CAMLIN PHOTONICS

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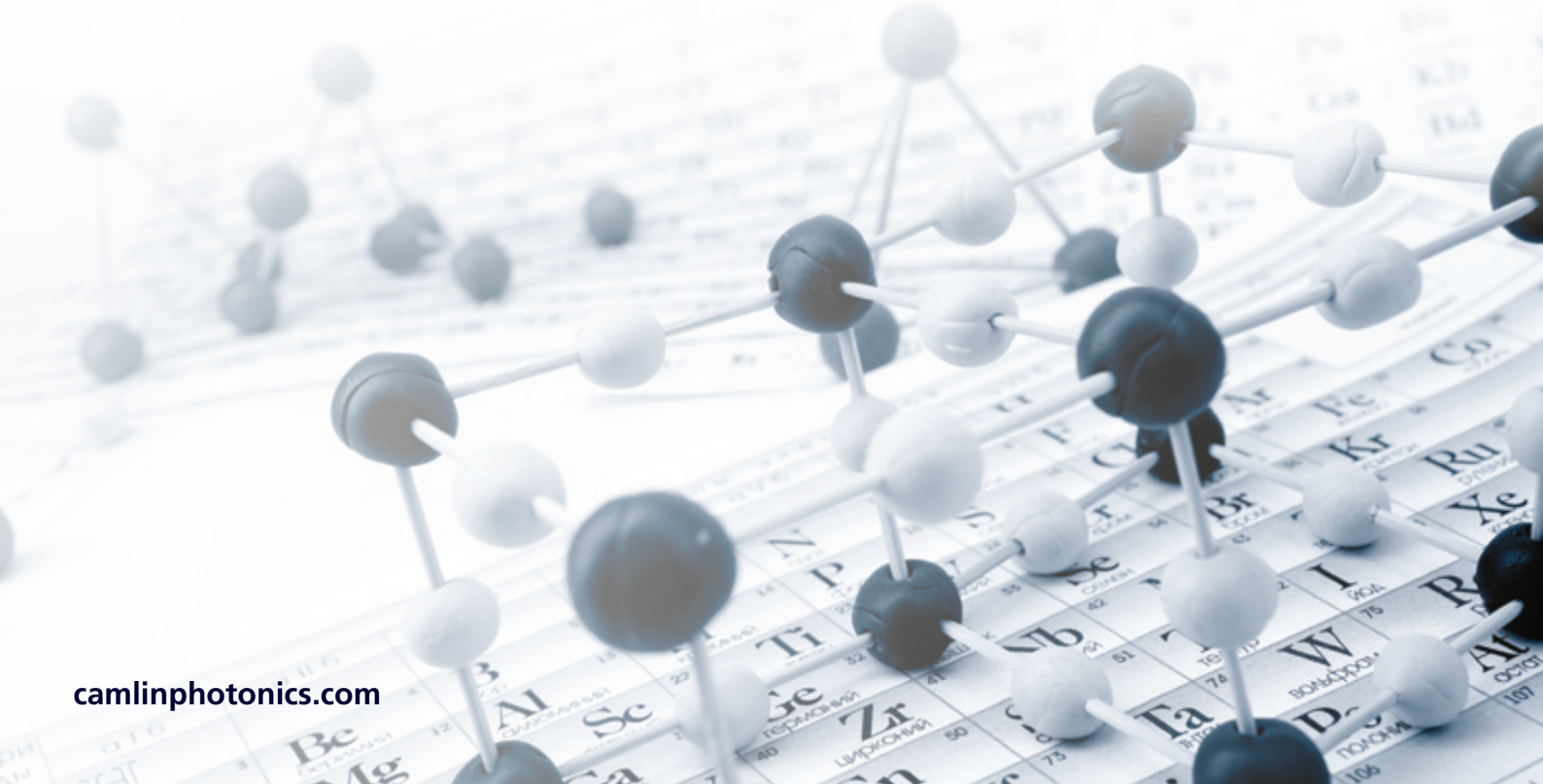
INTELLIGENT HYPERSPECTRAL IMAGING SOLUTIONS

Assessment, Quality Control & Security of Food Products with Hyperspectral Imaging



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FOOD ASSESSMENT, QUALITY CONTROL & SECURITY

During the last three decades, hyperspectral imaging (HSI) has developed into a smart analytical tool for food and agricultural inspection. The basic hyperspectral technique creates a spatial map of spectral features that enables identification of material components and their spatial distribution.

