COMMERCIAL REAL-TIME APPLICATION OF NIR CALIBRATIONS FOR THE MEASUREMENT OF DIGESTIBLE ENERGY

1B-110

Report prepared for the Co-operative Research Centre for an Internationally Competitive Pork Industry

By

Doug Pearson
Feedworks Pty Ltd
13 Main Rd Lancefield, Vic, 3435

September 2011

Established and supported under the Australian Government's Cooperative Research Centres Program

Executive Summary

Development and proceeding use of the NIRS AusScan® Digestible Energy calibrations has identified that there is significant variation between batches of cereals. The greatest benefit from application of these calibrations will be obtained through real-time analysis of cereal cereals prior to incorporation into diets. An NIR-Online® X-One inline NIRS was installed at Ridley Agriproducts Murray Bridge feedmill on the cereal transfer line. This line transports all cereals entering the mill to the hammer mill. The system logged data for 12 months of mill operation from March 2010 through to March 2011, recording multiple parameters including results from the AusScan® calibrations for Pig Faecal Digestible Energy (FDE)and Illeal Digestible Energy (IDE).
Considerable variation of all parameters was seen across all the measured cereal types including Wheat, Barley, Triticale, Oats, Lupins and Peas.
The cost of 1MJ/kg of cereal DE content is considered to be between $15 and $20/Metric Tonne. With the pig industry striving for greater feed efficiency this highlights the need for better control of DE variability within finished feeds. Ideally cereal DE content variations would be contained to within 0.5MJ/kg. Data logged by the NIR-Online® NIRS clearly shows that based on 1MT milled Wheat batches multiple batches over a 2 hour period would benefit from formulation adjustment.

Table of Contents

1. Introduction

The Australian pork industry has been involved in the development of rapid and objective tests for the assessment of feed ingredient quality since 1995. Through research projects funded initially by the Premium Grains for Livestock Program and the Grains Research and Development Corporation and subsequently through the Pig Research and Development Corporation, a series of near infra-red spectrophotometry (NIRS) calibrations have been developed for the measurement of digestible energy in cereals for pigs. After a protracted negotiation process, the Pork CRC now holds the license for these calibrations and has an obligation to drive their uptake within the pork industry. To date, the technology has been available to end users via bureau services offered through the South Australian Research and Development Institute and FEEDTEST through the Victorian Department of Primary Industries.

While useful, benefit from use of these calibrations will arise when they are applied at the point of feed manufacture so that variation in digestible energy content can be measured prior to inclusion in a diet and appropriate adjustments made to the formulation to accommodate this variation. Calibrations could be installed on existing equipment within feedmills, but this will require standardisation of NIR machines and maintenance of the calibration and to be fully exploited, mills will need to undertake routine sampling and measurement procedures on the cereals prior to, or following, milling.

The greatest benefit from application of NIRS calibrations for the analysis of cereals prior to incorporation into diets will be obtained through real-time analysis of cereal grains prior to incorporation into diets. In recent years the development of inline NIRS systems now provides the platform for continuous monitoring and adjustment.

The aim of this project was to collect 12 months' worth of real-time NIRS analysis data of typical cereals incorporated into pig diets. Provide a better understanding of the actual variations of digestible energy content encountered by a mill and justification for the development and implementation of mechanisms within the mill to swiftly respond to these variations.

2. Methodology

While a range of NIRS companies offer probes for apparent real-time analysis of cereal composition and characteristics, probes are not ideally suited to flow through measurements and are also better suited to powders than whole cereal grains. The NIR-Online® System has been developed specifically with real-time flow through analysis as an objective, and the equipment is designed for installation in hostile operating environments (such as the inlet to a hammer mill from a surge bin). NIR-Online® has a large (40mm) lens allowing for large amounts of product to be scanned which is of benefit when dealing with heterogeneous products. The NIR-Online® data management software, SX-Center®, is also able to deal with the large amounts of data generated by continuous inline NIRS monitoring. NIR-Online® is able to take spectral scan files from other NIRS systems along with the reference data for the chosen parameters and swiftly produce accurate calibrations for the NIR-Online® systems. Unfortunately AusScan® was not willing to release this data to NIR-Online®, so a less effective option was used. A NIR-Online® X-Rot (bench top formatted) system was taken to the Grain Research Centre in Narrabri and 374 of the stored AusScan® cereal samples were each scanned 2 times. Peter Flinn (Kelspec Services Pty Ltd, Vic), under the guidance of Thomas Qvarfort (NIR-Online®, Germany) then used the SX-Plus®, calibration software from NIR-Online® to create the following DE calibrations for the NIR-Online® system.

