final report

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Distinguishing lamb from hogget

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Abstract

Industry currently relies on dentition at slaughter as the sole grading tool for differentiating lamb from hogget and mutton. However, the sheep meat industry currently has no objective tool to distinguish lamb from hogget and mutton carcasses after the head is removed at processing. DPI Victoria had previously independently developed an application using multi wavelength spectroscopy to classify lamb, hogget and mutton on the basis of the spectral characteristics of nominated reference bones in the carcass associated with bone ossification status. The Australian Meat Processor Corporation in collaboration with Meat & Livestock Australia agreed to fund a study to validate the accuracy of multi wavelength spectroscopy to distinguish lamb from hogget and mutton carcasses after head removal.

The study was conducted on 1527 ovine carcasses (357 mutton, 269 hoggets and 901 lambs) processed at a commercial plant. An overall classification accuracy of 91% was achieved for the 1527 carcasses measured. The classification accuracy's for specific age classes were 92.1%, 85.5% and 92.4% respectively for lambs, hoggets and mutton. The classification accuracy's reported are for one measurement per carcass at a chain speed of 5.5 carcasses per minute. Collecting two or more measurements per carcass, which would be possible in an "off chain" location, would improve the instruments classification accuracy to the desired target of at least 95%. The results support the use of multi wavelength spectroscopy to provide an objective rapid tool the sheep meat industry could use to monitor and regulate the truth in labelling of lamb carcasses either on or downstream of the kill floor

Executive Summary

Industry currently relies on dentition at slaughter as the sole grading tool for differentiating lamb from hogget and mutton. However, the sheep meat industry currently has no objective tool to distinguish lamb from hogget and mutton carcasses after the head is removed at processing. This has led to claims of abuse within the industry of hogget and/or mutton being branded as lamb. Regulatory authorities are powerless to prosecute offending operators without a reliable objective method to distinguish the age class of ovine carcasses post slaughter. DPI Victoria had previously independently developed an application using multi wavelength spectroscopy to classify lamb, hogget and mutton on the basis of the spectral characteristics of nominated reference bones in the carcass associated with bone ossification status. The Australian Meat Processor Corporation in collaboration with Meat & Livestock Australia agreed to fund a study to validate the accuracy of multi wavelength spectroscopy to distinguish lamb from hogget and mutton carcasses after head removal.

The objectives of the study were to identify and test a customised spectrometer “prototype” that measures the wavelengths of importance to classifying lamb from hogget and mutton. A second objective was at chain speed test the accuracy of the “prototype” in classifying lamb, hogget and mutton from the processed spectral data from each carcass using DPI predictive algorithms

The study was conducted on 1527 ovine carcasses (357 mutton, 269 hoggets and 901 lambs) processed at a commercial plant. A Lab Spec Pro multi wavelength (350 to 1800nm) spectrometer manufactured by Analytical Spectrometer Devices USA was selected for the study. The spectrometer was selected on the basis of a number of specified performance criteria including portability, to ensure it had the capability to be used either on or downstream of the processing plant ie at retail or food service locations. Spectral measurements were collected on the rib bone of carcasses as they exited the kill floor to the chillers at the plant’s operating chain speed of 5.5 head per minute.

The results found that the instrument achieved an overall classification accuracy of 91% for the 1527 carcasses measured. The classification accuracy’s for specific age classes were 92.1%, 85.5% and 92.4% respectively for lambs, hoggets and mutton. The spectral wavelengths identified as important in distinguishing between the 3 age classes were associated with bone colour, moisture content and inorganic chemical composition. The hogget class was understandably the most difficult class to predict with 14.5% of hogget carcasses misclassified. The prediction model had a tendency to underestimate the “true” age category of the hogget carcasses. Of the 14.5% of hogget classes that were misclassified, the majority (69%) were misclassified as lambs and the remainder (31%) were misclassified as mutton. The classification accuracy’s reported are for one measurement taken per carcass. Collecting two or more measurements per carcass, which would be possible in an “off chain” location, would improve the instruments classification accuracy to the desired target of at least 95%.