As such HSI, has become one of the key analytical tools for evaluating food products, their authentication, and security. The reason for this is that the spectral features are a "fingerprint" of the material and spectral imaging has developed to be a fast, reliable technique, suitable for automated quality inspection.

Quality is not just about a single parameter, but is a combination of many parameters, especially in food assessment. It is here that optical spectroscopy and especially hyperspectral imaging has been very successful as it is non-destructive, non-contact, and can simultaneously determine several parameters in real time.

Size, shape, colour, and surface texture of food can be easily measured by conventional machine vision systems. The prediction of other parameters such as fat, sugar, moisture content, protein, material homogeneity, or materials hazardous to the consumer for food safety can be delivered by hyperspectral imaging.

HYPERION HYPERSPECTRAL IMAGING SYSTEMS: AN END-TO-END SOLUTION

Our products are designed as a complete end-to-end solution, to make robust, reliable, accurate and repeatable hyperspectral measurements and are easily adaptable to a wide range of processes. This approach ensures the user can measure, display, prepare calibration models and analyse HSI data in one system, with a clear work-flow, to ensure fast turn-around to provide parameters of interest with the best reliability and accuracy.

Important to all measurements is how to pre-process and analyse the data sets. Not only are our hyperspectral software tools comprehensive, we have the resources to help you with the analysis challenges that might occur. At Camlin Photonics dedicated scientists and engineers, with years of practical spectroscopy, machine vision, and artificial intelligence experience in both laboratory and industrial environments, are available to support your application needs.

Since the systems operate by the line push-broom scanning technique, the measurement and data analysis methods are completely transportable from research laboratory to on-line inspection. Desktop systems can use translation type scanners or high-speed conveyor belts depending upon the needs of the applications. This makes it very straight forward to deploy in factory as well as laboratory environments. Systems can also be configured fully enclosed and ready for steam cleaning in food factory situations.

Examples of system configurations and hardware and software specifications are in the HYPERION HSI technical data sheets.

In the handling of fruit and vegetables several steps occur from harvesting, cleaning, sorting, grading and packing before finally being shipped to market. Some damage is not easily seen by human eye, especially so on high speed processing lines. If sorted manually, it is slow, expensive, inconsistent, inefficient and subject to human perception and error.

Hyperspectral imaging has a superb performance for determining many parameters of fruit and vegetable health such as presence of bruises or damage, pH, soluble solids, as well as colour and appearance of the skin. For example, a damaged skin might carry the risk of pathogens. In addition, other defects such as chilling damage and internal lesions can be investigated. Indeed, for such analysis hyperspectral reflection modes can be extended to include transmission and also fluorescence imaging.

Fruit and vegetable maturity can be quickly assessed as well as their firmness. For example, as bananas ripen the water content of their skin declines resulting in drop in reflectance between 800 and 960nm. Determination of moisture in fruit by HSI allows the processor to act to prevent defects associated with high moisture contents – critical for food stability.

Application Example	Spectral Range	Parameter
Apple	VNIR & NIR	Bruise detection, firmness and soluble solids, chilling injury, sugar content, starch index and faecal contamination
Avocado	VNIR / NIR	Dry matter content
Banana	VNIR	Firmness, maturation, soluble solids, moisture content, colour.
Blackberry	VNIR & SWIR	Colour, maturity, sugar content
Cabbage	VNIR	Bacterial contamination
Carrot	VNIR	Moisture content, colour
Cucumber	VNIR	Bruises, chilling injury, internal damage (using transmission HSI)
Grapes	NIR	Phenol content, sugar content (°Bx), titratable acidity, and pH.
Mango	VNIR	Skin damage
Mushroom	VNIR	Chilling damage
Onion	NIR	Skin damage and skin souring
Orange	VNIR	Soluble solids
Peach	VNIR	Firmness, bruising, colour, pH, dry matter
Pear	VNIR	Bruising, firmness
Potato	VNIR / SWIR	Cooking time, potato blight, starch, sugar content, contaminations
Spinach	VNIR	E.coli detection, faecal contamination
Strawberry	VNIR	Bruises, chilling injury
Tomato	VNIR / SWIR	Bruises, cracks, firmness, internal damage, maturation