Pig
FDEGAR (Faecal Digestible Energy of the grain, MJ/kg as fed)
IDEGAR (Illeal Digestible Energy of the grain, MJ/kg as fed)

Broiler
AMEGAF (Apparent Metabolisable Energy of the grain, MJ/kg as fed)
AMEGII (AME Grain Intake Index)

Ruminant
ESTMESHP (Estimated Metabolisable Energy, sheep, MJ/kg of dry matter)
ESTMECAT (Estimated Metabolisable Energy, cattle, MJ/kg of dry matter

In early March 2010 an X-One NIR-Online® system complete with Bypass Sampler for automated sample collection was installed and commisioned on the cereal intake line pre hammer mill at Ridley Agriproducts Mill at Murray Bridge, SA. All of the cereal entering the mill passes this point, so it provides an ideal location for exposure to a number of cereal types.
The above noted DE calibrations were installed on the system as well as basic calibrations for Moisture and Protein. The Moisture and Protein calibrations were created by using the Automatic Calibration feature of the NIR-Online® system. Samples of cereal where captured via the Bypass sampler which automatically creates a date/time stamped data record in the software. The samples were analysed, for Moisture and Protein, in house by the Ridley staff using their lab NIRS system. These results were then entered into the NIR-Online® Automatic Calibration software and a calibration produced.
Data was recorded through to March 2011.

3. Outcomes

When the NIR-Online® system detects material in front of the scanner it creates a new “batch” entry in the data base with a beginning and end date/time. Ideally a signal is received from the mill control software into the NIR-Online® software denoting what product is being milled. Unfortunately due to the age and setup at Murray Bridge such a signal could not be accessed, therefore we had to rely on the operators to select a "Recipe" (Wheat, Barley, Triticale, etc.) from a list on the user interface page. This was not always done. To overcome this we created 3 predictor calibrations in an attempt to identify and confirm which cereal was milled using the spectral information. This worked well when the cereals were of reasonable quality, however at times the mill received mixed deliveries (e.g. wheat/lupin) and these would confuse the software. As a result the 7834 batch entries each had to be individually checked and a "recipe" manually allocated.

Cereal is received at the mill via truck and is transferred from the receival point into large storage silos adjacent to the mill, or occasionally directed immediately to the hammer mill from receival. Cereal from the storage silos is transferred via a single blown air transfer system, on which the NIR-Online® system was mounted to the hammer mill. From the hammer mill the milled cereal is then directed to multiple "day" bins of either 20 or 40 MT in capacity. During a normal days operation the cereal type being directed through the hammer mill is changed regularly to keep the day bins topped up. This results in hammer mill runs varying from less than 1 minute to over 2 hrs. This makes it very difficult to track the flow of the measured material after the hammer mill. As such investigation of how automated response to DE variations could be addressed real-time in this mill was not pursued.

The NIR-Online® system scanned the whole cereal at a rate of 78 spectra every 3 seconds and recorded the mean of these spectra every 6 seconds. At the end of each batch the average of each parameter for the batch is calculated. A yearly report calculating Average, Minimum, Maximum and Standard Deviation was generated from the SX-Center® software (See Appendix 1), a summary of each cereal type can be found in the following table.

