Spectral Separations of Potatoes and Honey

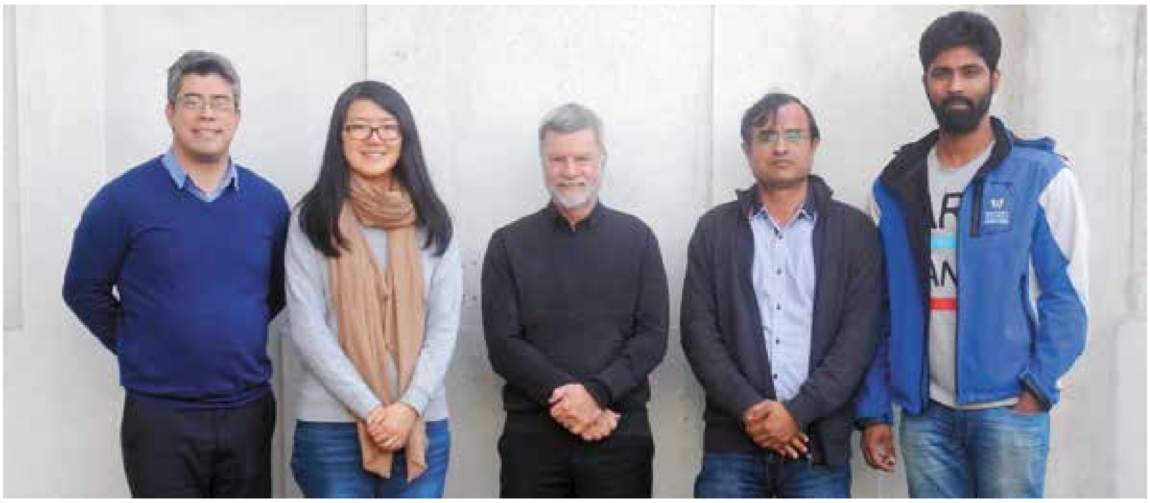
Authors: [1]Abhimanyu Singh Garhwal, [2]Reddy Pullanagari, [2]Mo Li, [1]Donald Bailey, [3]Marlon Reis and [4]Richard Archer

Affiliations: [1]School of Food and Advanced Technology, Massey University, Palmerston North

[2]Massey Agritech Partnership Research Centre, Massey University, Palmerston North

[3]AgResearch, Palmerston North, New Zealand

[4]School of Food and Advanced Technology, Massey University, and Riddet Institute, Palmerston North



The "Spectral Separations" team: Marlon Reis, Mo Li, Richard Archer, Abhimanyu Singh Garhwal, Reddy Pullanagari (Absent: Donald Bailey, Andrew East)

Potential use of hyperspectral imaging

The hyperspectral camera is rapidly putting affordable analytical power into the hands of food processors. Such cameras can capture an image where each pixel carries spectral information all the way from visible through infrared ranges. Resolution might be ~1000 by 600 pixels, each with ~500 spectral channels. If images are captured at 25 frames per second the rate of data generation is massive which is computationally challenging. Clearly image and spectral analysis becomes key to winning useful information. The example above is for a high-end hyperspectral camera and would still be expensive. But simpler models, still powerful, are getting cheaper and are readily available now.

The barrier to use is not so much acquiring the camera, as finding suitable software and routines to analyse spectral data from a particular product in real-time, and acquisition of good calibration data.

In the "Spectral Separations" project within the FIET programme, scientists and engineers from Massey University and AgResearch are applying these emerging tools to two New Zealand situations:

- Selecting out raw potato tubers infected with Liberibacter
- Separating frames of honey between those rich and lean in mānuka honey

Zebra Chip defect in potatoes

New Zealand grows around 525,000 MT of potato annually across more than 50 commercial varieties. Main varieties include 'Russet Burbank', 'Innovator', 'Rua', 'Nadine', 'Agria' 'Moonlight', 'Desiree', 'llam Hardy' and 'Red Rascal'. Over the past few years several commercially important varieties have shown high levels of infection by *Liberibacter solanacearum*. Infection starts at the leaf and migrates to the root – only some tubers are infected and only some parts of the tuber. The vascular bundles are far more prone than the starchy bulk.

