

FOOD inspection technology for high-volume food processing lines requires instrumentation that is specific to the processed product, robust and durable enough for the harsh environments of processing plants. They also have to be cost-effective to reflect the competitive nature of the food and agriculture markets.

Spectral sensing and, in particular, hyperspectral imaging is quickly being deployed as a key sensor technology to inspect food products for health-related conditions. This includes disease detection or contamination and as a means to analyse product



USDA ARS

Food Inspection:

THE Hyperspectral Perspective

Hyperspectral imaging is quickly being deployed as a key sensor technology to inspect food products.

By **David Bannon**, CEO, Headwall Photonics

quality attributes, such as ripeness and tenderness from the field to the distribution center.

There is currently a wide set of applications utilising hyperspectral technology ranging from the analysis of ripeness of harvested strawberries, to poultry line inspection for disease conditions and fecal contamination.

SPECTRAL CONTENT

Hyperspectral imaging instruments evaluate a product based on the unique chemical signature or 'fingerprint' of the product. While the industry has

implemented machine vision technology for years now, hyperspectral cameras provide critical information based on spectral content.

For example, conditions such as bruises on fruit, pesticide contaminants, or diseases can be quickly assessed in-line even though these conditions may not yet be visible to the naked eye of the human inspector. This allows food producers to screen or eliminate lower quality products before processing or packaging, and price higher quality products appropriately.

Over the past five or more years,

researchers at the US Department of Agriculture ARS (Agricultural Research Service) and industry leaders have worked to develop advanced hyperspectral process instruments that are specifically designed for food safety and inspection applications.

While hyperspectral imaging has been readily deployed for remote sensing as well as military & defense applications for over fifteen years, earlier agricultural applications of the technology involved airborne instruments for large scale farming operations for precision agriculture, analysing plant health, species identification, or nitrogen content of farm areas.

Now, technology advances in recent years have allowed growers, producers, and food processors to cost-effectively utilise these imaging instruments. This helps to increase throughput across production lines, while

improving process control and inspection capability with 'in-line' or 'at-line' deployment.

Hyperspectral imaging is a reflective spectroscopic technique providing the advantages of:

- Large field of view for wide area sampling of processed food and agriculture products
- High throughput inspection & screening for real-time processing & control
- Application and inspection specificity based spectral & spatial resolving capability
- In-line, non-destructive sampling that is readily incorporated into existing production processing technology

As a result, it allows food and agriculture producers to establish critical control points (CCPs) from the point of harvest through high-volume processing, inspection, and packaging.

APPLICATION IN FOOD INSPECTION

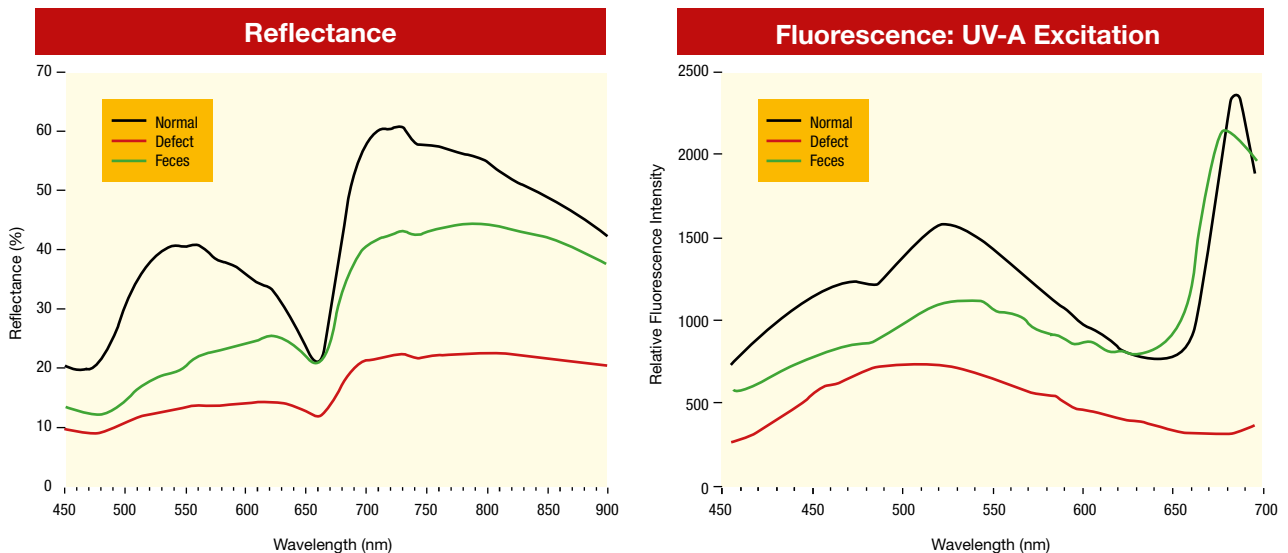
Utilising high efficiency diffractive optics, hyperspectral sensors can be configured to offer optical efficiency in wavelengths of interest across broad spectral regions for the specific fruit, vegetable, or meat product processed.

With the underlying advantage being deployment for high throughput scanning and

pork products and for disease detection in poultry products. By providing product information based on the spectral content of the meat, processors are able to pre-sort products according to quality, for example, fat content of pork or wholesomeness (disease detection) of poultry.

Through effective analysis and inspection of the product early on in the processing, producers are better able to control the quality of product moving along the processing line. This will therefore bring down the costs of the packaged product.