CEREALS & OTHER GRAINS

Hyperspectral imaging has been very successfully applied in this area and especially the high spatial resolution has become a bonus to measurement of cereals and grains. This has enabled real-time evaluation and sorting of kernels.

Parameters of interest are: size, shape, colour and appearance and with HSI being applied one can assess protein content, one of the most important parameters as it affects the functional performance of the processed product, as well as chemical composition of the kernels, oil and oleic oil, moisture content, wheat classes, contaminant and diluting compounds.

As well as sorting contaminated from healthy, for example insect contamination or indeed mycotoxins and aflatoxins such as *Aspergillus flavus* and *Aspergillus parasiticus* that are naturally growing in corn, other grains and peanuts.

Application Example	Spectral Range	Parameter
Barley	VNIR / SWIR	Aflatoxin B1, protein, moisture
Corn	VNIR / SWIR	Aflatoxin B1, moisture, oil content, Oleic acid, endosperm hardness, fusarium infection, *Aspergillus flavus* and *Aspergillus parasiticus*
Rice	VNIR	Type sorting, *Aspergillus oryzae* detection, contaminants such as grain sized plastics
Sesame	NIR	Oil content
Soy	VNIR	Colour, moisture
Wheat	VNIR / SWIR	Moisture content, class, protein, fusarium damage, insect damage, range of mycotoxins and aflatoxins

High Speed Sorting

High speed sorting or grading can be empowered by using hyperspectral imaging for a very wide range of applications including food sorting. The spectral signature combined with the spatial information allows excellent determination of substandard product, contamination, presence of foreign bodies, as well as defects by colour, shape, and size.

Using Near-Infrared spectral cameras provides the added benefit of being able to separate good products from foreign materials with otherwise similar colour and shape. The spectral signature is a superb discriminator in many cases for "the good, the bad, and the ugly" objects.

Our advanced machine learning and classification algorithms allow discrimination methods to be set-up for the process line and the output can be applied in real-time to interface to gravity, paddle separators, or robotic arm pickers, etc.

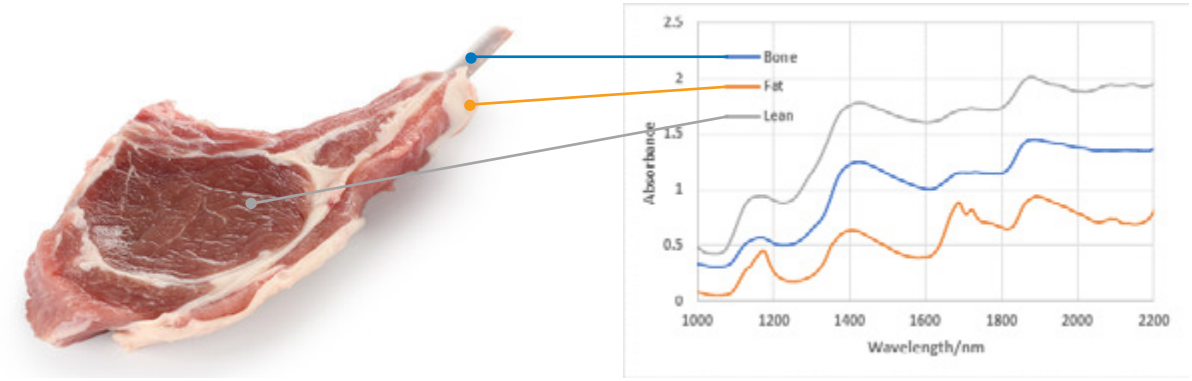



Demand for high quality meat products and consumer safety is increasing. Consumers qualify their purchases by colour, marbling, tenderness, and so on. Hyperspectral imaging has been applied in these areas to identify different red meat species, to predict: freshness, tenderness, determine fat, protein, collagen, and water levels as well as colour, drip loss, and pH. In addition, adulteration of product has been demonstrated by hyperspectral imaging in, for example, minced lamb meat.

