final report

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Objective Beef Hide Grading

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Abstract

There is currently a need in industry for an automated, objective grading solution for cattle hides. This project aimed to investigate this application further and assess its sensing requirements, particularly the applicability of hyperspectral imaging technology. Site visits to two processors were organised to understand the needs of the industry. Based on these site visits, a trial was then organised whereby one of the processors sent a number of hide samples to SCOTT's facility in Melbourne. This included multiple examples of the different types of defects experienced, as well as some examples of defect-free hide which may trick an automated system. The samples were scanned with a hyperspectral camera and analysed. While demonstrating some promise as a sensing technology for this application, it was found that the spectral information of the defects was very similar to that of clean hide. Due to these observations, it is believed that this is due to the chemical treatment of the hide homogenising the hyperspectral signature across it. This suggested that, while hyperspectral imaging may still provide a sensing solution, it may not be ideal. A further trial was conducted using high resolution 3D scanning and greyscale image analysis. The results of these trials suggest that a wet-blue / sammied hide inspection system is possible utilising 3D and colour imaging technology for sensing.

Executive Summary

Cattle hides are currently subjectively graded according to brands (size and position), open horn marks, healed scratches, such as barbed wire marks, insect damage, flay cuts, bacterial damage from poor cure or delays in processors, growth wrinkles and thickness and size of hide. On the grading table in a tannery grades can range in price from $10/m^2 for reject leather to $21.50/m^2 for first grade leather. Between these extremes, there is a graduated scale of price. All of this pricing is subjectively determined.

There is currently a need in industry to be able to achieve grading of carcase hides in an objective manner. This project is the first stage in understanding how hyperspectral imaging (a technology jointly invested into by Scott and MLA in other project areas) or other vision and sensing technologies may be able to objective determine and measure some of the defects known to cause hide downgrades.

The first task of the project involved consulting with, and visiting, two processors in order to further understand the needs of the industry. These processors operated at both ends of the hide supply chain. Processor A produces green hides which are sent off-site for treatment before going overseas for grading and processing. They were unsure of exactly how they were getting graded and were in the process of having this defined. Processor B operates its own tannery and processes hides through to the sammied state for sale. An operator visually grades hides as they feed them into the sammying machine. A number of different defect types are checked for and the hide is graded based on an estimate of the total saleable area of the hide (ie the total surface area free of defects).

Processor B supplied a number of samples for each of the different defects encountered. A number of samples of clean hide were also sent which possessed characteristics (e.g. uneven dying) which aren’t defects but may trick an automated system. These samples were scanned in the sammied state before being soaked in water and re-scanned to simulate scanning them in their wet-blue state.

A hyperspectral camera mounted on a conveyor was used to perform the trials. While a number of defects looked promising in their ability to be discriminated, it was found that the spectral information for the defects was largely unaltered from that of ‘clean’ hide. Based on these observations, it is believed that this is due to the chemical treatment of the hides homogenising the chemical signature throughout the sample, including the defects. Because of this, it is thought that hyperspectral technology, while plausible for the grading of wet-blue or sammied hides, may not be ideal.

A further trial was then conducted using a high-resolution 3D profiler which also outputs a greyscale image. The results of these trials were promising and it is felt that high-resolution 3D coupled with colour imaging would be able to deliver an objective wet-blue/sammied hide grading system.

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1 Background

1.1 Purpose

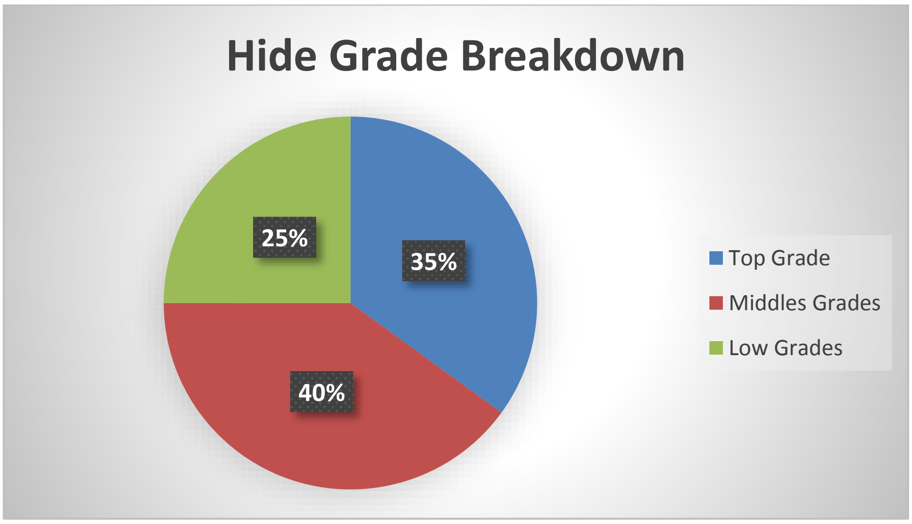
This project is the first stage in understanding how hyperspectral imaging (a technology jointly invested into by Scott and MLA in other project areas) or other vision and sensing technologies may be able to objective determine and measure some of the defects known to cause hide downgrades.

This project will collect, scan, and analyse a range of hides exhibiting various defects using HyperSpectral Imaging (HSI) to determine whether defects can be objectively identified and classified, and potentially offer objective grading of hides.

Cattle hides are currently subjectively graded according to brands (size and position), open horn marks, healed scratches, such as barbed wire marks, insect damage, flay cuts, bacterial damage from poor cure or delays in processors, growth wrinkles and thickness and size of hide.

On the grading table in a tannery grades can range in price from \$10/m^2 for reject leather to \$21.50/m^2 for first grade leather. Between these extremes, there is a graduated scale of price. All of this pricing is subjectively determined.

Reject leathers are virtually a loss leather sold at some 60% of cost price. Top grade leathers with acceptable scratch damage make up around 35% of production, middle grades around 40% and low grades 25% of production.



Any improvement in hide quality will automatically shift these grades to the top, and thus create a more economically viable product, which is able to attract a premium if quality can be guaranteed. This is proven in New Zealand where beef hides are free from brands and Europe where hides are free from scratch marks.

If quality improvements are made, it would take some time for this to be reflected in price, however, it must be clear that a premium would be paid if quality were lifted with a concentrated program that effected changes from the farm level. If HSI has the ability to measure hide damage then the Australian industry would have a technology that could automatically and objectively collate (and value) the cost of hide defects to the Australian beef supply chain and where in the supply chain the defects are caused.

A better understanding of the extent and frequency (objectively) of hide damage could enable the industry to move towards reclaiming some of the $200 million loss per year due to downgrades in the half a billion a year part of the beef supply chain business.

1.2 Significance –Hide Quality Issues State by State

Australian Herd from www.southernhide.com.au)

The Australian cattle herd is distributed over most of the continent except for the desert interior. The range of climate, topographic and pasture type is highly variable. About half the herd is on pastures north of the tropic of Capricorn. On the coastal fringes rainfall is plentiful. In the north, a monsoon weather pattern assures prodigious rainfall for the five to six summer months of the year and dry conditions during winter. Inland, where individual cattle holdings often cover thousands of hectares, climatic conditions are arid to desert, with extreme summer temperatures and sparse pasture. All these characteristics have their own unique impact on cattle hide quality.

The cattle in the southern regions graze more extensively on improved pastures in developed areas, where commonly the herds are polled or de-horned and are controlled by fences, including barbed wire fencing. In the north and in the interior the cattle herds range freely over large areas, much of it covered with bush and scrub which invariably scratch hides. The majority of cattle in the north are not polled or de-horned and so horn rakes are more common.

Cattle tick infests, to a lesser degree, all of the tropical areas, excepting the arid heartland, extending down the east coast of New South Wales. Although cattle tick is the biggest single cause of single parasitic damage to hide quality there are other varieties of parasites which, of restricted range and incident, also take a toll on hide quality.

All these factors, climate and pasture, fencing and bush, branding regulations and parasites are broadly grouped as environmental damages. Cattle are often trucked long distances in Australia from area of origin to place of slaughter. A further movement occurs from the place of slaughter to the place of hide accumulation and processing, and yet another from hide accumulation to point of shipment.

Tasmania – Free of nearly all brand marks, no cattle ticks, minimal parasite damage, generally clean grain, cattle generally de-horned or polled. Hence minimal hide defects.

Victoria – Body brands infreqent and when occurring are in the butt area (20-30% of stock), no cattle ticks, minimal parasite damage, clean grain and generally free from hide damage.

New South Wales – Branding popular, in the butt area and 40-70mm high, cattle ticks occur to a light degree, some horned stock but most dehorned or polled.

Southern Queensland – Branding is compulstory (30-65 mm) appearing anywhere on the body and often in multiple areas. Cattle tick and some other parasitic damage, particularly pin hole. Cattle is a blend of horned and dehorned.

Northern Queensland – Compulsory branding appearing anywhere on the body and frequently in mutiple series in a wide variety of sizes, but mostly large. Northern Queenslad is entirely within the tick zone and hence tick resistent breeds are common. Most herds are not dehorned and horn rake, scratch and parasite damage are common.

2 Project Objectives

At the conclusion of this project, Scott will have:

- Evaluated and demonstrated which hide defects can be objectively measured using hyperspectral imaging on the current Scott HSI camera or other vision / sensing technologies.

3 Methodology

This project was split into three milestones:

- Milestone 1:
    - Site visits were conducted to two different processors. A scope of works was completed for milestones 2 and 3.
- Milestone 2:
    - A processor supplied and shipped a number of hide samples exhibiting a range of defects to Scott Automation's Melbourne facility
    - These samples were scanned using the hyperspectral camera
- Milestone 3:
    - The samples were analysed to ascertain the suitability of using hyperspectral technology to grade hides

Two processors were engaged and site visits were conducted in order to answer these questions and develop the scope for the rest of the project.

Processor A produces green hides which are chilled and sent off-site to be treated and then exported to an overseas customer where they are processed in a tannery. The hides are graded at the tannery and payment is made. How the hides are graded is not currently known. Given their current supply chain setup, this processor would be interested primarily in grading of green hides. As they are sent to an overseas tannery though, it would be difficult to characterise and confirm defects present on green hides scanned at their plant.

Processor B operates at the other end of the supply chain spectrum. This processor possesses a tannery and hides are processed all the way through to the sammied state which are then sold. The total area covered by any defects is estimated by the grader by visual assessment. Hides are then graded based on total saleable area as well as which defects are identified. The hides are graded in a wet-blue state as some defects aren't visible to an operator once it has been sammied.

The defects identified include:

- scratches (healed and open)
- parasite damage
- brands (number and location)
- insect damage
- abattoir, mechanical or chemical damage

With their current commercial setup, this processor is only interested in grading either wet-blue or sammied hides. This site have informed that, in their case, the primary drivers are consistent, objective grading as well as offsetting the issues of labour availability and training – it takes a long time to acquire the skill of, not just identifying the defects, but then estimating resulting saleable yield at processing speed. An objective grading system would also allow more objective feedback to the producers on cattle hide issues (eg if a particular producer is consistently providing cattle with insect damage).

Processor B indicated they were able to provide a number of samples of hide demonstrating different defects for the purposes of trialling.

Proposed Scope:

Given the information acquired through the site visits, the following scope of work was defined for the project:

- Processor B to supply hide samples for testing in Melbourne. These samples would:
    - include multiple examples of each defect.
    - include some hide inconsistencies which aren't classed as defects but may 'trick' the hyperspectral camera (e.g. vein structures)
    - include samples of differently presenting 'good' hide
    - have the defect type provided with each sample
- The samples will then be scanned in Melbourne
    - The samples will arrive in the sammied state, so scans would first be of the hide in this state
    - Processor B have advised that we can 'simulate' scanning wet-blue hides by simply soaking the samples in water. Hides will thus be scanned and analysed in this state too to identify whether this affects the HSI results. If not, this would provide more flexibility for the installation of a commercial system.
- The samples will then be analysed
    - How homogenous is the signature of 'good' hide?
    - Which defects can we see?

    - Which defects are difficult to identify reliably?
    - Are there issues with false positives on the samples provided to trick the camera? If so, do they have unique signatures and can they be dealt with accordingly?
- Recommendations and specifications for a commercial hide grading system

The equipment used for the initial trials is as follows:

- Spectral camera
- Lighting
- Spectralon Calibration plate used to normalise the spectral data.
- Camera test rig

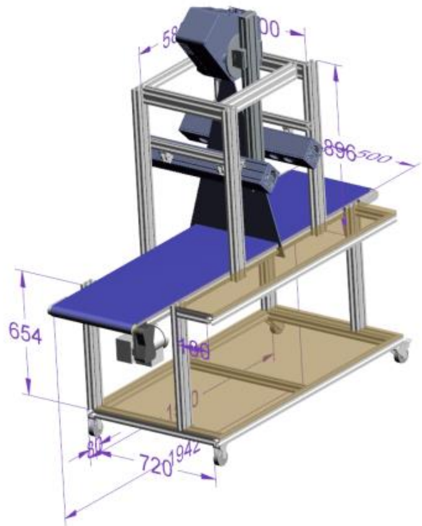


Figure 1 - Hyperspectral camera setup

The camera used was Specim AsiaFENIX with the following specifications:

- Spectral range: 380nm to 2500nm
- Spectral bands: 680
- Spatial resolution: 384px
- FOV: 32.2degrees
- Frame rate: up to 130Hz
- Minimum working distance: 850mm

The following methodology was used to conduct the experiment:

- Sammied samples were collected by a processor and delivered to the Scott Tullamarine office.
- The camera exposure and lighting settings were configured so that enough light entered the camera to capture good quality spectra while minimising the exposure time. Smaller exposure time will reduce the effect of motion blur while capturing the image from a moving target.

- A white and dark calibration image were acquired.
- Each sample was scanned individually with a constant conveyer speed. Each data cube was saved with a timestamp, sample number and defect category.
- Samples were scanned in the state that they were delivered (post-sammying, damp to the touch). The hides were then placed in water and rescanned in a wet state to simulate scanning in a wet-blue state.
- Each sample was individually analysed.
- A mean spectrum was collected using a region of interest (ROI) on undamaged portions of the hide as well as the damaged portion of the hide. The spectra were saved to separate data files with a filename being the timestamp of the original data file for traceability

The analysis of the hyperspectral data provides the following information:

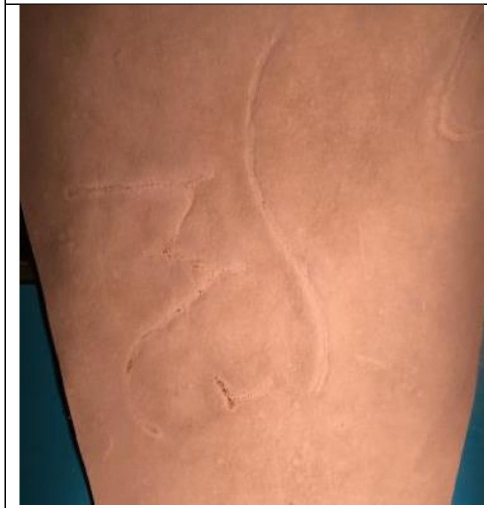
- The full spectra of acceptable hide variants and hide defects.
- An understanding of what wavelengths of light yield the best results for detecting particular defects.
- Understanding of what defects can be classified correctly and what can be misclassified.
- Understanding the limitation of the hardware used for the trials.