The results support the use of multi wavelength spectroscopy to provide an objective rapid tool that the sheep meat industry could use to monitor and regulate the truth in labelling of lamb carcasses. Whilst the project has validated both the operational capability and accuracy of the ASD Lab Spec Pro spectrometer to perform this application it was beyond the scope of this project to develop a fully customised instrument with dedicated software to fully automate the classification process. Additional investment by the company who commercialises the technology will be required to

achieve such an outcome. The application developed has been validated for hot carcasses and it is expected that it is also equally applicable for cold carcasses subject to checking the spectral wavelengths of importance are not affected by temperature. If so, minor changes to the predictive algorithms underpinning the classification process will be required to classify cold carcasses accurately. As with any spectroscopy based instruments their successful application does require close attention and adherence to standard operating protocols. This is particularly important in an industrial meat plant environment if the technology is to be successfully implemented.

Contents

1 Background

1.1 Background -

Near infrared spectroscopy (NIR) is a fast, environmentally friendly analytical method that has gained widespread acceptance in recent years. Multi-wavelength spectroscopy (MWS) is an expansion from NIR in that it collects spectra across a wider range of spectral wavelengths to the near infrared region. Depending on the chemical constituent of interest MWS collects spectra in one or more of the ultra-violet, visible or near infrared wavelength sectors. The meat industry has used NIR (near infrared spectroscopy) in the laboratory for routine fat and protein determinations where its precision and accuracy are fully equal to the wet chemical methods it has replaced. The advantages of NIR include:

- it gives faster results at a reduced cost,
- it is non destructive and requires no sample preparation, solvents or reagents,
- several NIR calibrations may also be used simultaneously on a single sample to give rapid, accurate multiple constituent analysis.

Application of NIR to "on line" uses in the meat industry has lagged behind other food based industries. NIR is widely used in the food industry to measure and importantly pay suppliers on the quality attributes of their products. Grain growers are paid on NIR estimates of the protein content of their grain. Similarly, sugarcane farmers are paid on NIR estimates of the sugar content of their cane.

Published reports indicate a variety of potential commercial applications aimed at enhancing the red meat industry's commercial competitiveness and its ability to improve the consistency of its products to consumers. Downey and Beauchene (1997) reported NIR technology could discriminate between fresh and frozen/thawed beef. Consequently, NIR could be used by food regulatory bodies to guarantee the authenticity of labelling of fresh versus frozen beef. Moss et al. (2000) reported that NIR could be used to discriminate between irradiated and non-irradiated pork with a high degree of accuracy. Forrest et al. (2000) showed that NIR spectra collected in pork carcasses 30 minutes post exsanguination were highly correlated with 24 hr drip loss (r=0.84, RMSEP of 1.8% drip loss). Anderson et al. (1999) investigated whether pH in pork could be measured spectroscopically in reflectance using the visual and near infrared regions. A moderate correlation (r=0.791 RMSEP 0.077 pH units) was reported between NIR predicted pH and measured pH using a standard glass electrode pH meter for two pork muscles measured 24 hours post exsanguination. Josell et al (2000) reported NIR could be used to measure the glycolytic potential of pork immediately post slaughter and in doing so differentiate between RN – and RN+ phenotype pigs. More recently NIR has been reported to have been successfully used to predict the physical traits of meat such as Warner Bratzler shear force values (ASD Inc pers comm.).

Recent research conducted by PIR Vic has developed an objective method for differentiating lamb from hogget and mutton using multi wavelength spectroscopy. Substantial changes occur in the organic and inorganic chemical constituents of bone with ossification. Multi wavelength spectroscopy appears to have the capability to measure these chemical changes associated with bone ossification. Baud et al found that multi-wavelength spectra collected on the rib bones of lamb, hogget and mutton carcasses 30 minutes post exsanguination were highly correlated with Ausmeat dentition age categories (R_2=0.93, RMSEP of 0.19 age category units).

2 Project Objectives -

2.1 Project Objectives

1. To identify and test a customised spectrometer “prototype” that measures the spectral wavelengths of importance to classifying lamb, hogget and mutton.
2. At chain speed test the accuracy of the “prototype” in classifying lamb, hogget and mutton from the processed spectral data collected from each carcass using DPI’s predictive algorithms.

3 Methodology -

3.1 Animals

The study was conducted on 1527 sheep carcasses (357 mutton, 269 hoggets and 901 lambs) processed at a G&V Hardwicks Pty Ltd Kyneton. This exceeded the original target of 450 carcasses (150 lambs, 150 hoggets and 150 mutton) to be measured at 2 plants nominated in the project contract. A lack of availability of hoggets prevented the study being extended to a second plant. The carcasses measured were representative of the plants scheduled production for that day.