The ability of hyperspectral imaging to characterise and determine the distribution of various chemical attributes in meat has made it a powerful technique for measuring concentration gradients and heterogeneity.

For example, the measurement of intramuscular fat is a very useful predictor of quality that affects juiciness and flavour, and even health for consumer as consumers are very conscious of the fat level in products. At slaughter, pH is one of the important parameters to measure as this affects meat colour, water-holding capacity, and texture, as well as inhibiting microbial growth and some enzyme functions.

Poultry inspection at high-speed is one application where hyper-spectral imaging is moving to on-line for the detection of faecal matter, tumours and wooden breast. Bones in chicken fillets is a particularly important consumer issue and hyperspectral imaging has demonstrated high accuracy in detection.



Application Example	Spectral Range	Parameter
Beef	VNIR / NIR / SWIR	Prediction of tenderness, identification and authentication, determination of pigments, pH, tenderness, fat content, water holding capacity, marbling, colour
Chicken	VNIR	Wooden (Woody) Breast, bones in fillets, water content, detection of tumours, bruising, extent of Deep Pectoral Myopathy, faecal and ingesta contaminants.
Lamb	VNIR / NIR / SWIR	Classification of muscle, fat content, pH, detection of adulteration, freshness, colour, conformation grading
Pork	VNIR / NIR	Freshness, tenderness and meat quality, drip loss, colour, pH (and in salted pork), *E.coli* contamination. Discrimination between fresh and thawed pork

SEAFOOD

Due to the high nutrition content of meats they are susceptible to microbial contamination and hence a consumer risk. Hyperspectral imaging is a promising technique for fast and accurate detection. It has already been applied to beef steaks and pork as well as in fish meat. Freshness is a key parameter of fish quality. Hyperspectral imaging has been successfully applied to this area and in high-speed production environments to measure fish freshness, effects of storage conditions and storage times, chilling and freezing effects as well as gaping, blood and melanin spots, bone detection in fillets, detection of amino and fatty acids, oxidation of lipids, and colour grading in a range of high value fish including: cod, salmon, trout.

Application Example	Spectral Range	Parameter
Bass	NIR	Freshness, fat content, moisture content
Cod	NIR	Freshness
Salmon, fresh, salted & smoked	VNIR / NIR / SWIR	Freshness, blood spots, melanin spots, gaping , bones, colour grading, fat content, astaxanthin content, total viable micro-organisms
Swordfish	VNIR / NIR	Freshness
Trout	VNIR / NIR / SWIR	Freshness, blood spots, melanin spots, gaping, bones, colour grading, fat content
Tuna	VNIR / SWIR	Total Fat, fatty acids, colour, freshness
Oyster	VNIR / NIR	Moisture, protein, fat, glycogen content and freshness

Processing Lines: Hyperspectral Imaging and Machine Learning

The main drivers in food processing remain: improving yield, reducing waste, enhancing reliability and guaranteeing hygiene and food safety. Success in these drivers depends upon effective processing equipment and also rugged, reliable measurement of product.

Camlin Photonics has extensive experience in deploying hyperspectral imaging and other optical spectroscopy equipment into a wide range of industrial and food processing environments. This has required robust instruments with appropriate IP ratings to ensure that they can be steam cleaned in normal food processing environments and still provide reliable high-speed measurements.

Our SpectraSENS software has support for touch screen use, and can take additional inputs such as barcode readers, weighing scales, and other input devices appropriate to the process needs. SpectraSENS can also measure the process line speed and adjust camera line-frame rates to ensure square pixels are automatically formed.

Whilst making hyperspectral measurements is important, processing the data to provide useful information is critical for improving the process yields. Our extensive capabilities in both machine vision and Artificial Intelligence algorithms have successfully been applied in this area. We have a dedicated team for such activities to support our customer applications and to provide meaningful quality information on their processes.