4 Results and Discussion

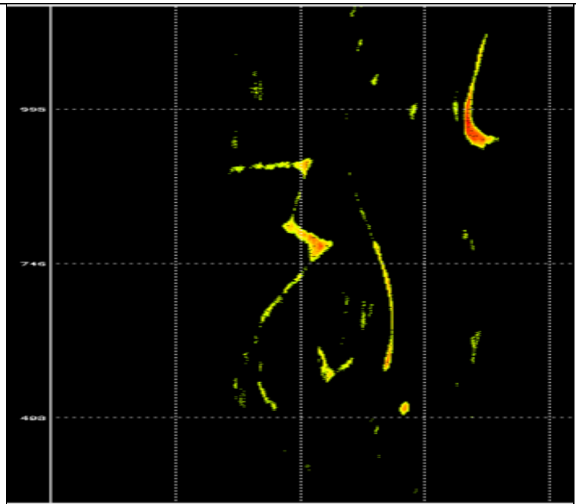
4.1 Hyperspectral Imaging

The following table is an analysis summary of all the samples provided for testing.

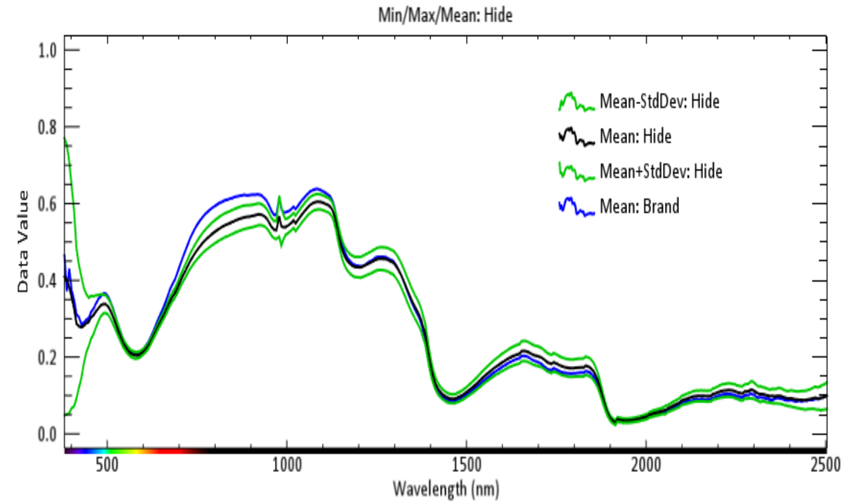
Sample 001 - Branding defect



Photograph of the defect



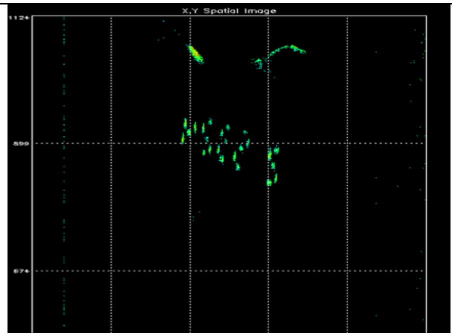
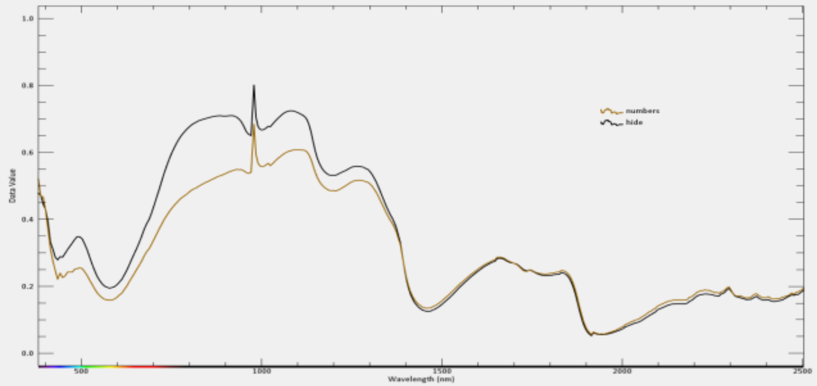
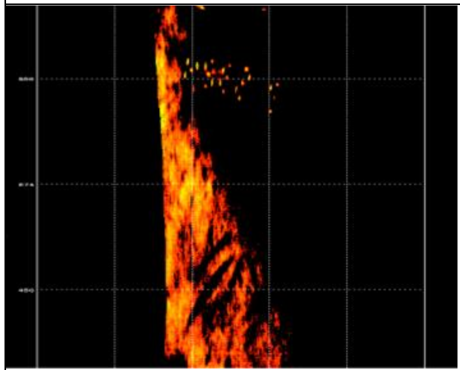
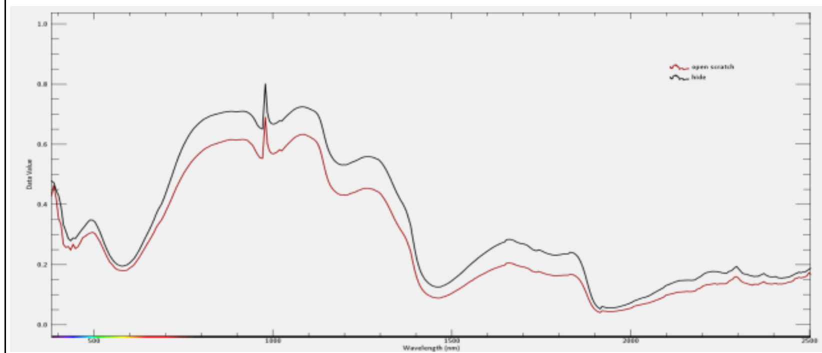
This is the best processed result of the hide. The image was generated by calculating the gradient from 580nm to 764nm then thresholding the image.

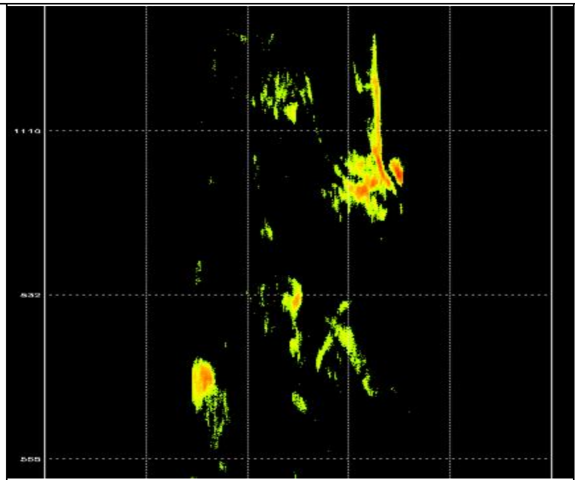
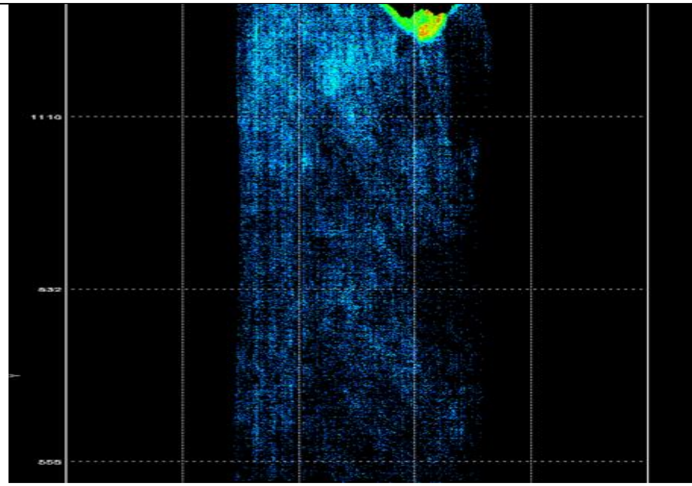


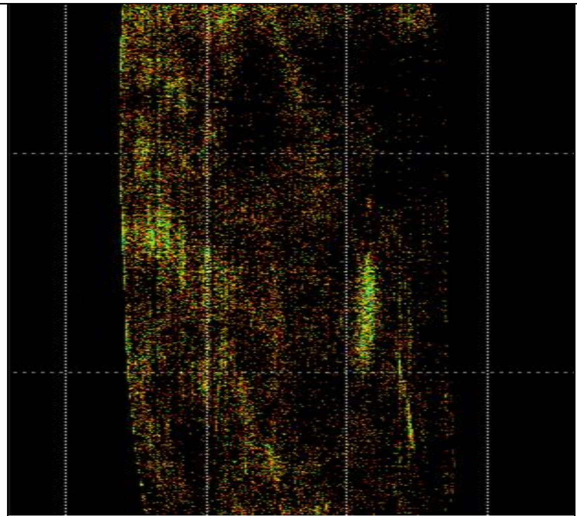
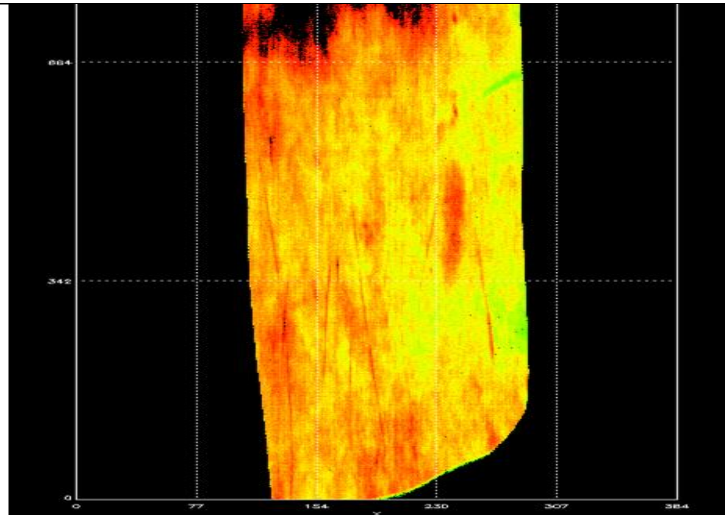
Spectra for the branding and spectra of clean hide. Note the first standard deviation illustrated by the green lines.

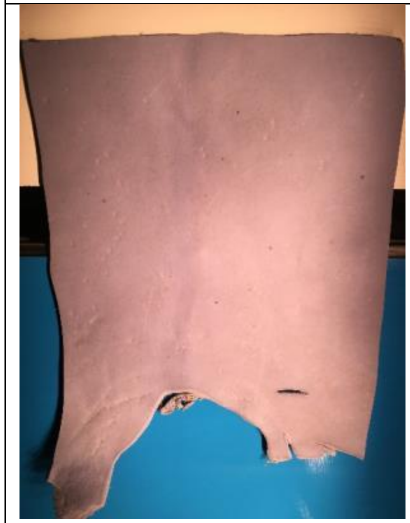
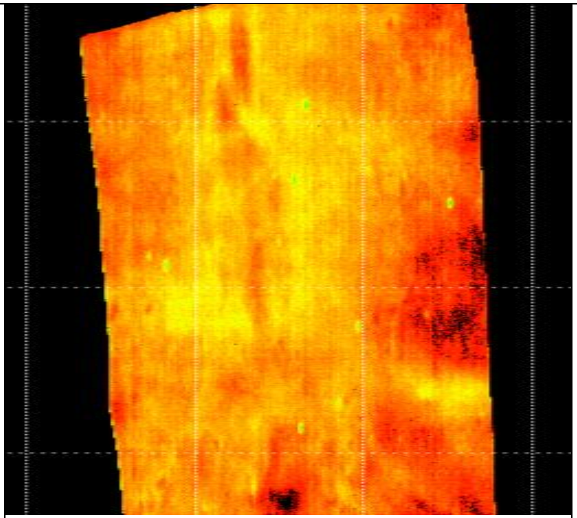
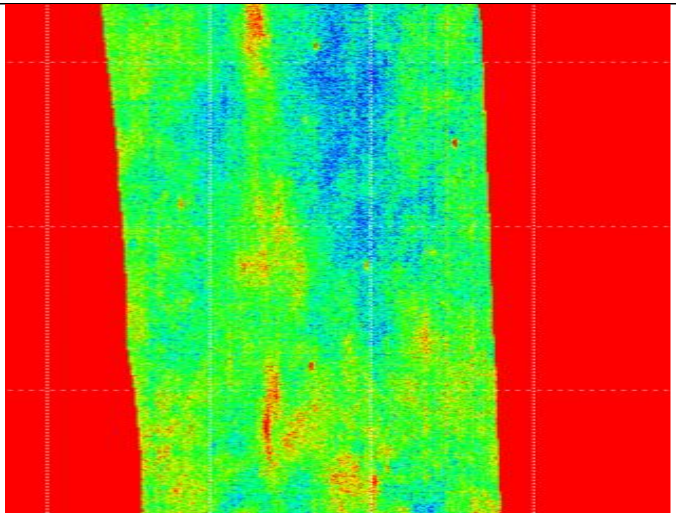
It is evident that the spectra of the branding is nearly identical to the spectra of the hide. Where the differences of the branding spectra are visible compared to the spectra of clean hide, the difference is just above one standard deviation. Therefore, confusion is possible and likely. Although we were able to extract the defect from the spectral data in this image, it may be harder to do with a lighter coloured hide.