3.2 Spectrometer

A Lab Spec Pro spectrometer manufactured by Analytical Spectral Devices Pty Ltd USA was purchased for the study. It was selected on the basis of it best meeting the following design specifications. In addition the company agreed to provide substantial in-kind support for the project.

Wavelength range: Capability to measure in the 350 to 1800nm spectral wavelength ranges ie UV, visible and NIR regions.
Portable: The spectrometer is portable giving industry the flexibility to use it either at the processing plant or further downstream in the marketing chain ie wholesalers, retail butchers, food service.
Industrially robust: The analyser could withstand the rigours of a meat processing environment including exposure to a high moisture industrial environment.
Operational speed: It must also be able to operate at chain speed (up to 10 carcasses per minute).

Budget constraints prevented the development of a dedicated instrument for this application. Consequently the operator interface of the instrument requires significant enhancement to ensure it is both operator and ergonomically friendly. The current instrument also requires considerable operator training to ensure its correct use.

3.3 Measurements

Plant measurement point The instrument collected spectra on individual carcases as they exited the kill floor to the chillers. This site was selected on the basis that it would test the instruments operational performance at commercial chain speed (5.5 carcasses per minute), there was suitable access to the carcasses compared to when loaded in the chiller and the carcasses could be measured at a consistent temperature.

Spectral measurements Spectral measurements were collected on the left side of each carcass at the 8th rib 2 to 3 cm from the spine. Chain speed constraints permitted only one measurement to be taken per carcass at the nominated rib site. The instrument was set to collect 15 scans per measurement using an optical fibre probe. It operated in reflectance mode.

Carcass dentition scores All carcasses were individually mouthed and their dentition score recorded. The carcasses fitted into one of 3 dentition categories described below

1. 0 permanent teeth (within this dentition class young lambs (unshorn sucker lambs) were distinguished from older (predominantly shorn) lambs
2. 2 permanent teeth partially or fully erupted (hoggets)
3. 4 or more permanent teeth erupted (mutton)

3.4 Statistical Analysis

The raw reflectance spectra were subjected to a first derivative transformation using the standard Norris method from the Unscrambler software package (settings: Segment size: 5, Difference: 4). Four indicator columns were added to the dataset:

- Lamb-HM: a variable that is set to 1 if the spectrum is from a young or older lamb and 0 (nought) if the spectrum is from either a hogget or an older animal.
- Ylamb: a variable that is set to 1 if the spectrum is from a young lamb otherwise nought.
- Olamb: a variable that is set to 1 if the spectrum is from an older lamb otherwise nought.
- Hogget: a variable that is set to 1 if the spectrum is from a hogget otherwise nought.
- Mutton: a variable that is set to 1 if the spectrum is from a full grown animal otherwise nought.

Using the Unscrambler software package PLS1 models were developed for predicting each of these 5 variables. In this way the set of 5 predictions from each spectrum can be looked upon as a sort of fingerprint of the carcass that can be used to differentiate between age groups.

A combination of predictions such as:
Lamb-HM, Ylamb, Olamb, Hogget, Mutton = 0.87, 0.15, 0.85, 0.23, -0.02 would with great probability belong to the Old lamb group whereas the combination
Lamb-HM, Ylamb, Olamb, Hogget, Mutton = 0.07, 0.15, 0.35, 0.23, 0.84 would be part of the mutton group.

In order to make these assignments automatically the prediction results were sent through a Kohonen map which is a type of neural network that is self organizing. Even though the Kohonen network needs to be trained the algorithm is unsupervised. In other words - unlike the PLS algorithm there is no chance of over-fitting.

Figure 1 shows a 6x6 square Kohonen Map with the 1527 classifications spread out over the 36 classes the network was set up to accommodate. Here group 0 are young lamb, group 1 are older lamb, 2 are hoggets and 3 are mutton.

