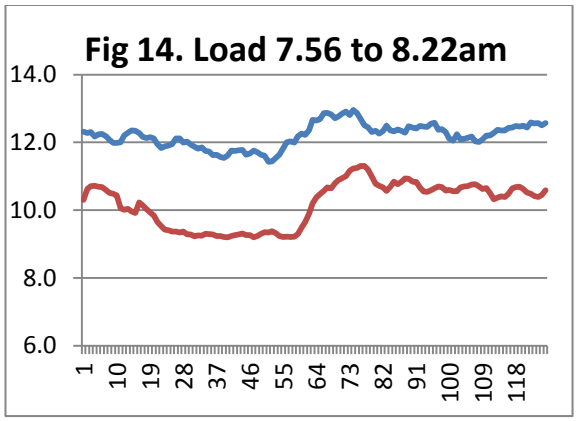


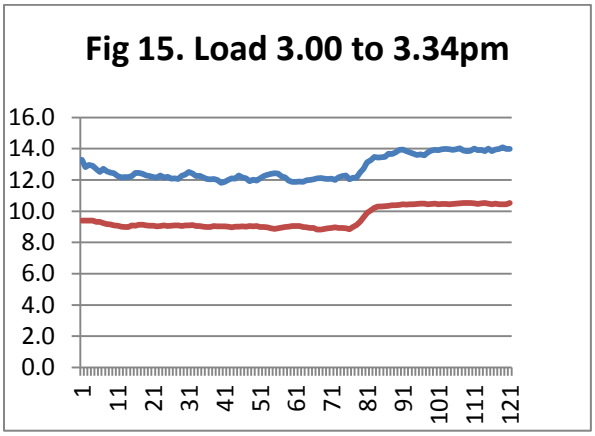
Figure 12. shows the same trend plots with a moving average of 5 readings. The moving average smooths the plots and makes it easier to see systematic changes rather than random changes.

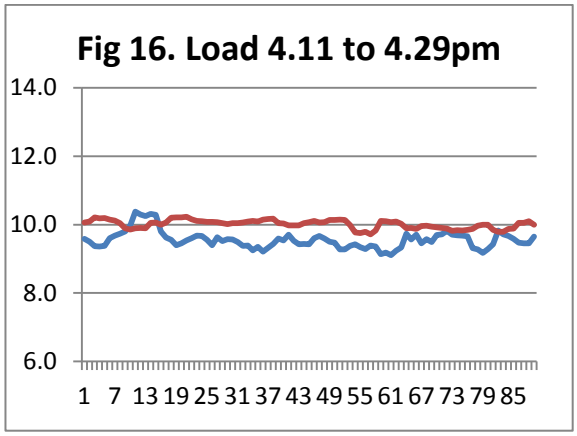


Since an objective of the Manildra Flour Mill was to see how much variation existed with each load, figures 13 through 16 show trend plots for 4 individual loads during the day.



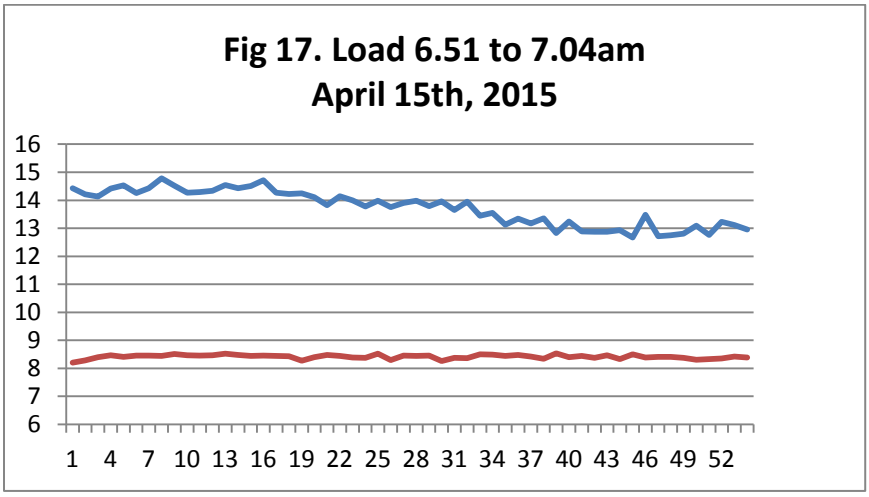






Figures 13 and 16 show loads where the protein results are consistent throughout the truck. Figure 14 and 15 show loads where the protein results shift as the load is emptied. The sample spear provides an average across the truck load however the in line measurement provides data that could be used to divert the high protein grain to achieve better segregation.

The following day provided data that highlighted the potential benefits of the in line measurement system. Figure 17 shows the trend plot of an early load where the protein varies from 14.5% at the start of the load and 12.8% at the end of the load.



Conclusion.

This study demonstrates that the CropScan 3000S In Line Whole Grain Analyser provides a means of continuously and accurately monitoring protein and moisture as truck loads are received into this flour mill. The system has now been operation for 10 months and has made over 500,000 measurements without any down time. Daily maintenance requires that the sampling head be blown out with an air hose. More spectra data and lab data have been added to the calibration models over the 10 months.

Manildra evaluated several in line NIR measurement system along with the CropScan 3000S. The CropScan 3000S scored a 91.56 out of 100 by Manildra based on accuracy, reliability, user friendliness, service provided and price. The report includes a comment in reference to all the systems evaluated: “The most economic unit gets the most points and the most expensive unit the lowest.”