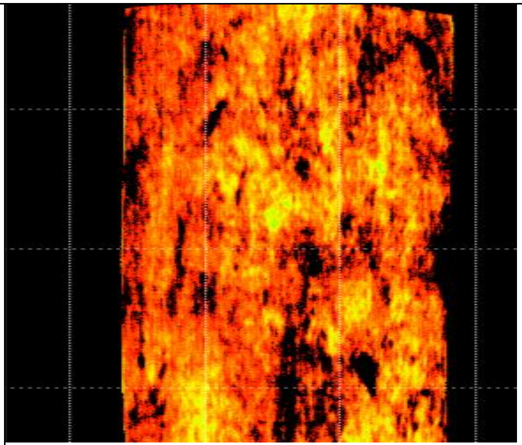
Sample 002 - Open scratch

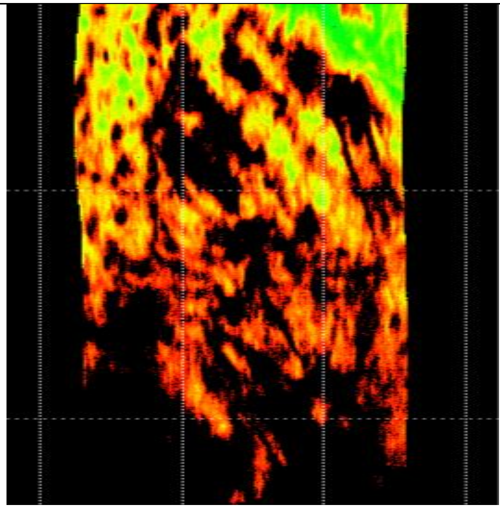
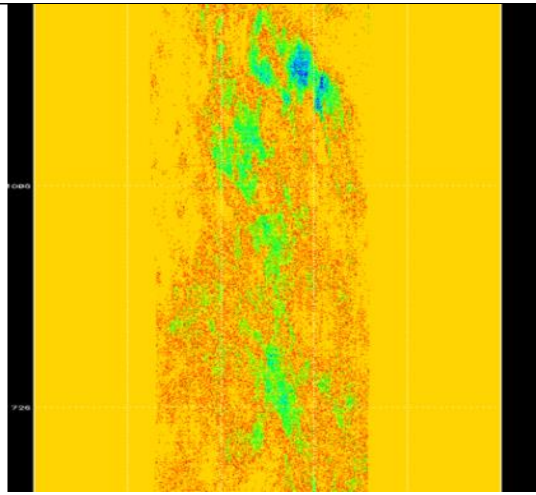
<table>
<tr>
<td rowspan="2">
Photograph of the defect</td>
<td>
This is a processed result of the hide. The image was generated by calculating the gradient from 820nm to 950nm then thresholding the image.</td>
<td>
The above spectra is of the number punch relative to the clean hides.</td>
</tr>
<tr>
<td>
This image was generated by calculating the gradient from 580nm to 768 nm.</td>
<td>
The above spectra is of scratch relative to the clean hides.</td>
</tr>
<tr>
<td colspan="3">It was extremely difficult to visualise the image of the scratch from the data captured during the trials. The most likely reason for this is the spatial resolution was too low and a combination with motion blur washed out the physical defect. The spectra indicated no unique absorption bands on the pixels that appear to be the scratch.</td>
</tr>
</table>

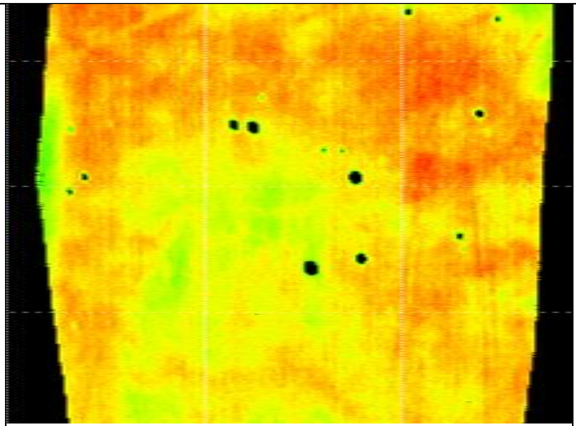
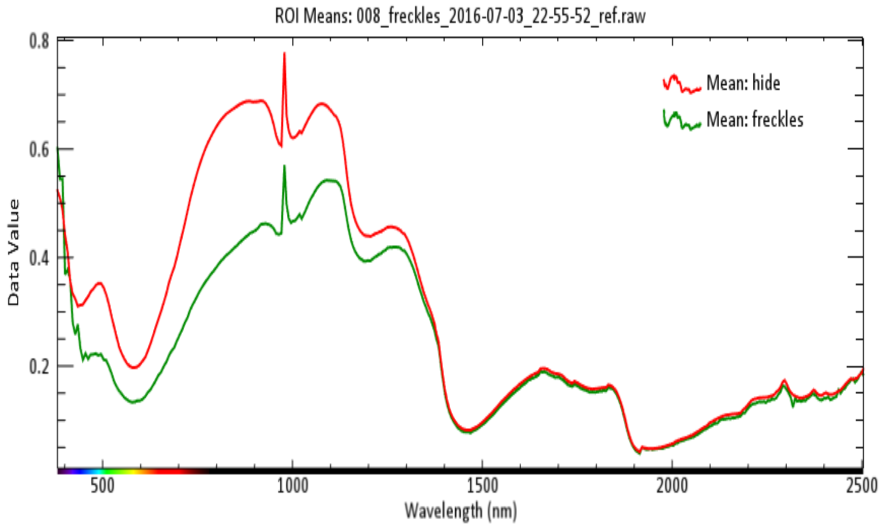
Sample 003 - Clean Hide		
 Photograph of the hide.	 Image was generated by calculating the gradient from 580nm to 764nm.	 Image was generated by calculating the gradient from 820 nm to 920nm.
The hide was analysed with the same methods used to identify other defects. A number of false positive results were generated as a result, indicating that particular care would have to be given when developing algorithms that this was addressed.		

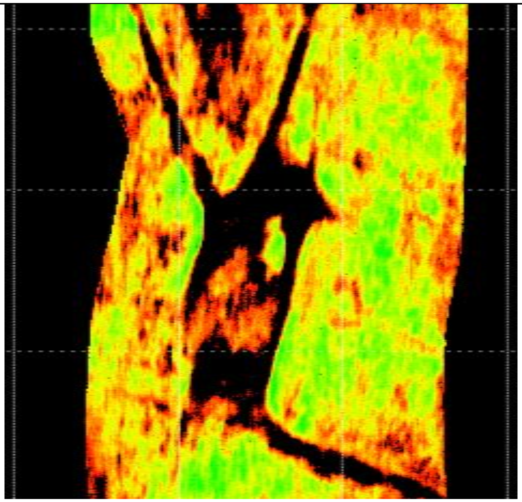
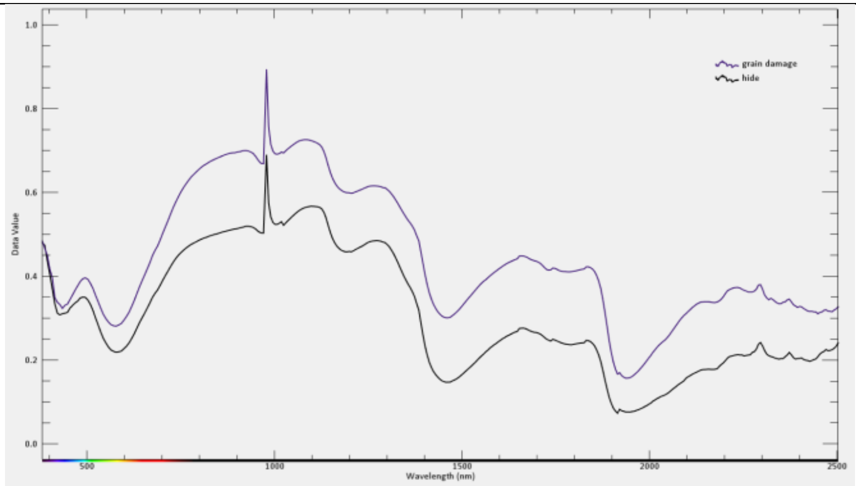
Sample 004 - Healed scratch		
		
Photograph of the defect	Image was generated by calculating the gradient from 820 nm to 920nm.	Image was generated by calculating the gradient from 580 to 764nm.
Defects for this hide were visible in the analysis. However, they were only visible due to the sharp change in contrast produced in the image (red streaks in the right-most image). If it wasn't for this change in contrast, the defect would be classed as a darker portion of the hide. Further work would have to be conducted in characterising these defects to ensure false positives aren't introduced. One potential opportunity area is using shape characteristics of the detected defects to further help classify them correctly.		

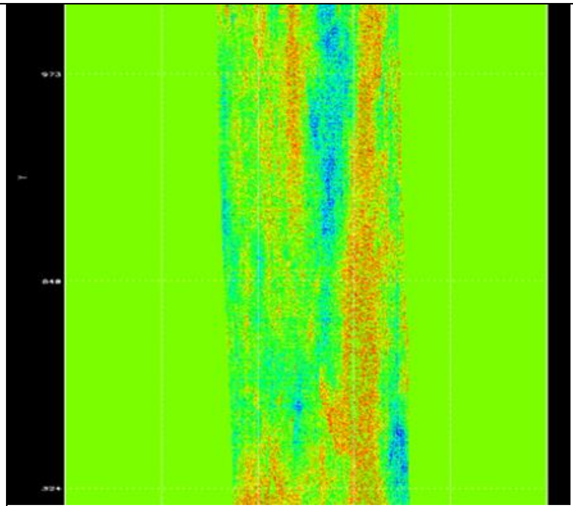
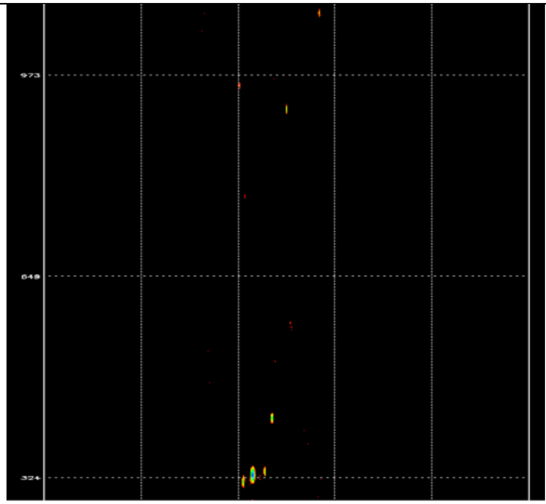
<table>
<tr><td colspan="3">Sample 005 - Open tick damage</td></tr>
<tr><td>
Photograph of the defect</td><td>
Image was generated by calculating the gradient from 580 to 764nm.</td><td>
Image was generated by calculating the gradient from 820 nm to 920nm.</td></tr>
<tr><td colspan="3">Defects for this were visible, however they were only defined by the sharp change in contrast. If it wasn’t for this change in contrast the defect can be classed as a lighter portion of the hide. Again, additional vision processing algorithms looking at shape characteristics of the pseudo-colour image generated from the hyperspectral image analysis may improve success rate.</td></tr>
</table>

<table>
<tr><td colspan="3">Sample 006 - Vertical Grain</td></tr>
<tr><td>
Photograph of the defect</td><td>
Image was generated by calculating the gradient from 580 to 764nm.</td><td></td></tr>
<tr><td colspan="3">Vertical grain was completely undetectable due to the spatial resolution of the camera. The camera utilised for the trial has a large spectral resolution to allow Scott to analyse spectral features over a wide range. As a result though, this camera has quite poor spatial resolution. It is possible that a different camera, with a spectral range concentrated on the ranges used for identification of the other defects but with a much higher spatial resolution than the Scott camera, would be able to identify these defects.</td></tr>
</table>

<table>
<tr><td colspan="3">Sample 007 - Rooping</td></tr>
<tr>
<td>
Photograph of the defect</td>
<td>
Image was generated by calculating the gradient from 580 to 764nm.</td>
<td>
Image was generated by calculating the gradient from 820 nm to 920nm.</td>
</tr>
<tr><td colspan="3">Rooping is defect caused by processing equipment, therefore not causing a chemical change but textural damage. Thus, this defect was not able to be isolated using hyperspectral imaging.</td></tr>
</table>

<table>
<tr><td colspan="3">Sample 008 - Freckles</td></tr>
<tr>
<td>
Photograph of the sample</td>
<td>
Image was generated by calculating the gradient from 580 to 764nm.</td>
<td>
</td>
</tr>
<tr><td colspan="3">Freckles are likely to be confused for physical damage to the hide due to the fact that freckles possess some unique spectral properties. These will need to be taken into consideration to prevent false positive defect detection.</td></tr>
</table>

Sample 009 - Grain Damage		
 Photograph of the defect	 Image was generated by calculating the gradient from 580 to 764nm.	
There are no characteristics of this spectra that strongly and uniquely define this defect from clean hide. Vision processing algorithms, in conjunction with spectral analysis algorithms, may be able to provide a result with this defect. Care will have to be taken however that these algorithms were robust enough to not introduce false detection in clean hide.		

Sample 009 - Healed tick damage		
 Photograph of the defect	 Image was generated by calculating the gradient from 820 nm to 920nm.	 Image was generated by calculating the gradient from 580 to 764nm.
These defects were not detectable by the hardware due to the spatial resolution of the camera. A higher resolution camera may be able to detect this defect.		

Sample 010 - Hair and hair root

Photograph of the defect

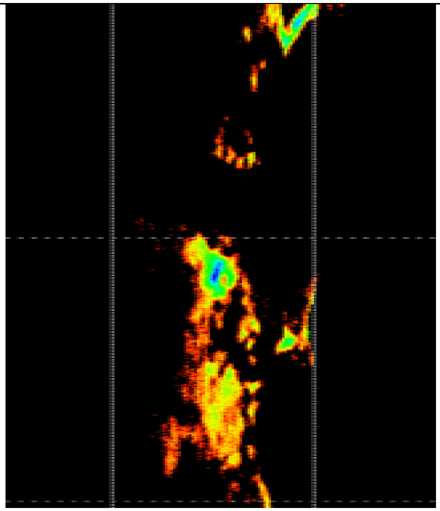
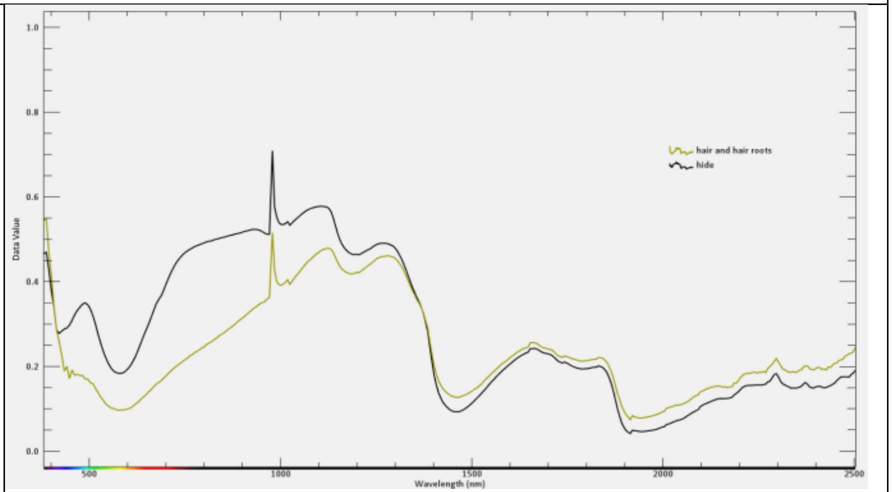
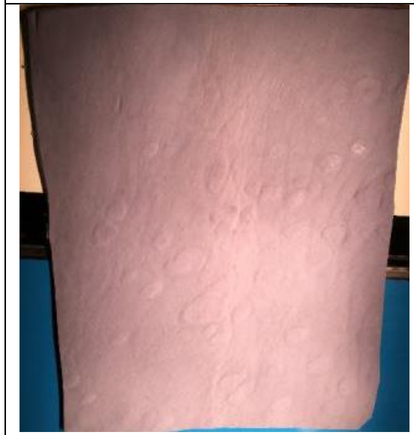
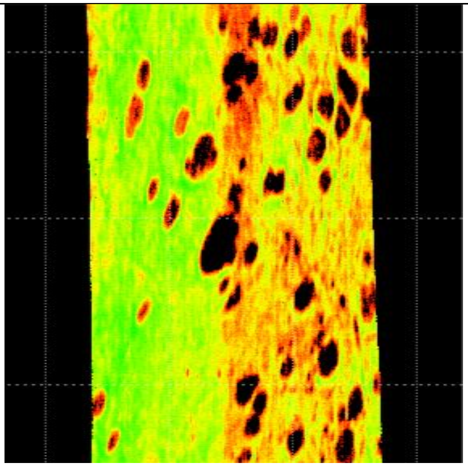
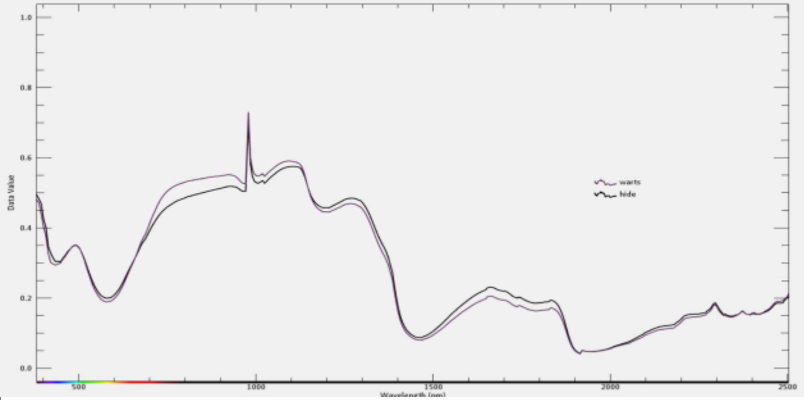
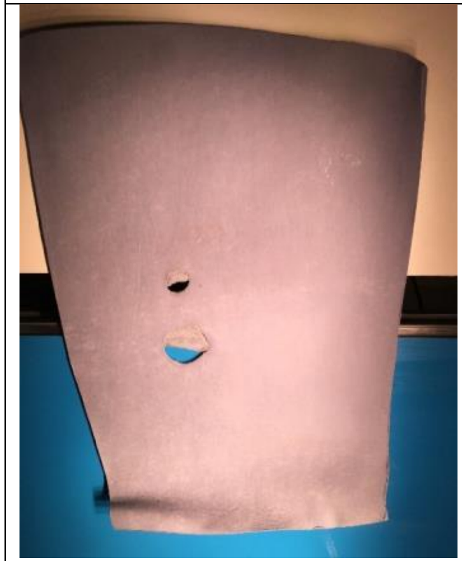
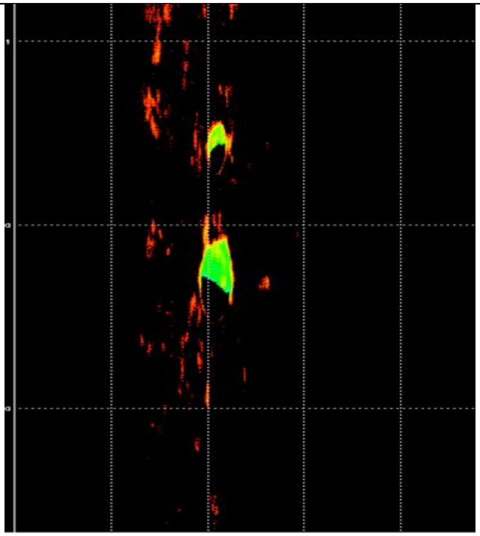
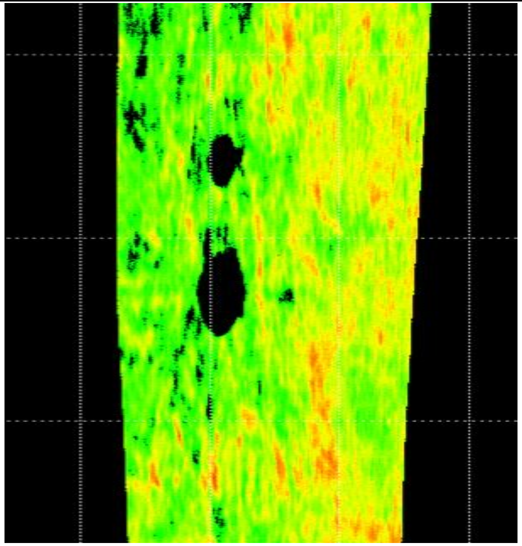