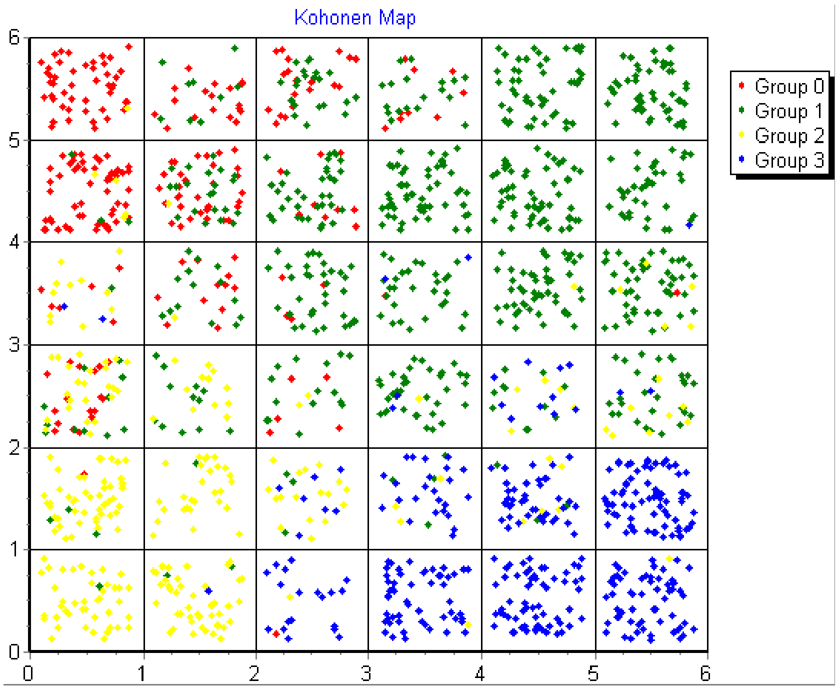

Figure 1: Classification result using a Kohonen classifier

The Kohonen network identifies which inputs (sets of 5 predictions from the PLS models) it perceives as typical for the 4 categories.

Figures 2 to 5 show the typical signatures for the 4 different age groups.

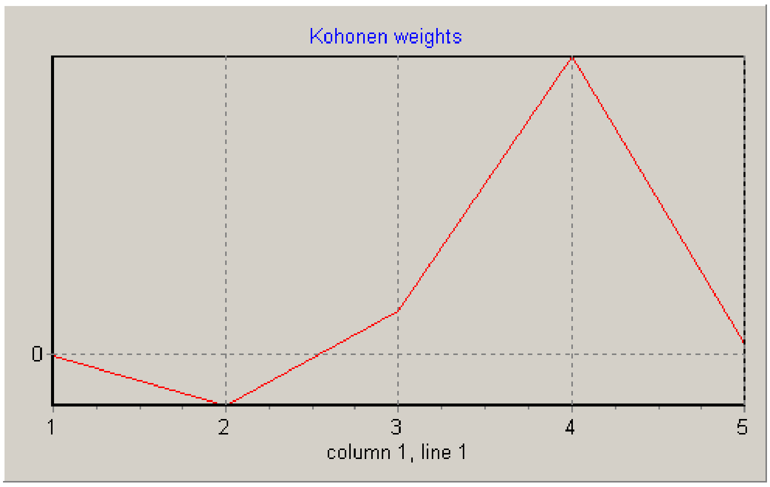

Figure 2: The typical signature for a hogget (0,0,0,1,0)

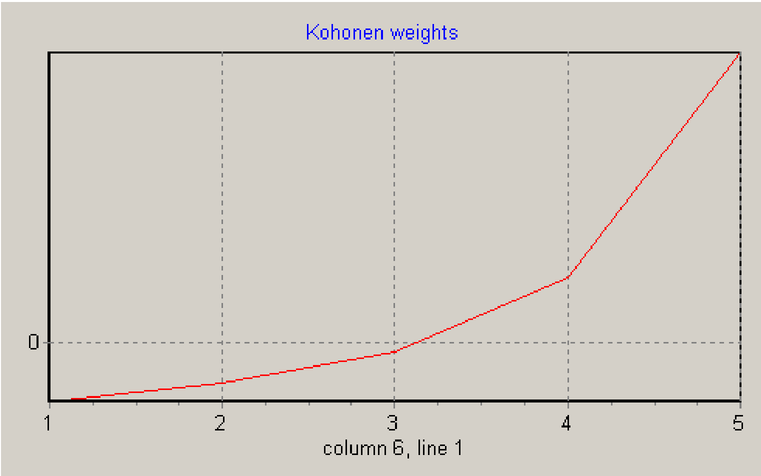

Figure 3: The typical signature for mutton (0,0,0,0,1)