Liberibacter infection shows up as the Zebra chip defect in cooked potato chips – the most affected zones brown to a higher degree on cooking as shown in Figure 2. Incidence of this disease in New Zealand potatoes has become the main constraint for exporting intact tubers to markets like Japan, resulting in significant economic loss (estimated at ~$40M annually). Currently, the chip-processing industry relies on manual destructive visual assessment to identify diseased tubers. Potatoes New Zealand, representing the New Zealand industry, have been seeking a non-destructive approach to segregate diseased and good intact tubers.

Literature review

We conducted a detailed literature review to explore the potential technology options for non-destructive detection of Liberibacter infection (aka Zebra chip disease) in potato tubers. Visible near infrared (Vis-NIR) reflectance spectroscopy has the potential to detect tubers with elevated levels of reducing sugar, which has direct relation with the disease severity in potatoes.

Survey of commercial facility

To understand the potato industrial processing system, we conducted a scoping survey of a commercial potato processing facility. We aimed to identify the best stage in the potato processing process for application of a non-destructive technology like Vis-NIR spectroscopy with least disruption.

Proof of concept study

We collected potato tubers after washing and before peeling in a proof of concept study using Vis-NIR to segregate potato tubers with disease incidence. This proof of concept study revealed that using Vis-NIR spectroscopy, 96-97% of diseased tubers could be segregated successfully, just using that small part of the spectrum.

Figure 2: Liberibacter-infected potato chips exhibiting zebra chip disease

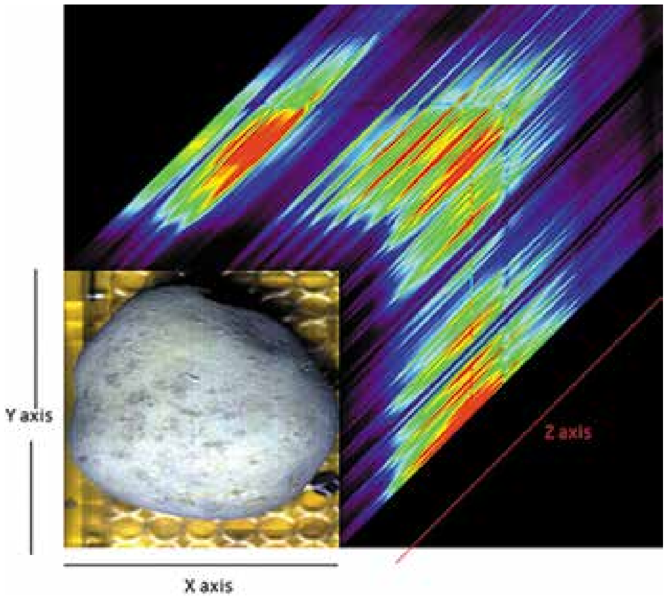


Figure 3: Hyperspectral image of potato

Hyperspectral camera, illumination, sample and computer

Simple NIR spectroscopy requires scanning a single tuber at a time. At industrial scale this would require singulating potatoes travelling down the line – a significant modification. The hyperspectral camera can inspect all the potatoes across the width of the existing conveyor at once. Furthermore the standard non-imaging NIR instrument registers an average signal across the whole section of tuber in its field of view. By contrast, a hyperspectral imaging camera can register small areas of defect undiluted by surrounding healthy tissue – this makes it more sensitive if coupled with the necessary image processing. A hyperspectral image of a potato is shown in Figure 3.

Hyperspectral imaging (HSI) is promising but requires work to enable its industrial application to segregate diseased potato tubers. This project is developing techniques to examine and aggregate information from almost all the surface of a rolling tuber, and to isolate each tuber within a complex moving image. Other important factors in the study are the effects of disease development stage, potato varietal differences, tuber sizes and orientation, the presence of other defects and storage variables. We have assembled a diverse project team of food and postharvest technologists, HSI and NIR spectroscopy experts and potato industry stakeholders.

Impact of surface dirt

Trial one looked at how much cleaning of the potato was required before scanning. Potatoes were sourced from a supermarket and dry brushed leaving some adhering dirt. We used two cameras: a Headwall Photonic (500 to 1700nm) and a Specim FX-10 (400 to 1000nm) to scan 71 individually identified tubers. We then washed and dried (for 5-10mins) each tuber and scanned them again in the same sequence. A third group of washed and dried tubers was tempered by applying a dye in spots, and then scanned by both cameras. We analysed the three data sets to evaluate ability to discriminate between treatments.

