The benefits of hyperspectral imaging

Hyperspectral inspection of fish quality (image courtesty Maritech AS).

Euan Smith and *Nick Barnett* explain how advances in hyperspectral imaging can boost food quality and process control.

Where colour cameras capture images in three wavebands – red, green, and blue (RGB) – hyperspectral imaging (HSI) captures many, sometimes hundreds, of spectral bands. A camera is 'hyperspectral' if it captures contiguous wavebands anywhere from the visible to the far infra-red.

Human colour vision provides some limited indication of food quality, such as the ripeness of fruit or superficial bruising. HSI can extend this identification and classification much further, revolutionising inspection at all stages of food processing. Looking beyond RGB enables identification and classification of unwanted incoming product, monitoring of key processes, and outgoing quality assurance.

Recent advances in camera sensors and imaging techniques are reducing the cost, and in some cases, the size of HSI cameras. Whereas improvements in image processing, including machine learning and increased computing power are simplifying production-line integration to provide actionable data. Furthermore, as a non-contact inspection technology, HSI generates no additional waste as no product needs to be probed or modified in any way.

Identifying unwanted matter

While food sorting can be done by human workers, visual inspection requires consistent attention to detail inevitably leading to mistakes due to fatigue and distractions. Automated optical sorters making decisions based on colour, size, and shape of product, provide continuous monitoring and benefits in accuracy and consistency. However, contaminants, defects and unwanted material are not always easy to detect based on just an RGB image. By inspecting over many wavebands, HSI is able to better discern foreign objects, such as grit or stones, in coffee beans or rice.

An example of this is when sorting nutshell from nuts on a process line. Prediktera AB, a Swedish supplier of HSI software for real-time

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analysis, has developed classification models based on its Breeze software. Training data were collected using a hyperspectral camera operating in the SWIR (short-wave infra-red, 1000nm – 2500nm) range with samples of nuts (almond, hazelnut, pecan and walnut) and shells for each nut. A classification model enabled rapid real-time identification and sorting of nuts into different categories and detection of shells.

Assessing freshness and quality

When it comes to evaluating quality and freshness, HSI can be used to analyse moisture content, fat, protein, and to detect chemical changes caused by product degradation or adulteration. It has been shown to be a powerful technique to assess marbling, ageing and potentially, tenderness in meat. In the fish industry it has been used for sorting species, quality grading and parasite detection with higher precision and far higher speed than by human visual inspection. And spectral cameras can provide faster, more objective assessments of fish quality with reduced manual handling and labour costs.

The Maritech Eye scanner has been developed by Maritech AS (Norway), in close cooperation with Nofima, NEO/HySpex, Lerøy Norway Seafoods, and Lerøy Havfisk, and uses a Baldur V-1024 camera operating in the visible and near infra-red. It was originally launched for white fish applications in 2020, then for red fish in 2021. It scans fish early in the production process to see through the skin, analyse and document blood spots, and enabling the grader to sort at speed.

HSI is also used for quality assessment and sorting of berries and other small fruits that are sensitive to handling and storage, and where quality parameters tend to deteriorate rapidly if the product is not managed carefully. Spectral imaging can evaluate external attributes – such as colour, texture, firmness, surface damage, bruise, defects, and contaminants – and spectral data can be correlated to destructive wet lab analysis results to determine the internal nutritional parameters without damaging the product. Typical parameters suited for spectral analysis include flavour, moisture content, dry matter, total soluble solid content, anthocyanin, acidity, pH, sugar content, and vitamin C.

NEO/HySpex has built an automated classification model to identify and separate healthy and rotten blueberries in real-time. Similarly, the Agro Food Robotics programme at Wageningen University has developed an HSI system that images trays of fruit, allowing the water and sugar content to be mapped.

Improving process control

HSI has wide application in process control too. For example, NEO/HySpex has developed a solution for cocoa bean quality control. The standard procedure for testing quality is a destructive process where the cotyledons of cocoa beans are exposed by cutting the beans into halves, then visually examining them to identify the presence of slaty or white beans, mould, germination, and over- or under-fermentation within a sample batch. HSI, combined with a trained classification model, has shown classification accuracy close to 80% without having to cut the beans open.