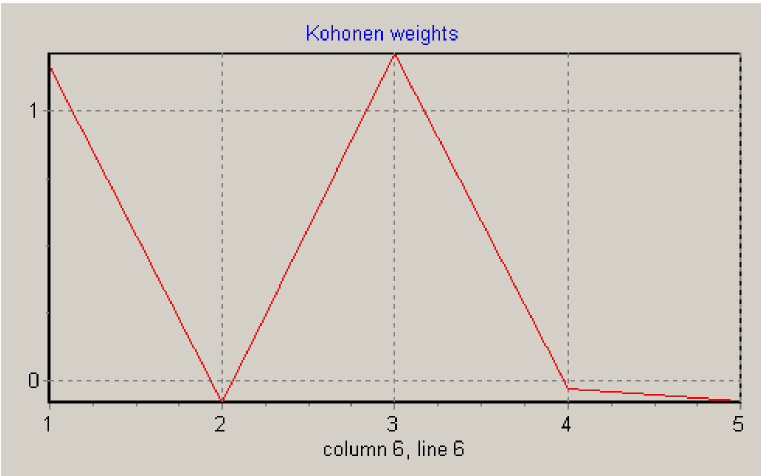

Figure 4: The typical signature for an older lamb (1,0,1,0,0)

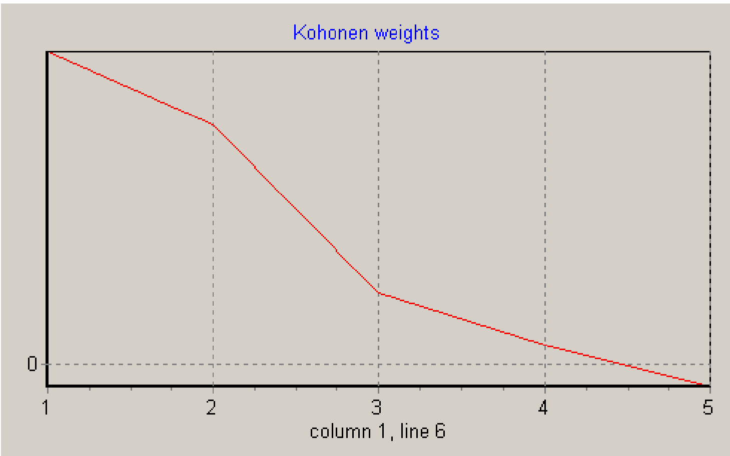

Figure 5: The typical signature for a young lamb (1,1,0,0,0)

The columns and lines noted in figures 2 to 5 refer to the columns and lines in figure 1. The Kohonen algorithm automatically places the perfect examples of each of the 4 groups as far apart on the map as possible. Spectra from carcasses that do not conform to a single group will be placed on the map in such a way that their distance from a group is inversely proportional to their probability of belonging to this group.

A single location in the Kohonen map (one of the 36 cells in figure 1) is assigned to a certain age group if it has a majority of samples belonging to that group in it (normalized to the total number of individuals in each group).

Mathematically it is a straight forward procedure to use a trained Kohonen classifier. All it requires is to calculate the Euclidian distance between a new test vector (from the 5 PLS models) and the template vector assigned to each cell in the trained Kohonen map.

4 Results and Discussion -

4.1 Classification accuracy

Table 1 summarises the results on the classification accuracy of the instrument. An overall classification accuracy of 91% was achieved when assessed for all categories. The targeted classification accuracy was 95%. The classification accuracy achieved for each specific sheep class was 92.1%, 85.5% and 92.4% for lambs, hoggets and mutton respectively This classification accuracy is based on one measurement taken per carcass.

Table 1 Classification accuracy of the ASD spectrometer to distinguish lamb, hogget and mutton

Class	No. head scanned	No. head correctly classified	Classification accuracy %
Lamb	901	830	92.1
Hogget	269	230	85.5
Muttton	357	330	92.4
Total	1527	1390	91
Milestone targets	450		95

The spectral wavelengths identified as important in distinguishing between the 3 age classes were associated with bone colour, moisture content and inorganic chemical composition. The hogget class is understandably the most difficult class to predict accurately with 14.5% of hogget carcasses misclassified. The prediction model had a tendency to underestimate the “true” age category of the hogget carcasses. Of the 14.5% of hogget classes that were misclassified, the majority (69%) were misclassified as lambs and the remainder (31%) were misclassified as mutton (Table 2).