We applied the supervised classification method Partial Least Squares Discriminant Analysis to separate spectral data. The results from this analysis clearly categorised potatoes into three groups' i.e. unwashed (encompassed by blue circle in Figure 5), washed (orange circle) and tempered (grey circle). This small experiment has proved that the technique is powerful and can detect major differences easily. Since dry brushed and washed potatoes register so differently, mixtures of the two may be difficult to process accurately: washed potatoes probably permit more accurate detection of disease. Later trials will concentrate on washed and dried potatoes.

Disease detection across multiple varieties

Our current work is on detection of disease state in 'Russet Burbank' potato variety using a VIS-InGaAs hyperspectral camera which acquires 235 bands in the spectral range from 548 nm to 1701 nm. We are comparing a variety of data analytical techniques. From the torrent of spectral information generated we can distil down to the fraction of 1% where the key information is held with respect to infection. This will permit us to filter spectral data close to source so that image processing need be done on quite lean data flows. There is plenty of other useful information in the images, on other potato diseases, although these are not the current focus of the work.

Manuka Honey in the frame

The second application addressed by the "Spectral Separations" project is grading on the basis of the "manukaness" of honey in cells within the honey frame just prior to extraction. This project is being done in conjunction with a major New Zealand honey company. If honey is truly mānuka under the official MPI definition, it has higher value than non-mānuka honey. If it has higher non-peroxide activity, it is likely to have higher value in the pottle than lower activity honey. This effect shows up in the UMF-value graph which is quite strongly curved.

When a frame of non-mānuka honey is extracted along with true

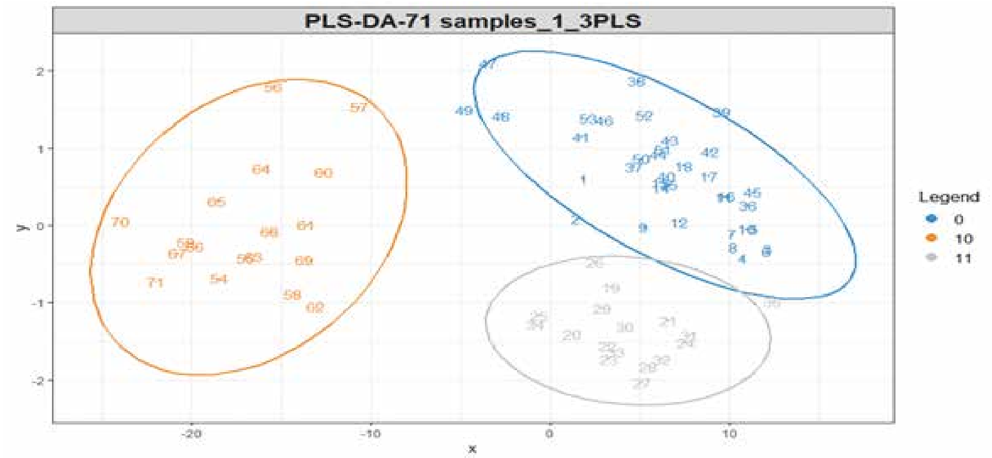


Figure 5: Results of PLS-DA modeling of spectral data of potatoes showing discrimination possible

mānuka honey, it dilutes the latter and could take it below the high-value threshold. If a frame of good mānuka honey gets extracted along with non-mānuka its honey ends up in a low value drum and its owner misses out on some returns. The beekeeper will get optimal returns when all the good, strong mānuka honey is extracted into one drum and all the poorer non-mānuka honey is extracted into another.

Current practice is to treat all the frames in all the honey boxes from one apiary of multiple hives as being the same. The "Spectral Separations" project is using a hyperspectral camera to assess honey, cell by cell, in a freshly uncapped frame. From that, the average content of the whole frame gets calculated. Frames with distinct zones of weak and strong can be identified as well. The camera will be deployed in the extraction plant and will operate at normal line speed, identifying which frames go into the "rich" extractor and which into the "poor" extractor. Initial results are very promising.

FIET
Food Industry Enabling Technologies

Food Industry Enabling Technologies (FIET) is funded by the Ministry for Business, Innovation and Employment and its purpose is to support new process developments that have the potential to add significant value to our national economy. The programme has six partners, Massey University (the host), Riddet Institute, University of Auckland, University of Otago, Plant and Food and AgResearch. Funding is $18m over six years (2015-2021) and targets pre-commercialisation activities. If you are interested in more information, then please contact either Ross Holland (R.Holland1@massey.ac.nz) or Professor Richard Archer, Chief Technologist, (R.H.Archer@massey.ac.nz).