Table 1. Variation in Wheat 2010 (March to Dec)

	Moisture	Protein	FDE	IDE
Average	10.57%	12.94%	13.505	11.725
Min	5.04%	4.06%	11.200	9.387
Max	14.56%	16.42%	14.268	14.200
Std. Dev.	0.82%	1.36%	0.274	0.566

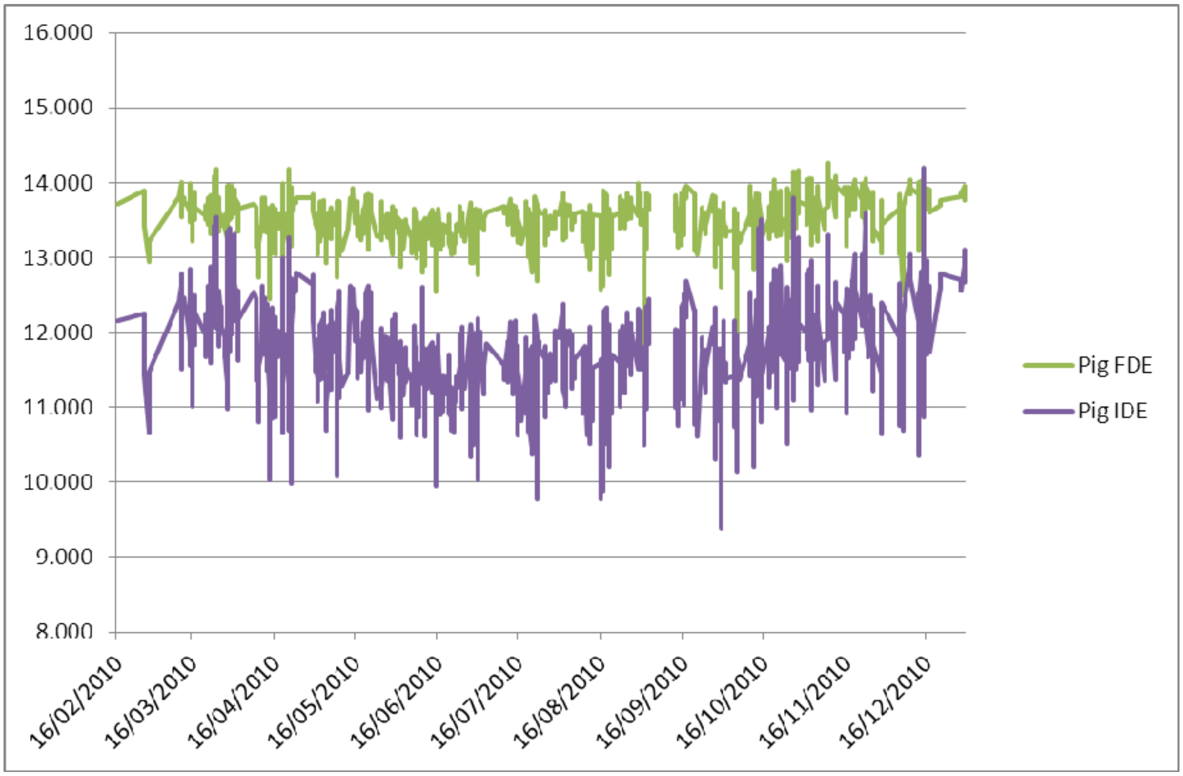
Table 2. Variation in Barley 2010 (March to Dec)

	Moisture	Protein	FDE	IDE
Average	10.56%	11.23%	12.784	9.903
Min	5.79%	4.14%	11.107	7.977
Max	15.79%	16.97%	14.550	13.223
Std. Dev.	1.49%	2.18%	0.299	0.459

Table 3. Variation in Triticale 2010 (March to Dec)

	Moisture	Protein	FDE	IDE
Average	9.87%	11.64%	13.198	11.950
Min	7.49%	9.39%	10.871	10.155
Max	12.08%	16.07%	14.403	14.325
Std. Dev.	0.79%	0.82%	0.413	0.561

Figure 1 Wheat - Pig Faecal Digestible Energy and Illeal Digestible Energy 2010.