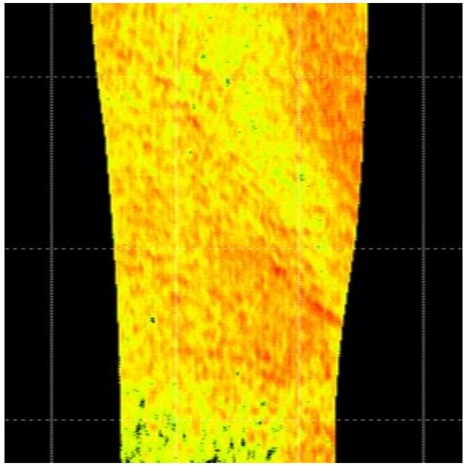
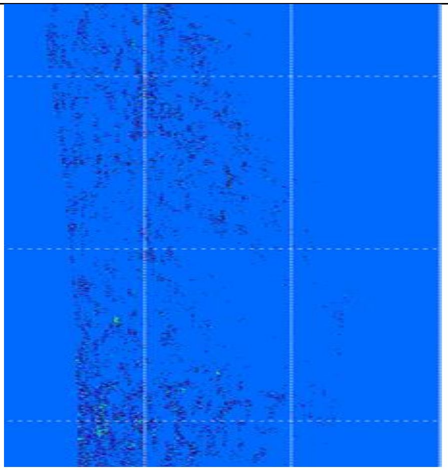
Image was generated by calculating the gradient from 580 to 764nm.

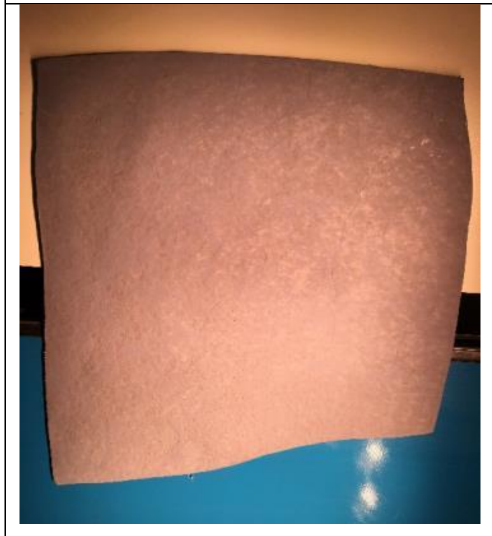
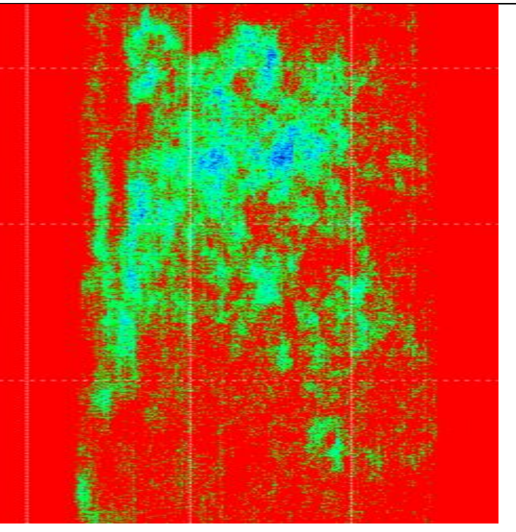


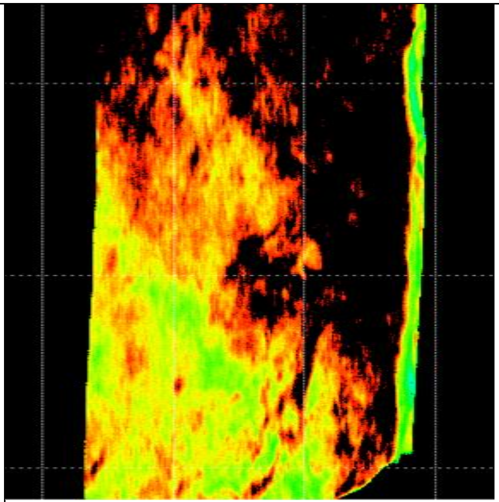
The spectra of the hair appear to be relatively unique from 700nm to 1300nm. It should be detectable and classified correctly depending on how homogeneous the hair spectra is.

<table>
<tr><td colspan="3">Sample 011 - Warts</td></tr>
<tr>
<td>
Photograph of the defect</td>
<td>
Image was generated by calculating the gradient from 580 to 764nm.</td>
<td>
</td>
</tr>
<tr><td colspan="3">The spectra of the warts is almost identical to the spectra of the hide. Isolating these defects robustly will therefore be difficult using the spectral information from the hyperspectral camera. Augmenting with other vision processing algorithms may enable robust detection but this would need to be verified across a range of hide samples.</td></tr>
</table>

<table>
<tr><td colspan="3">Sample 012 - Holes</td></tr>
<tr><td>
Photograph of the defect</td><td>
Image was generated by calculating the gradient from 580 to 764nm.</td><td>
Image was generated by calculating the gradient from 580 to 764nm.</td></tr>
<tr><td colspan="3">Holes are detectable.</td></tr>
</table>

Sample 013 - Open tick		
 Photograph of the defect	 Image was generated by calculating the gradient from 580 to 764nm.	 Image was generated by calculating the gradient from 820 nm to 920nm.
The spectral features in the image suggest that this defect would be difficult to isolate from clean hide.		

Sample 014 - Parasite damage		
 Photograph of the defect	 Image was generated by calculating the gradient from 820 nm to 920nm.	
This will likely be confused for normal hide as there are no strong and unique features in the spectral signature for parasite damage which suggests robust classification may be possible.		

Sample 015 - Vertical Grain		
 Photograph of the defect	 Image was generated by calculating the gradient from 580 to 764nm.	
This will likely be confused for normal hide.		

Sample 016 - Open scratch

Photograph of the defect

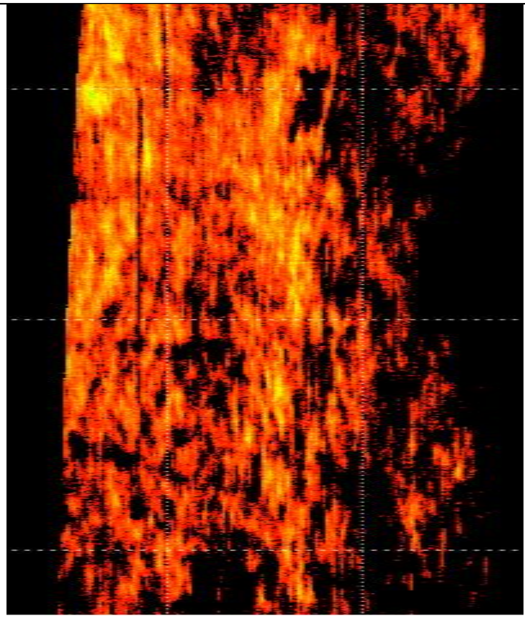
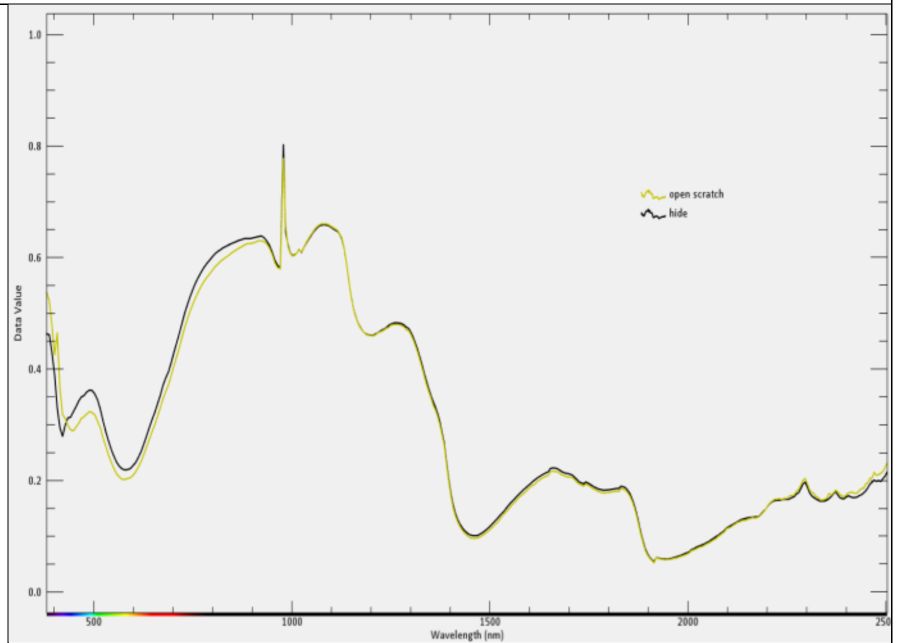


Image was generated by calculating the gradient from 580 to 764nm.



This will likely be confused for normal hide. The most likely reason for this is the spatial resolution was too low and a combination with motion blur washed out the physical defect. The spectra indicated no unique absorption bands on the pixels that appear to be the scratch.

It can be seen that the majority defects demonstrated little change in spectral signature compared to the rest of the hide. It is thought that this is due to the chemical processing of the hide, which strips away any chemical information which may be used to differentiate defects from normal hide. While it appears as though the defects could still be detected, the most promising methods revolve around texture analysis which may simply require a high-resolution colour camera rather than a hyperspectral camera. There are still concerns however that this may lead to a significant false positive and false negative identification rate.

4.2 High Resolution 3D Scanning

A second trial was conducted using high-resolution 3D scanning of the hides. The following methodology was used to conduct the experiment:

- A three dimensional profiler was used to conduct the trial which possessed a height resolution of 20 microns.
- The camera was set up to minimise the width of the scanning window, this has the effect of increasing the pixel resolution of the camera.

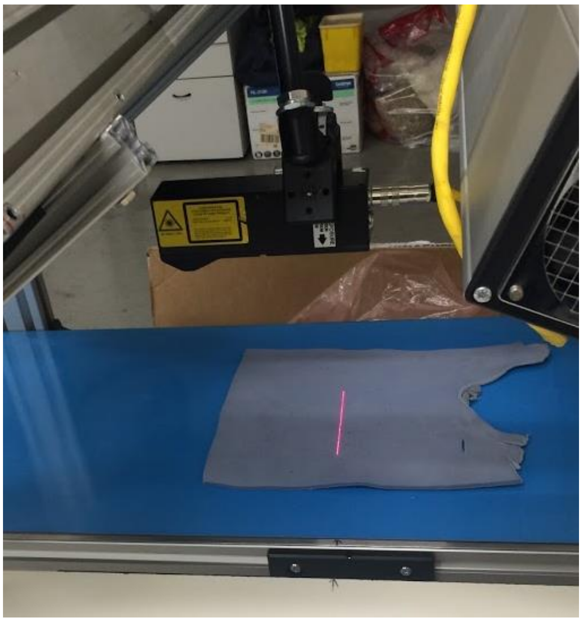
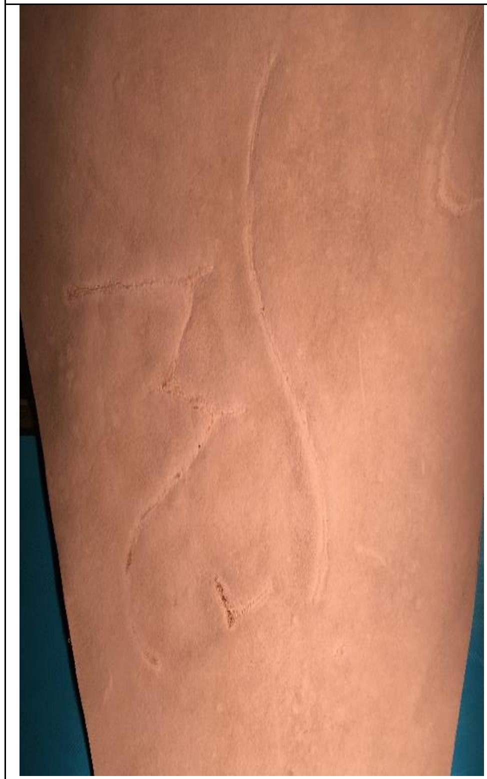


Figure 2 - 3D camera setup for hide profiling

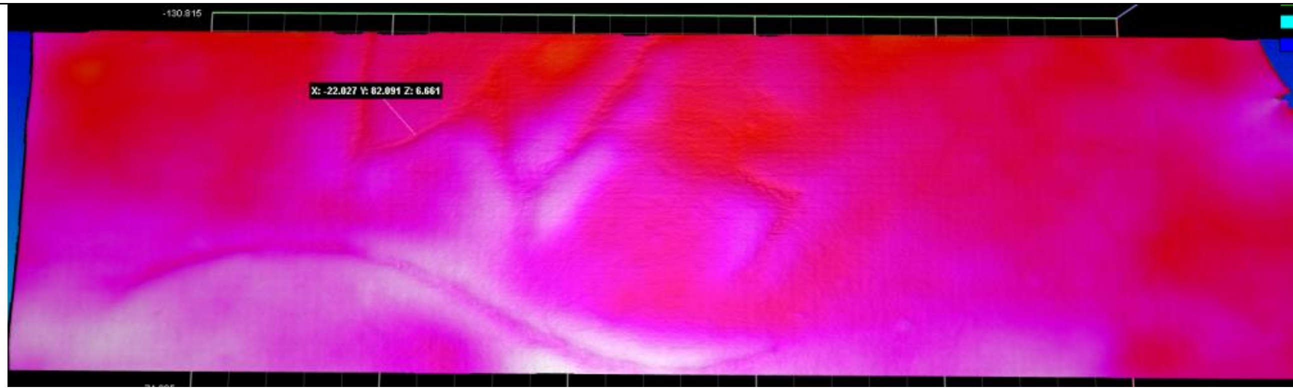
- Each sample was scanned individually with a constant conveyer speed.
- Samples were scanned in the state that they were delivered (post-sammying, damp to the touch).
- Each sample was individually analysed. Manual measurements were taken on the point cloud produced.