Table 2 Actual versus predicted classifications of the 1527 ovine carcasses measured

		Predicted Class			Total true class
		Lamb	Hogget	Mutton	
True Class	Lamb	830	64	7	901
	Hogget	27	230	12	269
	Mutton	17	10	330	357
	Total predicted class	874	304	349	1527

Collecting two or more measurements per carcass substantially improves the instrument's classification accuracy. Multiple measurements reduce the prediction classification error by a factor of the square root of n where n is the number of measurements taken. Multiple measurements also improves the probability of the instrument classification being correct to over 99% for all classes.

Whilst the confidence limits of the current prediction model are high based on a large number of samples (1527) the predictive accuracy is also founded on the assumption that these samples are representative of the general sheep population. As is normal practice with other spectroscopic applications the prediction model should be reviewed regularly as more data becomes available to broaden the range of samples that are used to generate the prediction model and ensure this assumption is correct

Table 3 Error and confidence estimates of the instrument classifications in relation to the number of measurements taken per carcass

	No. of measurements per carcass	Predicted Class		
		Lamb	Hogget	Mutton
Estimated error of prediction	1	0.51 classification units		
	2	0.36 classification units		
Probability of the instrument being correct	1	92.1%	85.5%	92.4%
	2	99.4%	97.9%	99.4%

5 Success in Achieving Objectives -

5.1 Success in Achieving Objectives –

The project has successfully met its stated objectives. The ASD Lab Spec Pro was able to measure the spectral wavelengths of importance to classifying lamb, hogget and mutton when operated at chain speed. An overall accuracy of 91% was achieved in classifying lamb, hogget and mutton from the processed spectral data collected from each carcass using one measurement per carcass. It is considered that the project target of 95% classification accuracy could be achieved if multiple measurements were taken.

6 Impact on Meat and Livestock Industry –

6.1 Impact on Meat and Livestock Industry

The results support the application of multi wavelength spectroscopy as a truth in labelling tool for the sheep industry. It provides an objective tool that industry can use to distinguish lamb from hogget and mutton in processed carcasses after head removal. In the current regulated environment the technology would provide regulatory authorities with the capability to objectively audit industry compliance to lamb branding. Currently there is no other alternative technology available that can be reliably used after head removal. The technology would still have an application in a de-regulated environment should state meat authorities relinquish their regulatory role in ensuring the authenticity of the lamb brand. The technology would enable retailers, food service companies and consumers the ability to seek independent verification on the age class of the product they have purchased if compulsory branding of lamb carcasses were discontinued.

7 Conclusions and Recommendations -

7.1 Conclusions and Recommendations

The results support the use of multi wavelength spectroscopy to provide an objective rapid tool that the sheep meat industry could use to monitor and regulate the truth in labelling of lamb carcasses either on or downstream of the kill floor. Whilst the project has validated both the operational capability and accuracy of the ASD Lab Spec Pro spectrometer to perform this application it was beyond the scope of this project to develop a fully customised instrument with dedicated software to fully automate the classification process. Additional investment will be required to commercialise the technology. The key recommendations to achieve such an outcome are as follows:

Key Recommendations

1. Multi wavelength spectroscopy provides an objective rapid and accurate technology that the sheep meat industry could use to more reliably monitor regulate the truth in labelling of lamb carcasses after head removal.
2. At least two measurements per carcass should be taken to optimise the instrument prediction accuracy.
3. The application has been validated for hot carcasses. It is expected it would be equally applicable for cold carcasses but may require some minor changes to the predictive algorithms if there are temperature effects on the spectral bands of importance to ensure a high level of accuracy.
4. As with any spectroscopy based applications their success requires close attention and adherence to standard operating protocols. This is particularly important in an industrial meat plant environment.
5. The instrument requires a simplified operator interface and supporting customised software to automate the conversion of the spectral information to an actual ovine classification category. Currently this is done manually.
6. As is normal practice with other spectroscopic applications the prediction model should be reviewed regularly as more data becomes available to ensure the data set used to develop the prediction model(s) are representative of the general sheep population.

7.

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