It should be noted the above figures are calculated on each of the batch averages, considerable variation was seen within batches across a typical day of milling.

A full set of monthly reports were also generated for each of the cereal types. The reference for these files can be found in Appendix 2.

To gain a more defined image of what was occurring the actual measured parameter data for Moisture, Protein, FDE and IDE was extracted for the months of March and June 2010. The reference to these files can be found in Appendix 3.

The graphs below (Figures 2 and 3) show a 2hours 26minutes run of Wheat on the 31st March 2010 and 2hours 37minutes run of Wheat from the 3rd June 2010. It can be seen that over this time period there are significant variations in all of the measured parameters.

Figure 2 Wheat 2hours 26minutes 31st March 2010

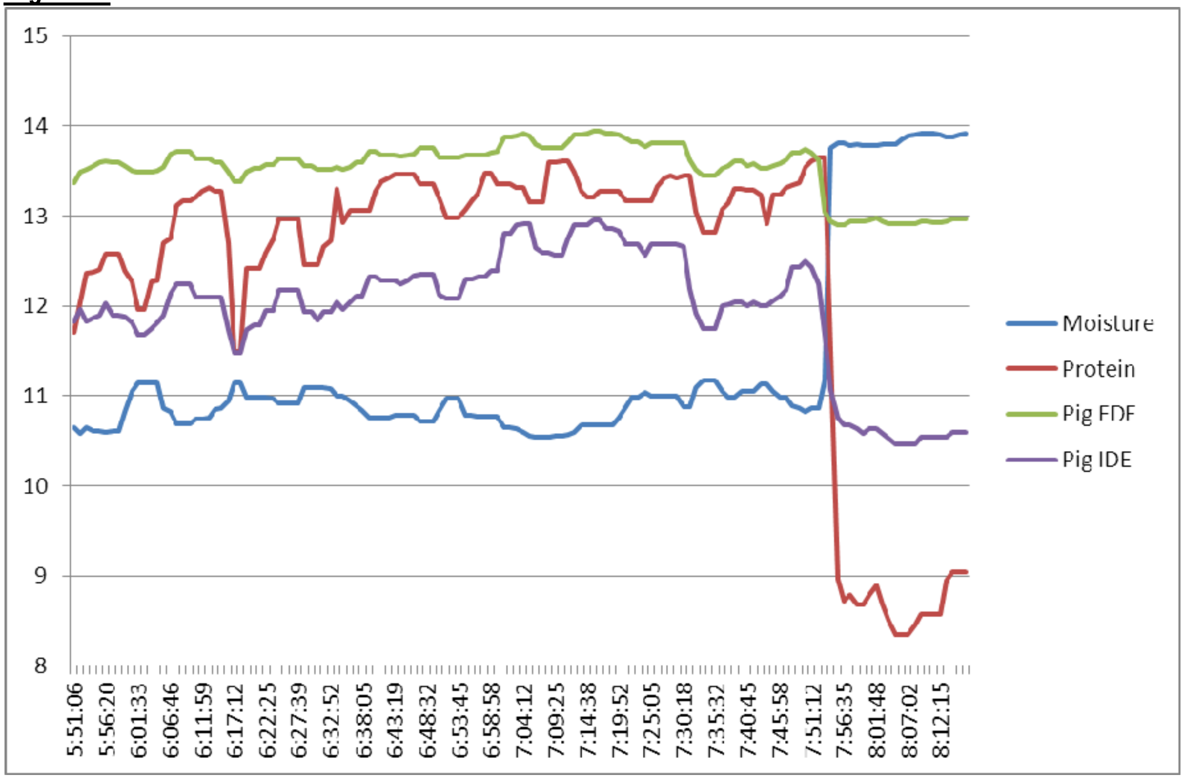
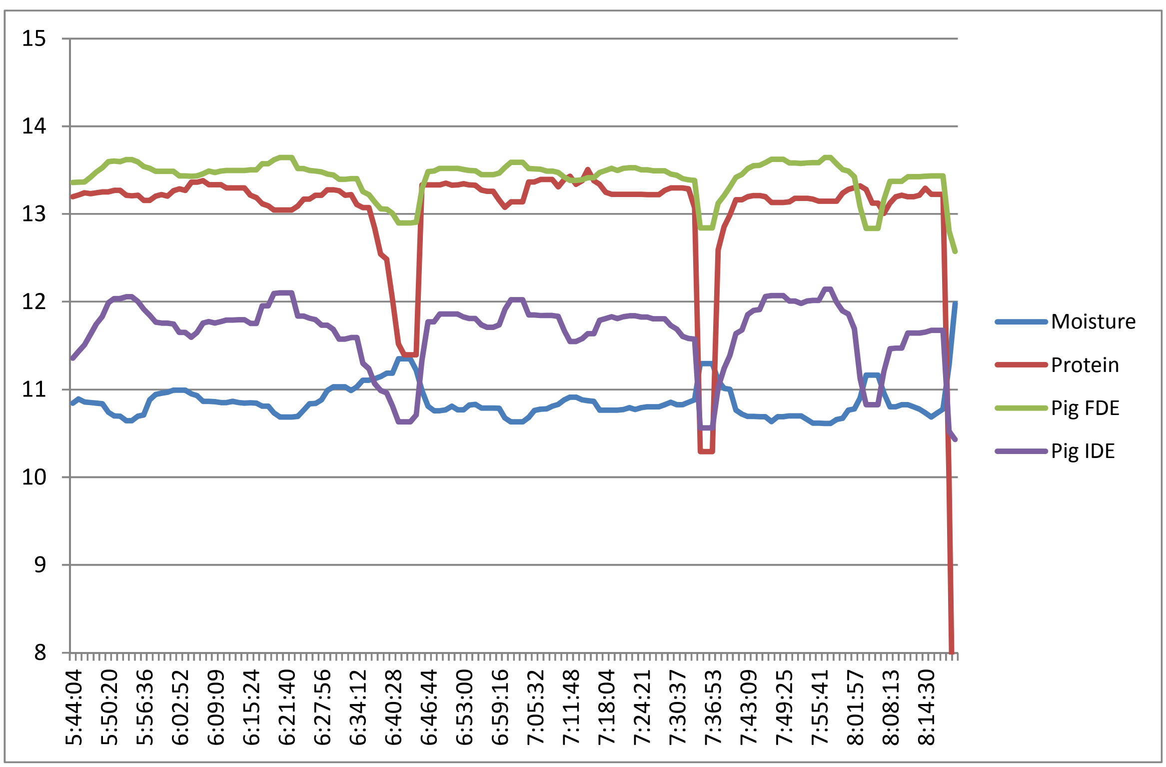