The following table is an analysis summery of all the samples provided for testing.

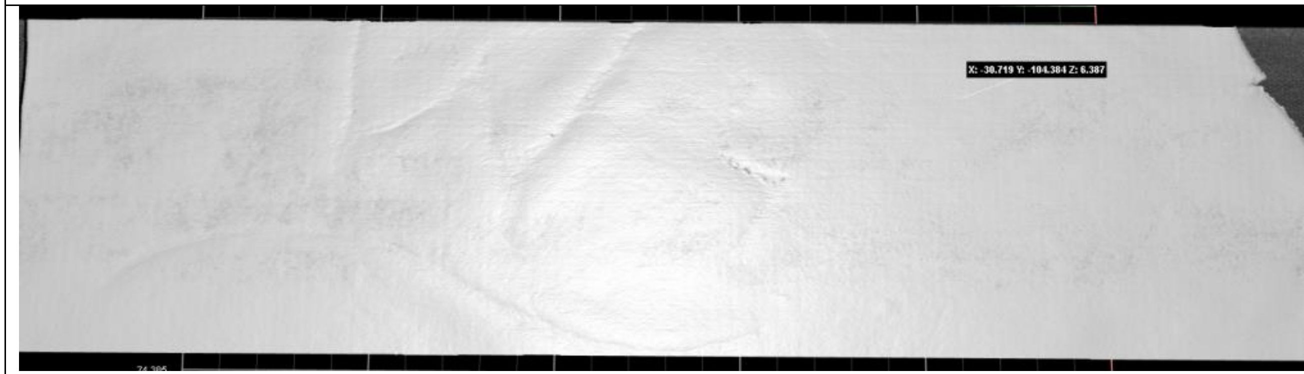
Sample 001 - Branding defect



Photograph of the defect

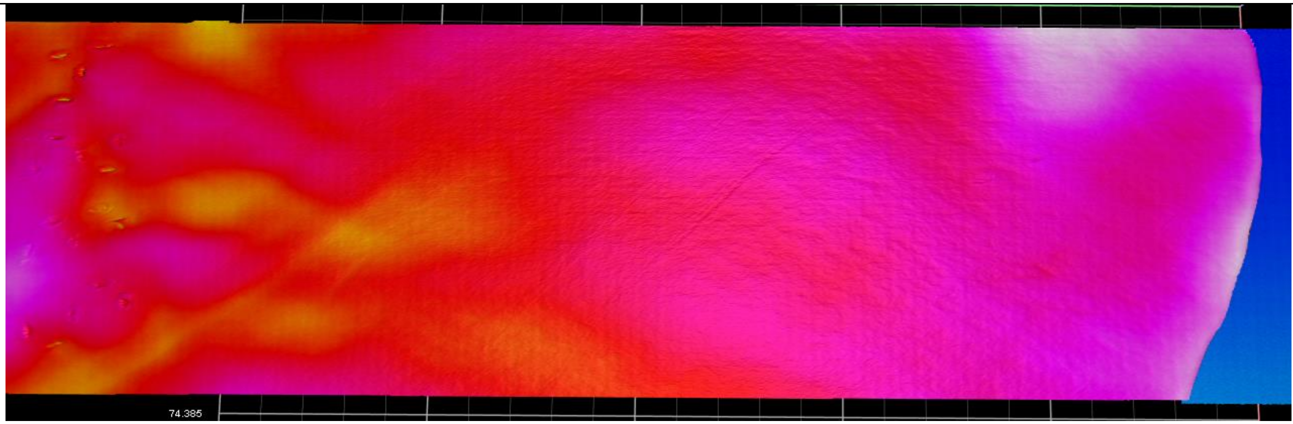
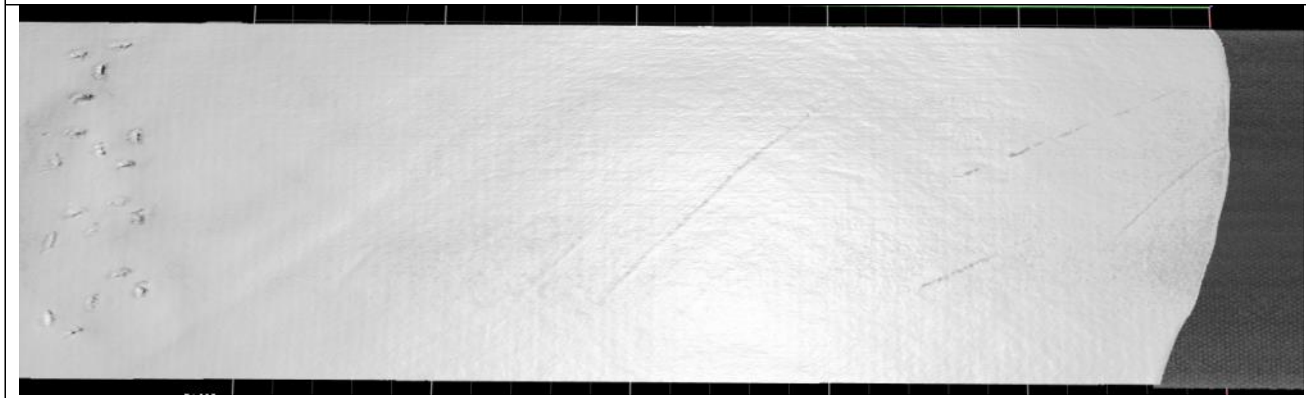


This is 3D height map of the hide.

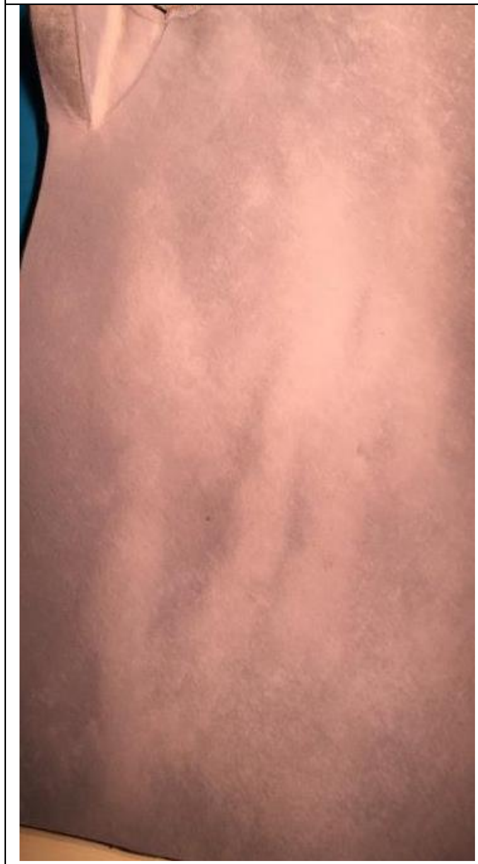


This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.

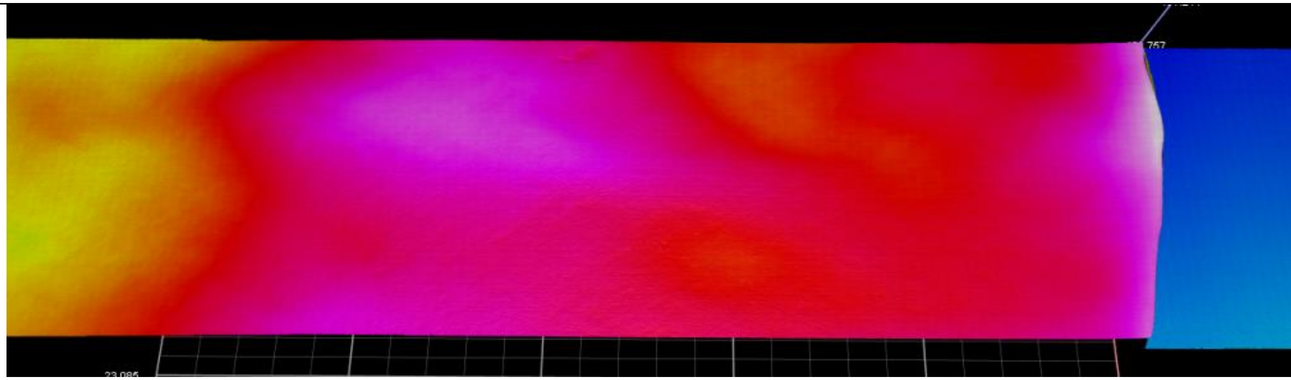
This branding defect will be detectable using the 3D image. During testing we measured a height indentation of up 0.6mm from the surrounding surface. The grayscale image is harder to see, however, using a colour camera in conjunction with the 3D information will bring out the colour variation in the surface of the hide.

<table>
<tr><td colspan="2">Sample 002 - Open scratch</td></tr>
<tr><td rowspan="2">
Photograph of the defect</td><td>
This is 3D height map of the hide.</td></tr>
<tr><td>
This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.</td></tr>
<tr><td colspan="2">Not all of the open scratched were visible in the 3D image, however, they are clearly visible in the grayscale image. We believe using a colour sensor will bring out the colour variation in the surface of the hide to aid in identifying this defect.</td></tr>
</table>

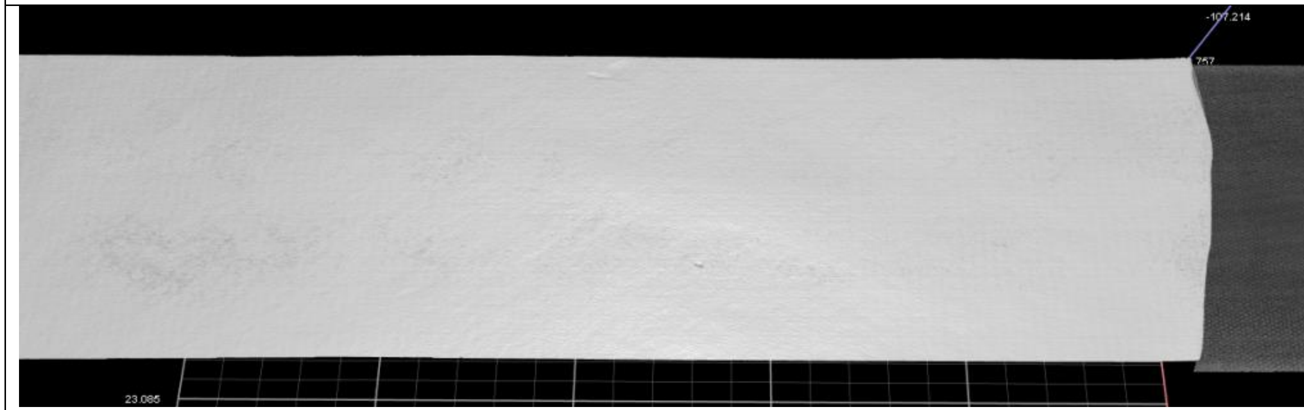
Sample 003 - Clean Hide



Photograph of the hide.



This is 3D height map of the hide.

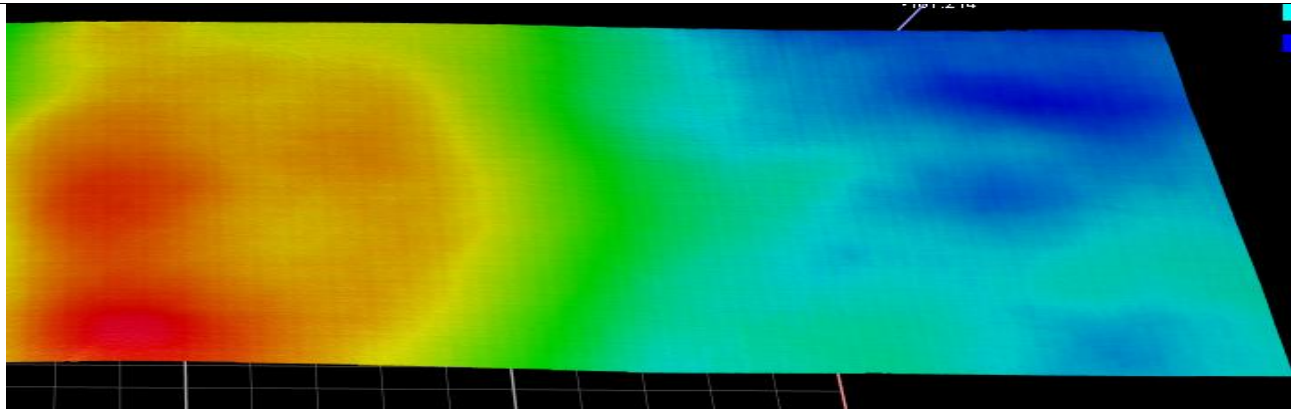


This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.