At various points in harvesting and packaging, producers and



Differences in hyperspectral signatures of Golden Delicious apples based on condition of fruit (Source: USDA ARS)

Hyperspectral imagers are used to capture just the critical spectral and spatial attributes of the food products within the field of view of the sensor. When combined with established spectral libraries and algorithms that characterise product acceptance parameters, hyperspectral sensors can make 'accept or reject' decisions when deployed at critical points in the processing line.

spectral imaging over a conveyor processing line, the sensors enable a set of inspection capabilities. This is as food producers and packagers ramp up volume with precise inspection control over key steps in the production process.

For example, key application areas where hyperspectral imaging holds considerable potential for producers is the inspection of fat content in

distributors capture precise spectral information from processing control points for a much larger number of product samples. Traditionally, the industry sampling of product conditions has been limited either by simple machine vision or single point spectral instruments deployed in an off-line manner.

The limitation of these systems is that they are only capable of sampling a very small area or

number of the overall product flow, and do not lend themselves to high speed production processes. In addition, these options are costly due to labour required to do the testing, poor sampling rates, and the time required for the analysis.

DEFINING HYPERSPECTRAL ANALYSIS

Along the processing line, hyperspectral imagers capture and build a wavelength intensity map of a scene with high spatial resolution. The combination of spectral data and spatial detail enables the high-speed analysis of chemical content, uniformity, quality, and a host of other product characteristics and attributes.

Within a food inspection operation, the hyperspectral imaging instrument yields the following results:

- Rendered view of the processing line based on known chemical spectra or established spectral libraries
- For in-line or at-line deployment, spectral wavelengths of interest can be interrogated based on defined intensity thresholds as material and samples pass by the imaging sensor
- For any point or pixel within the field of view, the chemical spectra or spectral signature of any particular point can be determined while maintaining the integrity of spatial information obtained

Due to the criticality of food processing applications, the imaging performance of the sensor is critical. Therefore high quality imagers do not use transmissive optics or prisms within the instrument design, as these components contribute to the degradation of image

performance and measurement accuracy.

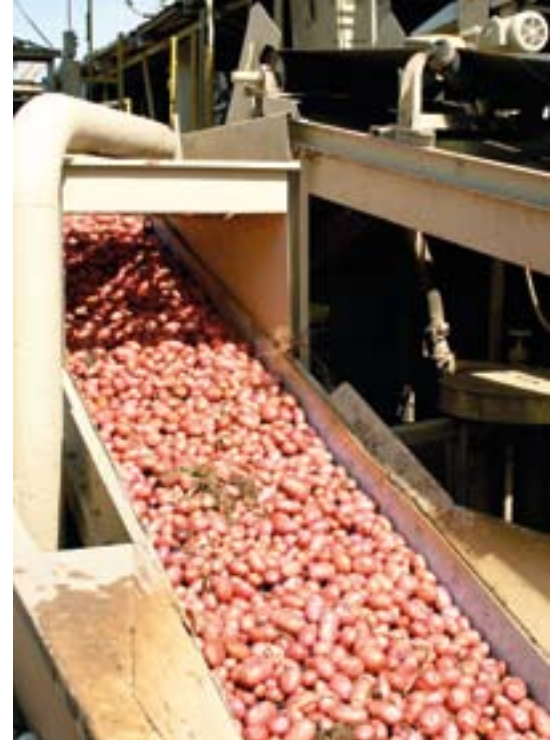
Hyperspectral imagers are deployed as a scanning 'push-broom' spectral imager. For each moment in time or frame capture by the sensor, the scene observed by the instrument fore-optic lens is imaged onto a tall slit aperture of the hyperspectral instrument.

The scene that fills the slit aperture of the sensor is re-imaged through the spectrometer with the wavelengths dispersed by a diffractive grating onto a two dimensional focal plane array (FPA) such as a charge coupled device or CCD.

One axis of the focal plane array (pixel-rows) corresponds to the imaged spatial positions within the field of view all along the slit height. The second axis (spectral for pixel-columns) corresponds to the spectral wavelength that is linearly dispersed and calibrated. Each two-dimensional image or frame capture is digitised by the FPA to build a dataset that comprises all of the spectral and spatial information within the scene or field of view of the sensor.

While scanning a wide conveyor belt or processing line, multiple two dimensional image frame captures are rapidly taken as tablets pass by the hyperspectral imager. These individual frames are taken at very high speed and are stacked like a deck of cards to produce a data file commonly called a hyperspectral datacube. The value of each pixel within this hyperspectral datacube represents the wavelength calibrated spectral intensity of that pixel's small field of view on the scene.

Imaging performance attributes that are critical to the successful deployment of hyperspectral sensing for food safety inspection is the



achievement of high spectral and spatial resolution coupled with exceptional photometric accuracy.

GOING FORWARD

While hyperspectral imaging has been established as a proven, hardened technology for the harsh environments of military, defense, and remote sensing deployments, the use of hyperspectral imaging for in-line food safety and food quality inspection has demonstrated considerable value over the past few years.

Understandably, critical application drivers in the adoption of in-line hyperspectral inspection instruments are both food safety and quality, as well as tenderness. With the introduction of commercially available hyperspectral instruments that operate to inspect high volume processing lines, these hyperspectral imaging sensors are now being deployed to increase processing yields in a cost-effective manner at points along the production process with an attractive return on investment, and short payback period. **APFI**

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