Figure 3 Wheat 2hours 37minutes 3rd June 2010



4. Application of Research

Real-time inline monitoring of the cereal intake line has shown that there is significant variation in DE as well as Moisture and Protein. Ultimately to achieve greater feed efficiencies feed would be produced at a consistent DE content. This can only be done through continual reactive adjustment within the feed milling process. The transfer rate of the cereal tube at Murray Bridge is rated at around 20MT/hour. Typically in a 3 tonne mix of pig feed there is approximately 1MT of Wheat. By averaging the results from the two 2hr Wheat runs every 3 minutes we can gain a average DE for every 1MT of Wheat (See Figures 4 and 5, “FDE React”). By applying a standard requirement of 13.5MJ/kg FDE (See Figures 4 and 5, “Mill Set”) with a range limited to 0.5MJ/kg, it can be seen that multiple 1MT batches through the span of the 2 hour run would need correction (note bars in “red”). Considering a cost of 1MJ/kg of cereal DE content between$15 to $20/MT, adding Wheat at a rate of 60% to the diet, these out of spec 1MT batches represent finished feed value variations of around $4 to $6/MT on Wheat alone.

Figure 4 Wheat 2hours 26minutes 31st March 2010, 1MT Batch Average, 13.5MJ/kg Set Standard, Range 0.5MJ/kg.