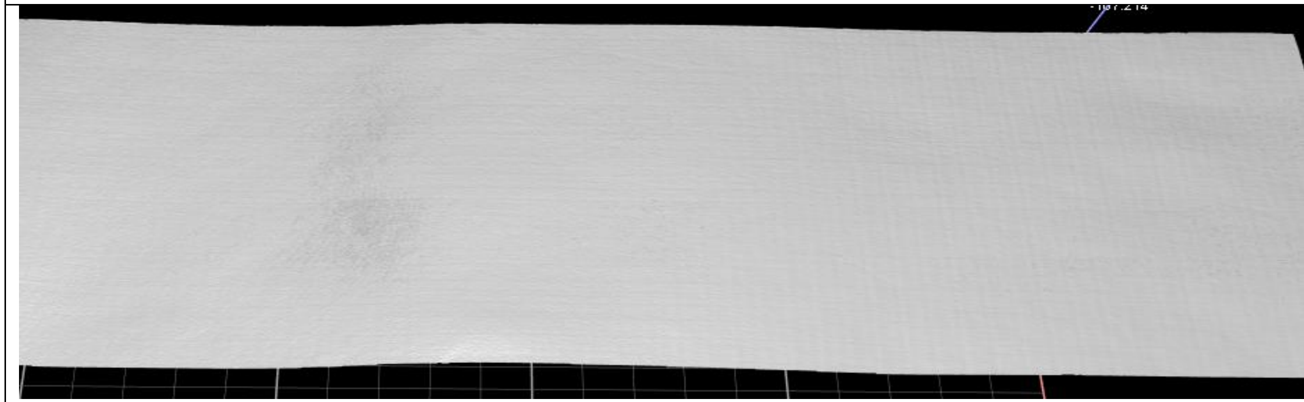
Note that a deep pit was detected in the top of the hide using the 3D image.

Sample 004 - Healed scratch

Photograph of the defect

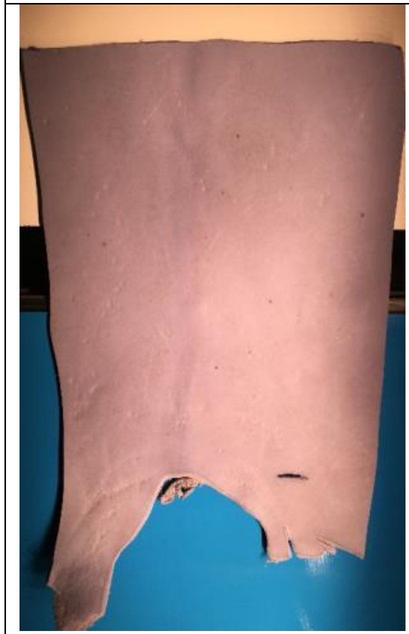
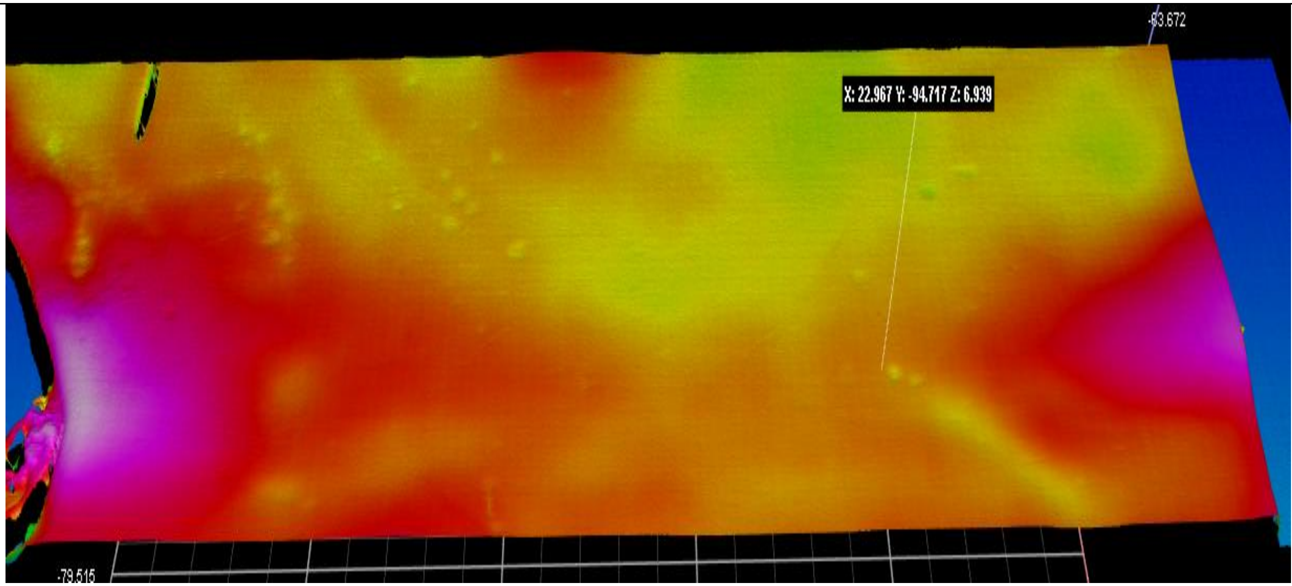


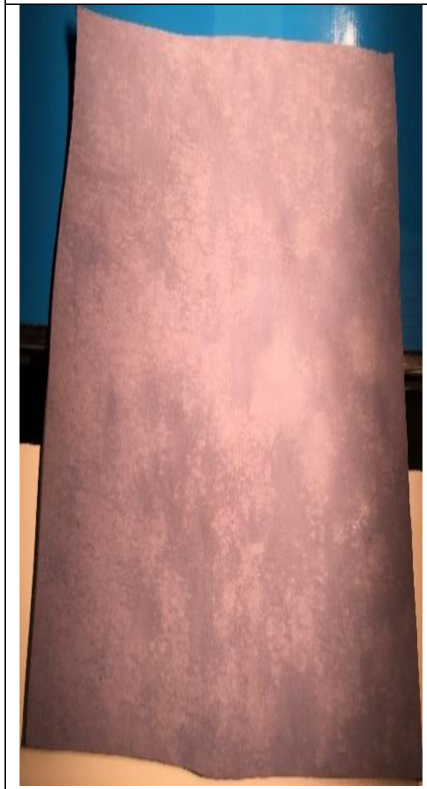
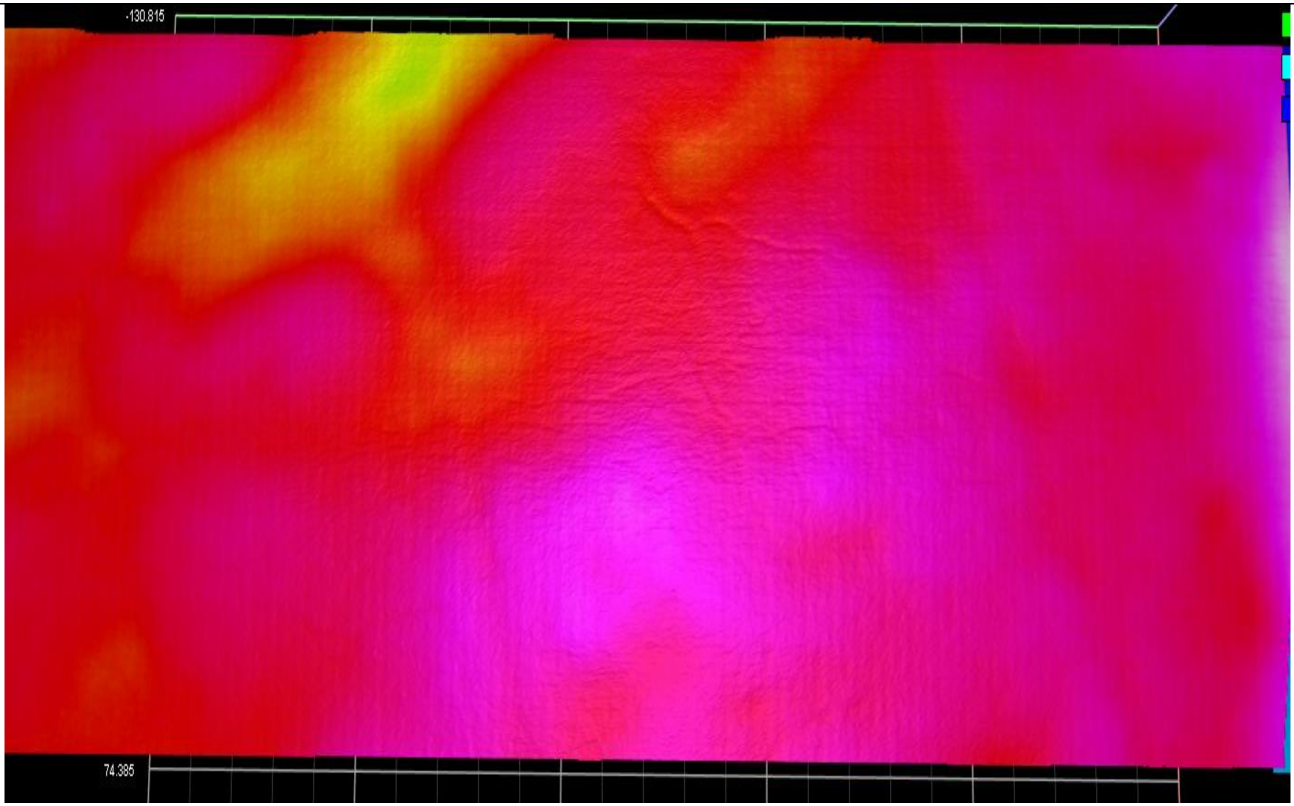
This is 3D height map of the hide.



This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.

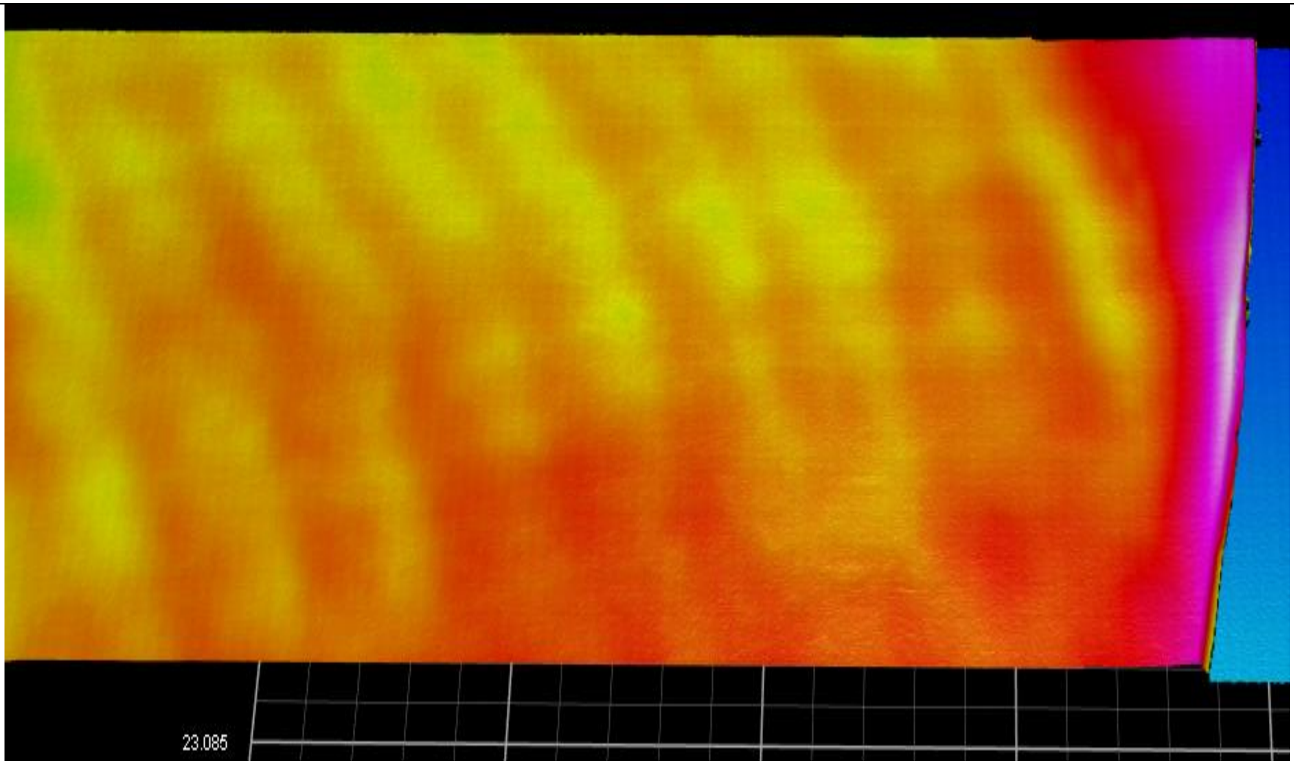
The healed scratches on this hide to not show any visible surface indentation on the 3D image, nor are they visible in the grey image. We believe that a colour camera may highlight the defect on the surface of this hide.

<table>
<tr><td colspan="2">Sample 005 - Open tick damage</td></tr>
<tr><td>
Photograph of the defect</td><td>
This is 3D height map of the hide.</td></tr>
<tr><td colspan="2">This defect can be classified using the 3D profile. Height indentations of up to 1mm were detected by the 3D camera.</td></tr>
</table>

Sample 006 - Vertical Grain	
 Photograph of the defect	 This is 3D height map of the hide.
Vertical grain is visible in the 3D image however further trials would be necessary to provide robust detection.	

Sample 007 - Rooping

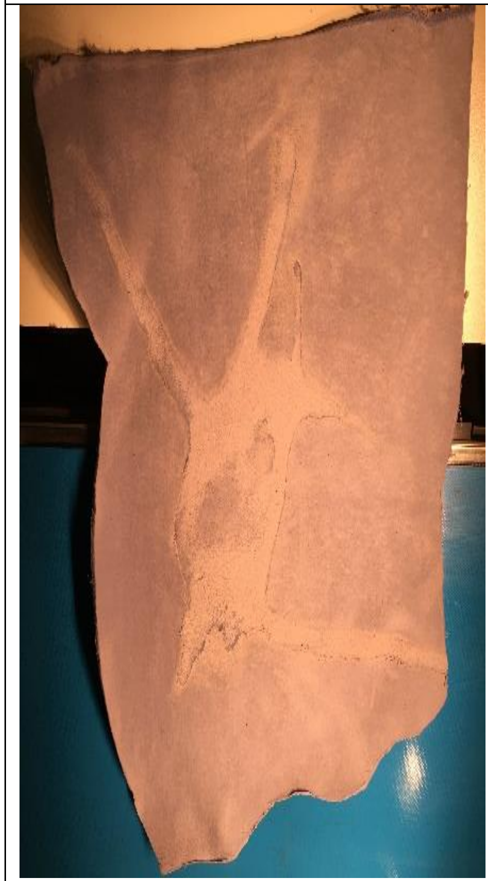
Photograph of the defect



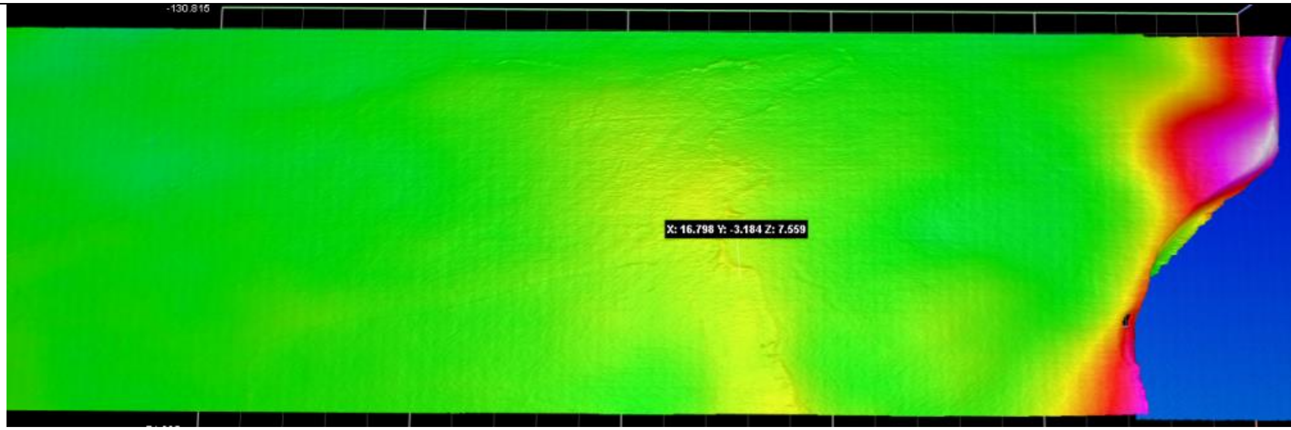
This is 3D height map of the hide.