In dairy products it is possible to measure chemical composition based upon the spectral signature. For example, classification of cheeses based on their fat, protein and carbohydrate content using either NIR or SWIR spectral ranges. The spectral and spatial information can demonstrate the distribution of water, fat, is it hard or soft, and if there are other materials in the cheese that might affect its preservation or pose a risk to the consumer.

In addition, hyperspectral imaging has been successfully used for detection of contaminant materials such as waste plastics in cheese and other food groups.

In milk and other turbid food materials the absorption and scattering over the VNIR spectral range can be related to fat with excellent correlation. Indeed, the adulteration milk powder products for both milk formula and animal feeds by adding melamine has been well reported to enhance the apparent protein content of the product.

Hyperspectral imaging in the NIR can provide excellent sensitivity to detect melamine at even relatively low contaminant levels. In the case of melamine in milk powders circa <200ppm concentration levels are reported.

Application Example	Spectral Range	Parameter
Cheese	NIR / SWIR	Protein, fat, carbohydrates, moisture
Milk	VNIR / NIR	Fat content, detection of Melamine in milk powder

Good Health

To maintain good health the body needs functional foods and hyperspectral imaging has been applied to characterise these foods, at least to characterise the key molecules that give the attributes to the functional food. For example, products high in Omega-3 and Omega-6 are valued for good brain health and vision; and raising the level of "good" cholesterol respectively and as such products rich in these fatty acids are premium products at higher sales price. Hyperspectral imaging has been used in the NIR to identify and classify functional foods and to quantify Omega-3 levels in for example fish, olive oil, garlic, flax seeds and walnuts and other nuts. While Omega-6 is reported in chicken, pork, beef, dairy, vegetable oils and some baked items such as cookies, and bread.

Fish oil and other food supplements, as well as pharmaceutical materials that are suspended in liquids such as oils are commonly packed in soft-shell gel capsules. These capsules are generally made from gelling agents in a water solution such as animal proteins (gelatine) or plant polysaccharides. Often additives are added to the gels to change their properties such as hardness, colour, surface treatment and so on, or added as preservatives.

Since the gel capsule holds a liquid, its integrity and product lifetime is very important. Hyperspectral imaging can identify the gel capsules materials, their colour and properties, as well checking contents, leakage and gas ingress.

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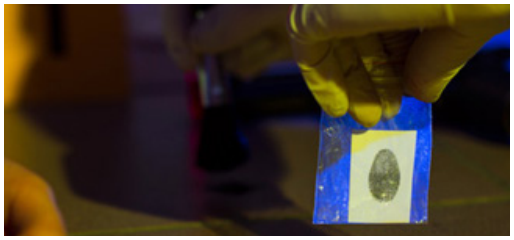
Other Hyperspectral Imaging Applications

At Camlin Photonics we have successfully delivered hyperspectral imaging systems in many other applications. For example:

- **Art conservation** - Hyperspectral imaging can reveal underlying paints and can be used to confirm the chemical constitutes of a paint, binding agents, and other materials.
- **Forensics** - Hyperspectral imaging can reveal altered text in documents, body and other fluids in scene of crime as well as bruising and wound age profiling.
- **Industry quality control** - Hyperspectral imaging can detect foreign objects in production lines.
- **Medical** - Hyperspectral imaging has a wide range of applications in the medical field. These applications range from differentiating between different types of tissue, to detecting abnormal blood flow or oxygen supply.
- **Recycling** - Infrared hyperspectral imaging can differentiate between different types of plastic regardless of the colour of the plastic, which facilitates recycling processes.



ABOUT US

Camlin Photonics are specialists in optical spectroscopy and provide a wide range of both hyperspectral and conventional spectroscopy instruments and full systems. All our products are supported by leading software for data acquisition, analysis and display. At Camlin Photonics we take care of the technology, so you can focus on what matters to you.

We believe in high quality engineering and design, allowing us to develop market leading products and services. Within our Photonics Research Facility, we have the capability to rapidly develop new products and systems and welcome the opportunity to partner with our customers on new developments – both within the scientific research community and for equipment for industrial applications.

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