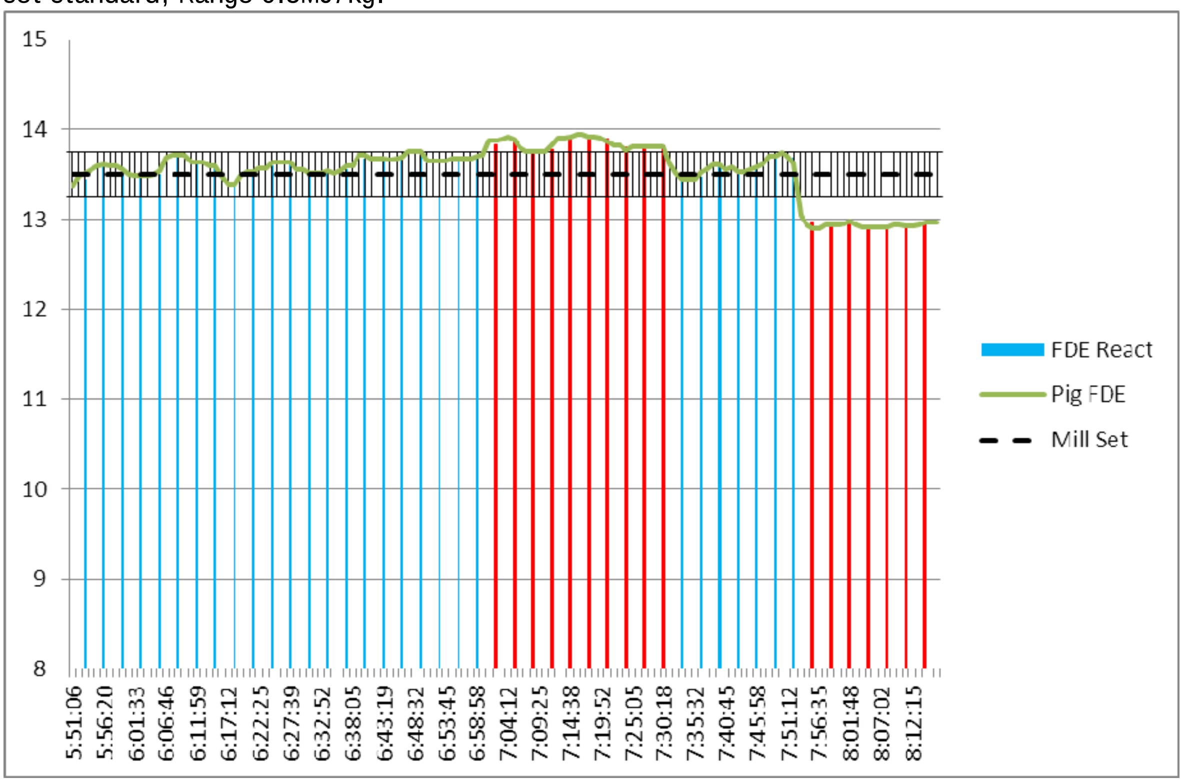
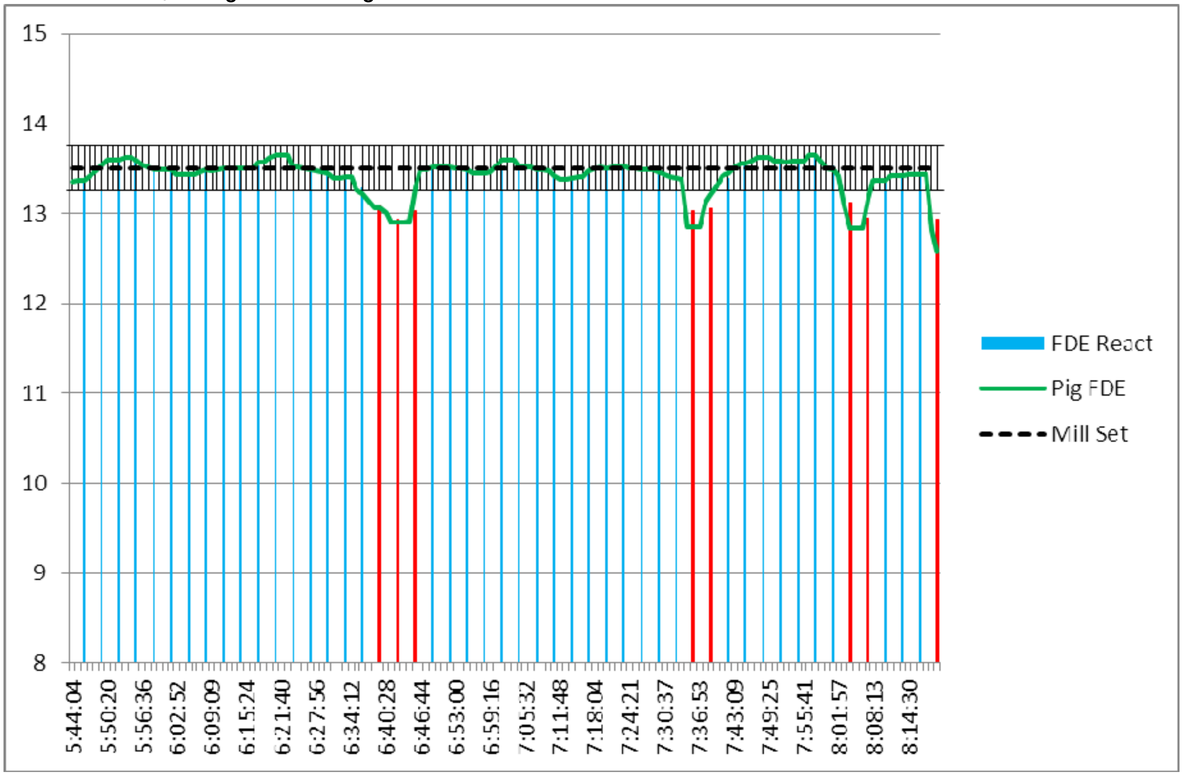