Rooping grain is visible in the 3D image however a more complex identification algorithm will be required to ensure no false matches occur for this defect.

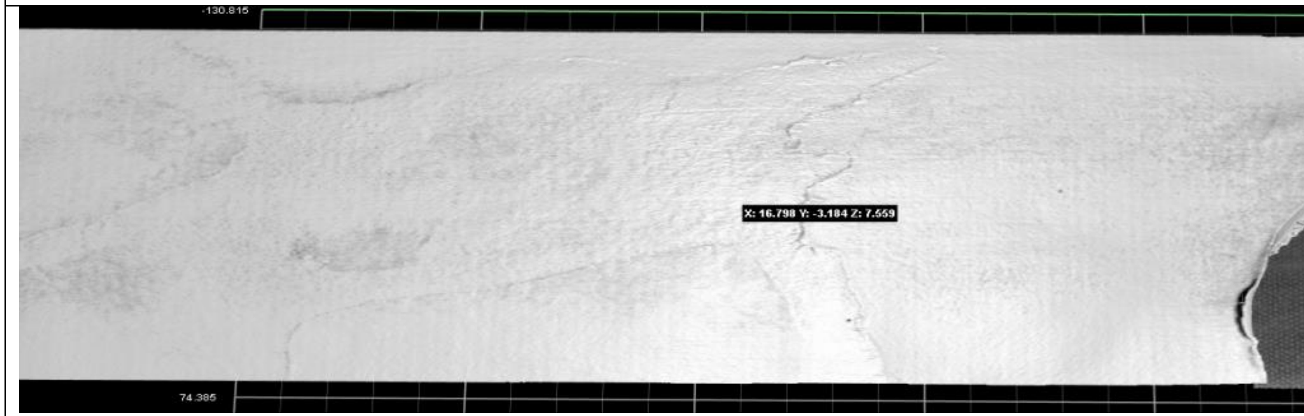
Sample 009 - Grain Damage



Photograph of the defect

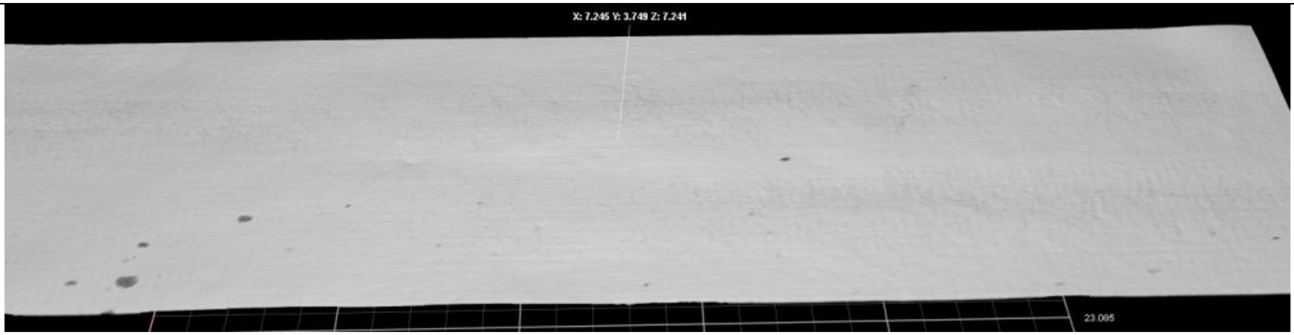


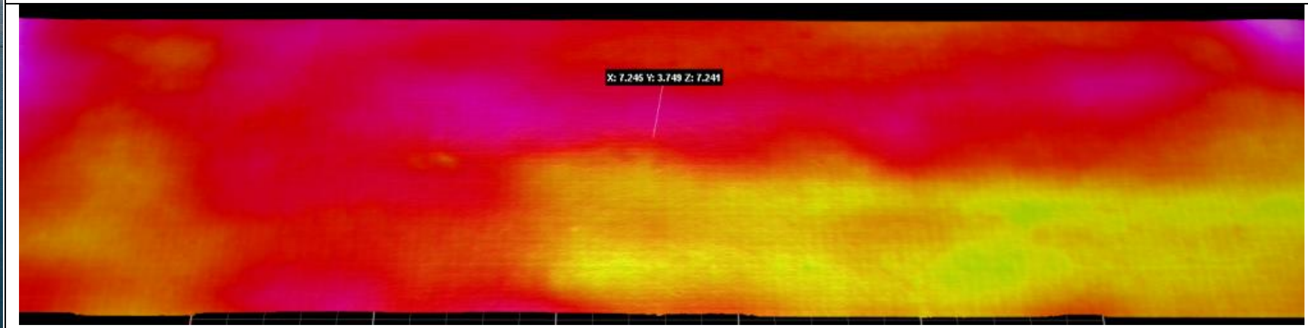
This is 3D height map of the hide.



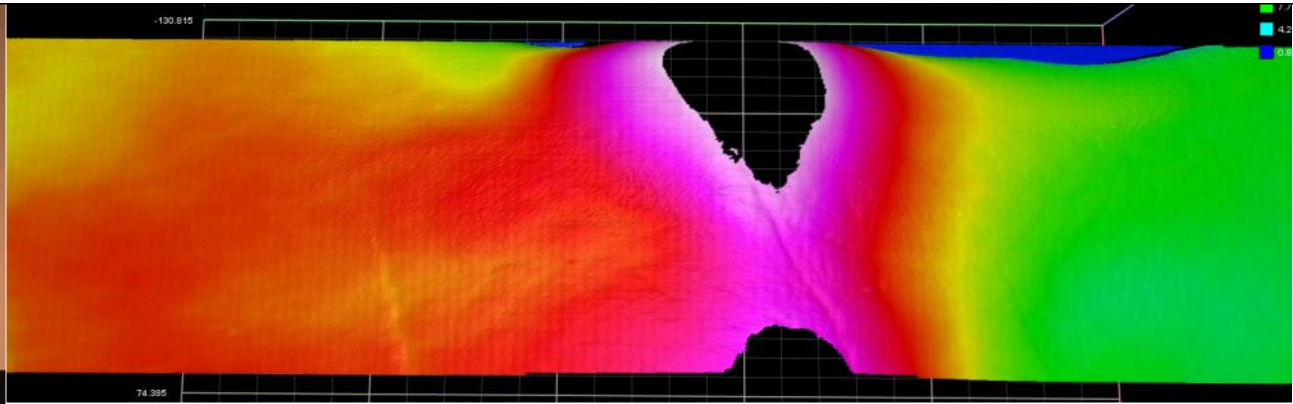
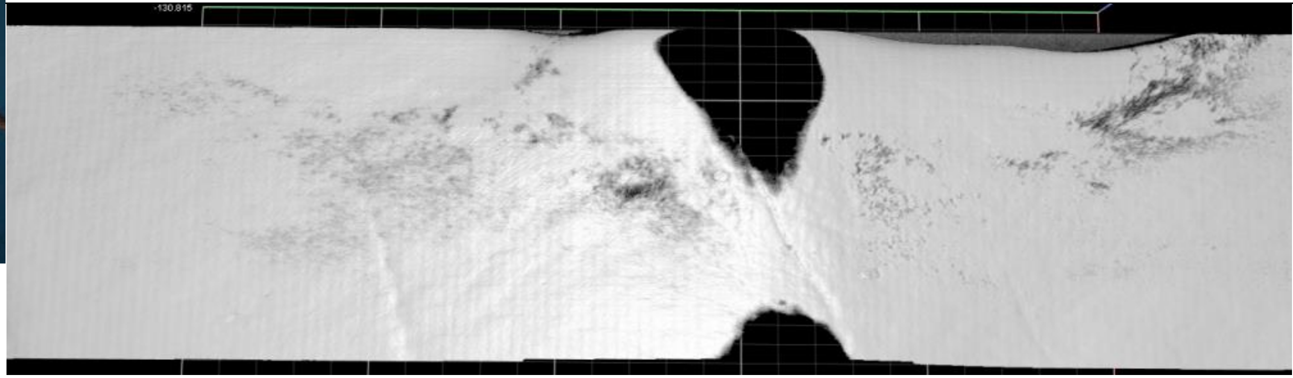
This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.

The edges of the damage are visible in both 3D and grey images; however, the centre is difficult to detect purely from the 3D data. We believe that augmenting the 3D data with colour information however would enable this defect to be classified.

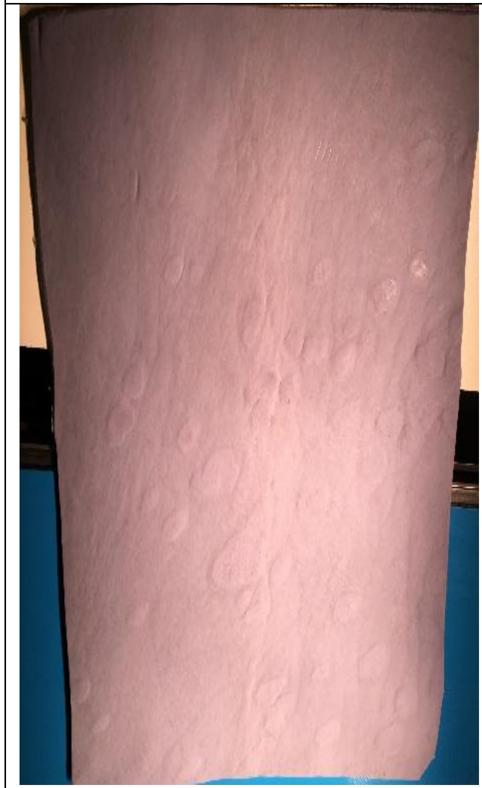
<table>
<tr><td colspan="2">Sample 009 - Healed tick damage</td></tr>
<tr><td rowspan="2">
Photograph of the defect</td><td>

Note the freckles can be seen and classified by their circular features.</td></tr>
<tr><td>

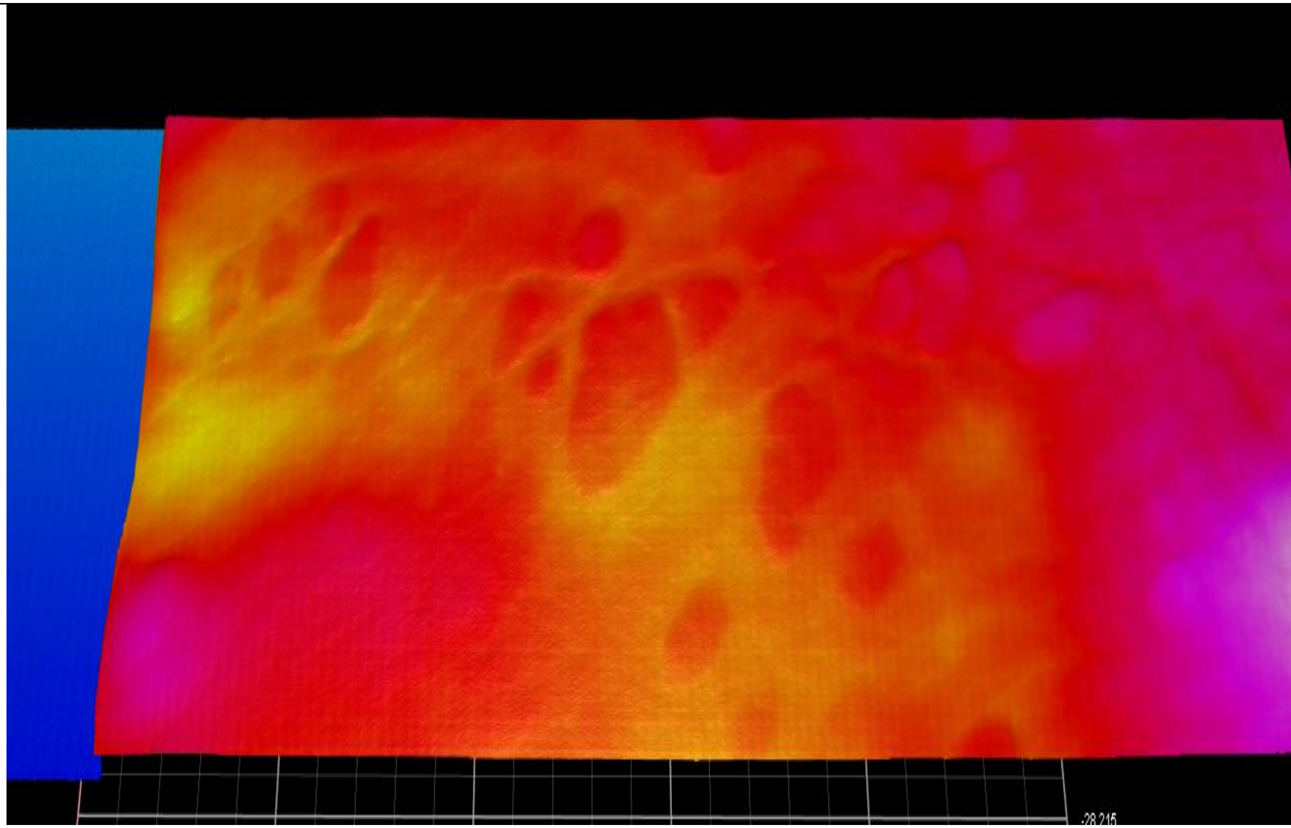
This is 3D height map of the hide.
Some of the tick damage can be seen but not all.</td></tr>
<tr><td colspan="2">Some of the tick damage can be detected in the 3D image but not all of it. A colour sensor would further serve to highlight the defect on the surface of this hide. Please note that the freckles can be accurately classified and ignored by their rounded attribute and the fact that they exist on the grey image and on the 3D image.</td></tr>
</table>

Sample 010 - Hair and hair root	
 Photograph of the defect	 This is 3D height map of the hide.  This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.
Hair and hair root are detectible by the grey image but not the 3D image. Note that an open scratch was detected on the 3D image.	