This technique can enable automated inspection lines to provide real-time evaluation results for sorting and pricing, and can also assess germination, over-fermentation, mould, and white beans. Enabling the analysis of all beans can provide a more reliable assessment of the overall quality, especially compared to the traditional sampling process.

HSI is a powerful non-contact technology that can perform numerous inspection and metrology tasks within the food processing industry. It has, however, had limited applications within the sector to date, probably due to high camera costs (particularly for short-wave infra-red cameras) and image processing requirements.

Recent advances in sensing materials, image processing and computing power are starting to make the technology much more accessible. These improvements and lower-cost approaches will enable HSI to be more widely used for routine food processing tasks such as separating ingredients from foreign or unwanted material. For example, for sorting nuts from their shells through to identifying and removing plastics or other unwanted by-products of previous handling stages. It can also check incoming produce for quality and authenticity, for example the ripeness of fruit or identifying if cod has been replaced with a lower-cost white fish.

The greater adoption of HSI over the next few years should help to improve food quality and reduce waste, thereby reducing both processing costs and carbon emissions and delivering improved value for all of us as consumers. ■

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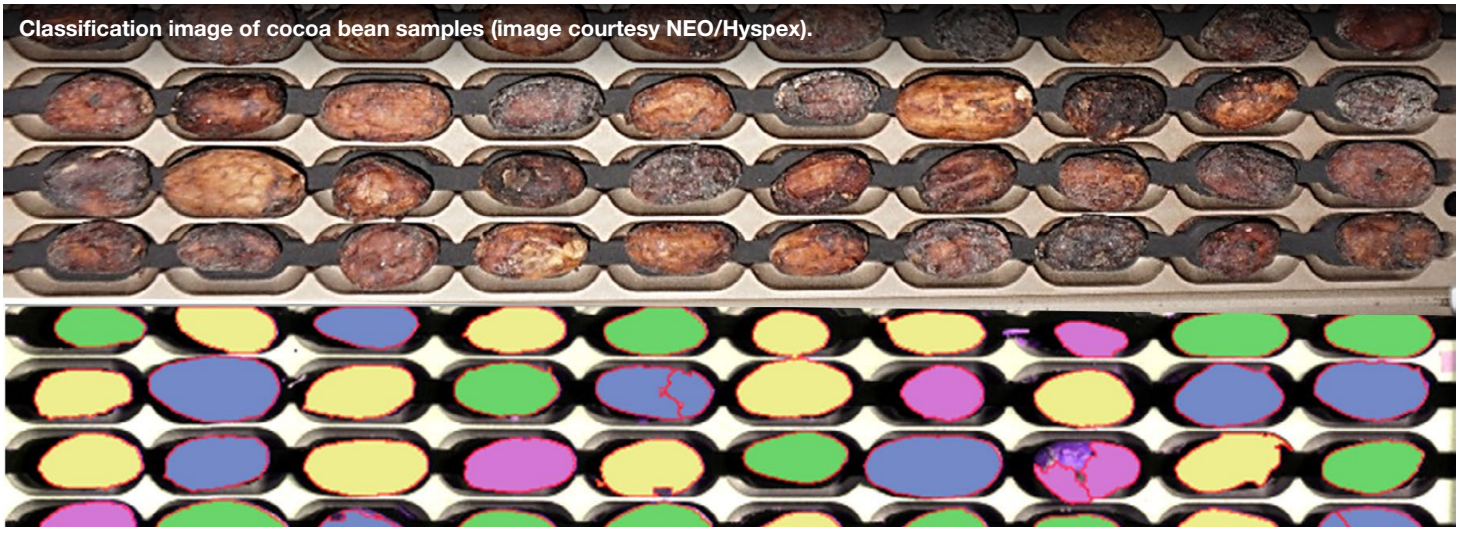

Classification image of cocoa bean samples (image courtesy NEO/Hyspex).