Figure 3 Wheat 2hours 37minutes 3rd June 2010, 1MT Batch Average, 13.5MJ/kg Set Standard, Range 0.5MJ/kg.



By using real-time inline NIRS there are a number of ways a mill can manage the variations in cereal. Each load can be analysed at intake and segregated to maintain an average for each storage silo. Most mills however do not have enough storage capacity or room to provide storage capacity to achieve this. Alternatively the milled cereal could be segregated into smaller batch bins post hammer mill to maintain an average. Once more most mills do not have space and this would also require significant re-engineering. Ideally all dry ingredients would run past an inline NIRS immediately before the mixer. This would allow the individual ingredients to be analysed and the formula adjusted to accommodate any variations. This would however require a DE calibration based on milled cereal.

The concept of changing formulas “on the fly” was discussed with two prominent mill control companies, Norvidan and Gordyn & Palmer. Both agreed that this was very possible with control software and could not see any real issue.

5. Conclusion

Inline real-time NIRS analysis of a typical mill cereal intake line has confirmed there is considerable variation both across and within batches of cereal typically used in Pig diets. It is possible that handling and transport causes separation within cereal batches with heavier cereals migrating to the bottom and lighter cereals and screenings etc. being pushed to the top. This would explain why periodic pulses of out of spec material were detected by the NIR-Online® system. The ultimate way for a mill to address and adjusting for all across and within batch variations would be to analyse the milled cereal pre mixer with an inline NIRS. This signal can then be integrated into the mill control software to vary formulations on the fly.

6. Limitations/Risks

To achieve accurate adjustment to cereal DE content in feed formulations calibrations based on milled cereal is required.

7. Recommendations

As a result of the outcomes in this study the following recommendations have been made:

1. Creation of milled cereal DE calibrations for use with inline NIRS to accommodate accurate real-time feed formulation adjustment
2. Installation of an inline NIRS system pre mixer in a feed mill to confirm a mill can operate efficiently with automated formulation adjustment.