Sample 011 - Warts



Photograph of the defect

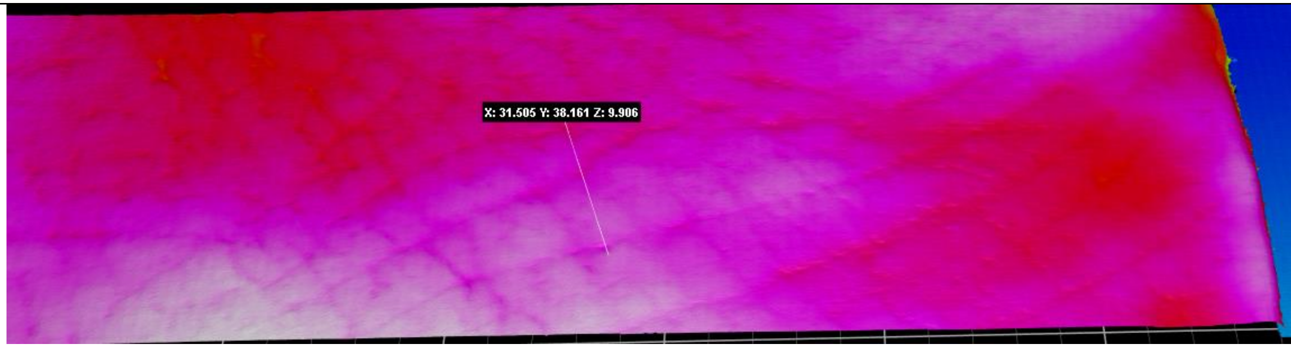


This is 3D height map of the hide.

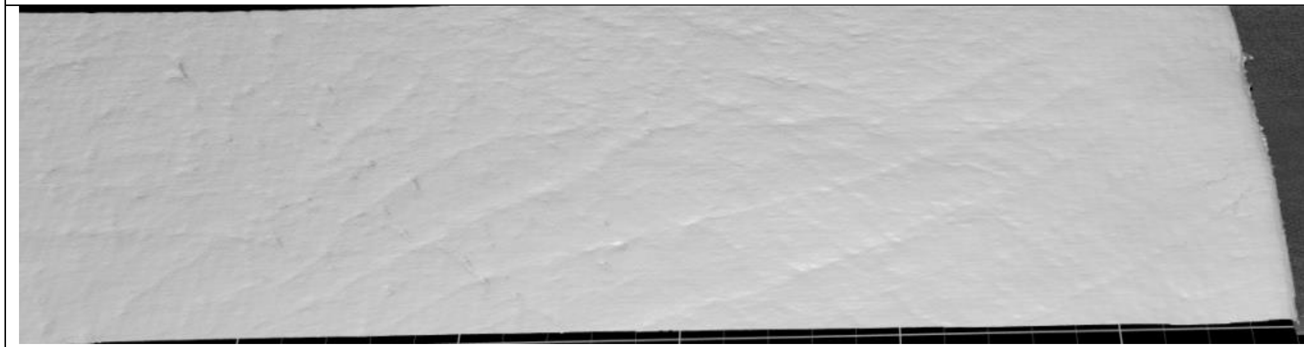
Warts can be classified using the 3D image.

Sample 013 - Open tick

Photograph of the defect

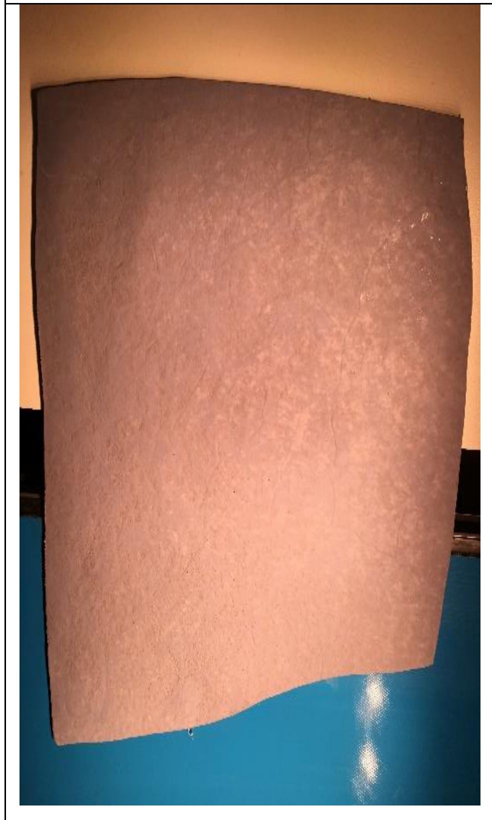
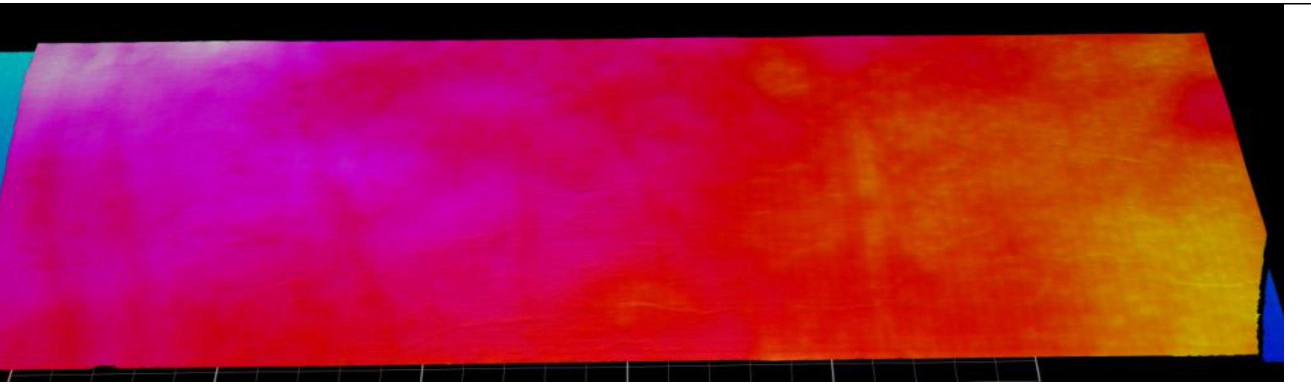
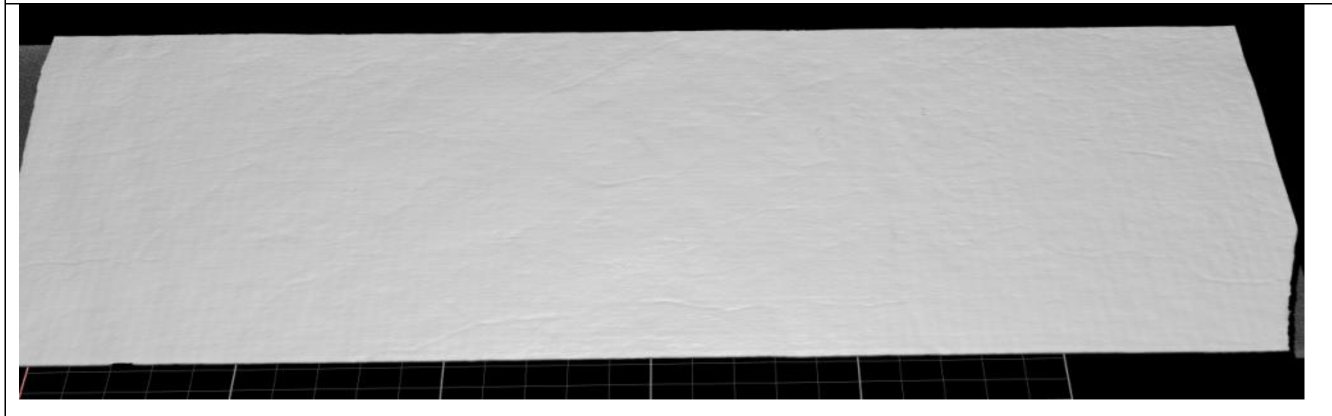


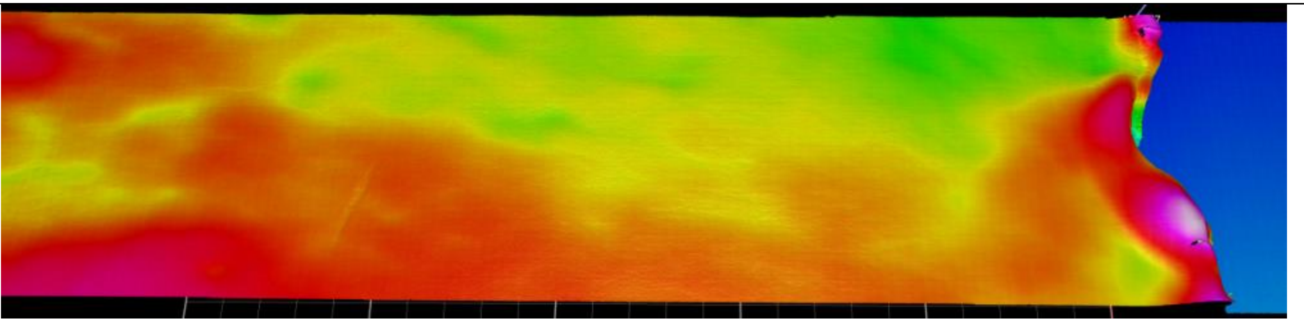
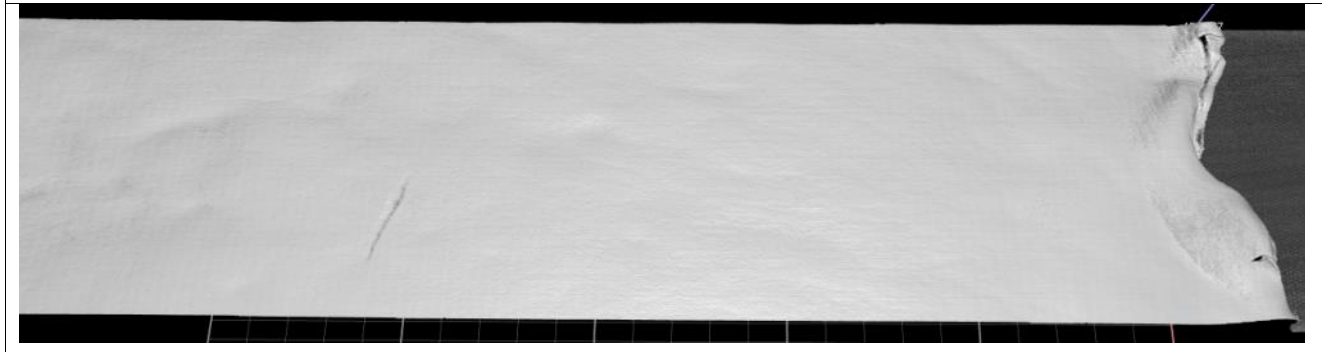
This is 3D height map of the hide.



This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.

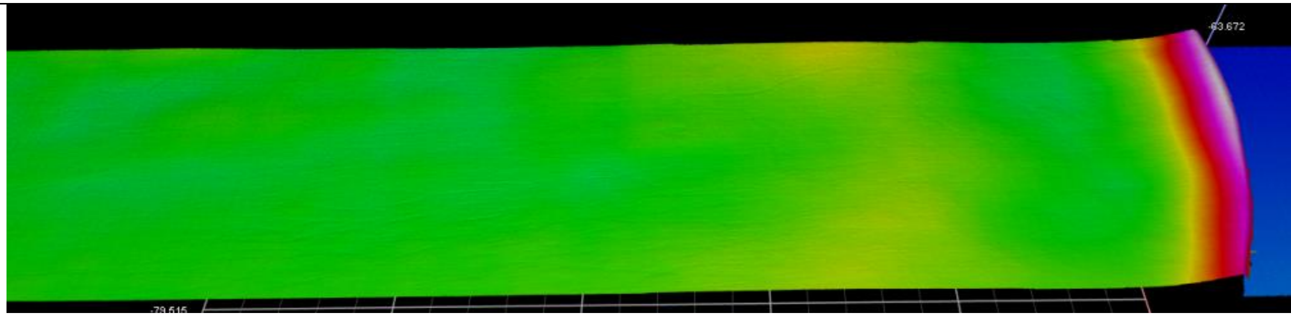
Most of the open tick damage registered an indentation of up to 0.6mm in the 3D image. This defect can easily be classified.

Sample 014 - Parasite damage	
 Photograph of the defect	 This is 3D height map of the hide.  This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.
Not all of the damage can be detected by the 3D image. Augmenting the 3D information with a colour image may highlight the defect on the surface of this hide however.	

<table>
<tr><td colspan="2">Sample 015 - Vertical Grain</td></tr>
<tr><td rowspan="2">
Photograph of the defect</td><td>
This is 3D height map of the hide.</td></tr>
<tr><td>
This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.</td></tr>
<tr><td colspan="2">Some hotspots visible in the 3D image as well as the greyscale image. The open scratch is clearly visible.</td></tr>
</table>

Sample 016 - Open scratch

Photograph of the defect



This is 3D height map of the hide.

This is an image of the grayscale intensity of each pixel overlayed on the 3D surface pf the hide.

The open scratch registered an indentation of up to 0.2mm on the 3D image but not all damage presented as an indentation. Some of the defects are visible in the grayscale image but not all. We believe that a profiler with colour capability may highlight the defect on the surface of this hide.

Overall the 3D scanning trial of sammied hides was very successful, with the vast majority of the defects being detectible either in the greyscale or the 3D image. Scott Automation and Robotics believe that with the use of a 3D profiling camera that has the additional ability to generate a colour image we will be able to classify the majority of the defects online.

5 Conclusions

The main challenge with performing spectral analysis on wet-blue hides is that they have been chemically treated, the natural collagen removed and replaced through the complex ions of chromium, depending on the compounds used. The result of this essentially leaves the outer surface of the hide and the inner structure chemically identical. Therefore, the anticipated result of hyperspectral analysis of treated hides would show very similar spectra, in particular in the short wavelength infrared wavelengths.

Thus, the process of tanning a hide causes all hides to become chemically homogenous on the outer surface as well as below the surface. For this reason, all hides tested exhibit identical spectral characteristics above and below the surface.

The equipment used to conduct the trials although capable of detecting very small and subtle spectral variations has a very poor spatial resolution. It was therefore incapable of detecting very small spatial features. However, a system could be designed with a camera of sufficient resolution for this task.

Most hide defects can be characterised by physical indentations to the hides surface. Variation in pigmentation is not categorised as a defect and, in fact, pigmentation creates challenges for the graders as wells as machine vision equipment.

All spectral variation detected in between good hides and defects only presented in the visible to near infrared spectral, presenting itself in only very slight drops in intensity. No additional absorption or reflectance bands were detected. Due to these reasons most will be susceptible to false classification because of reflection and variations in skin colour.

Scanning hides after they have been wet presents no benefits in hyperspectral imaging. On the contrary it causes light bleaching and made it harder to analyse the data.

While many of the defects failed to present strong and unique spectral signatures, an opportunity still exists whereby vision algorithms could be explored to use in conjunction with spectral analysis to allow more robust detection. Such algorithms would take into consideration other features presented by the defect, including size, shape, distribution etc.

At this stage however, it appears that using a hyperspectral camera to grade processed hides presents minimal benefits.

A further trial was conducted with a high-resolution 3D camera which also outputs a greyscale intensity image. The results of these trials were extremely promising – the 3D and greyscale images complimented each other well in identifying each of the defects. It is thought that using a 3D camera with colour imaging capabilities may further improve robustness. Given the results of these trials, Scott believe that a hide inspection system utilising high-resolution colour and 3D imaging is achievable. A range of vision processing algorithms would be utilised with varying complexity in order to classify each defect effectively. It is envisioned such a solution would be more cost-effective than a hyperspectral solution while also be more suited for this particular application.

It should be noted that, while hyperspectral technology may not be the best sensing solution for the grading of wet-blue and sammied hides, this may not be the case