8. References

Appendices

Appendix 1:

Wheat Year 2010 Sort.xlsx
Trit Year 2010 Sort.xlsx
Barley Year 2010 Sort.xlsx
Oats Year 2010 Sort.xlsx
Lupin Year 2010 Sort.xlsx
Peas Year 2010 Sort.xlsx
Wheat Year 2011 Sort.xlsx
Trit Year 2011 Sort.xlsx
Barley Year 2011 Sort.xlsx
Oats Year 2011 Sort.xlsx
Lupin Year 2011 Sort.xlsx
Peas Year 2011 Sort.xlsx

Appendix 2:

Wheat Feb 2010.xlsx
Wheat Mar 2010.xlsx
Wheat Apr 2010.xlsx
Wheat May 2010.xlsx
Wheat Jun 2010.xlsx
Wheat Jul 2010.xlsx
Wheat Aug 2010.xlsx
Wheat Sep 2010.xlsx
Wheat Oct 2010.xlsx
Wheat Nov 2010.xlsx
Wheat Dec 2010.xlsx
Wheat Jan 2011.xlsx
Wheat Feb 2011.xlsx
Wheat Mar 2011.xlsx

Barley Feb 2010.xlsx
Barley Mar 2010.xlsx
Barley Apr 2010.xlsx
Barley May 2010.xlsx
Barley Jun 2010.xlsx
Barley Jul 2010.xlsx
Barley Aug 2010.xlsx
Barley Sep 2010.xlsx
Barley Oct 2010.xlsx
Barley Nov 2010.xlsx
Barley Dec 2010.xlsx
Barley Jan 2011.xlsx
Barley Feb 2011.xlsx
Barley Mar 2011.xlsx

Trit Feb 2010.xlsx
Trit Mar 2010.xlsx
Trit Apr 2010.xlsx
Trit May 2010.xlsx
Trit Jun 2010.xlsx
Trit Jul 2010.xlsx
Trit Aug 2010.xlsx
Trit Sep 2010.xlsx
Trit Oct 2010.xlsx
Trit Nov 2010.xlsx
Trit Dec 2010.xlsx
Trit Jan 2011.xlsx
Trit Feb 2011.xlsx
Trit Mar 2011.xlsx

Oats Feb 2010.xlsx
Oats Mar 2010.xlsx

Oats Apr 2010.xlsx
Oats May 2010.xlsx
Oats Jun 2010.xlsx
Oats Jul 2010.xlsx
Oats Aug 2010.xlsx
Oats Sep 2010.xlsx
Oats Oct 2010.xlsx
Oats Nov 2010.xlsx
Oats Dec 2010.xlsx
Oats Jan 2011.xlsx
Oats Feb 2011.xlsx
Oats Mar 2011.xlsx

Lupin Feb 2010.xlsx
Lupin Mar 2010.xlsx
Lupin Apr 2010.xlsx
Lupin May 2010.xlsx
Lupin Jun 2010.xlsx
Lupin Jul 2010.xlsx
Lupin Aug 2010.xlsx
Lupin Sep 2010.xlsx
Lupin Oct 2010.xlsx
Lupin Nov 2010.xlsx
Lupin Dec 2010.xlsx
Lupin Jan 2011.xlsx
Lupin Feb 2011.xlsx
Lupin Mar 2011.xlsx

Peas Feb 2010.xlsx
Peas Mar 2010.xlsx
Peas Apr 2010.xlsx
Peas May 2010.xlsx
Peas Jun 2010.xlsx
Peas Jul 2010.xlsx
Peas Aug 2010.xlsx
Peas Sep 2010.xlsx
Peas Oct 2010.xlsx
Peas Nov 2010.xlsx
Peas Dec 2010.xlsx
Peas Jan 2011.xlsx
Peas Feb 2011.xlsx
Peas Mar 2011.xlsx

Appendix 3:

March 2010 Wheat M-P-IDE-FDE.xlsx
June 2010 Wheat M-P-IDE-FDE.xlsx