

Spectroscopy Applications in the Agricultural Industry



The agricultural industry is responsible for meeting the food production demands of an ever growing population. Maximizing production while still protecting the environment is a grave concern in many parts of the world today. Modern food production is increasingly turning to the science of spectroscopy to monitor crop health and improve production yields.

Avantes spectrometers are trusted by researchers in the biological sciences and by agricultural equipment manufacturers to provide accurate spectral data at a fair cost. After more than two decades developing spectrology solutions for numerous applications, we have the expertise to assist with designing an optical spectroscopy system for any application.

Applications in Crop Production



Nitrogen Concentration in Rice

Monitoring plant health characteristics and improving crop conditions are instrumental in maximizing production yield. Researchers from the Institute of Digital Agriculture at the Zhejiang Academy of Agricultural Sciences in Zhejiang, Hangzhou China developed a series of indices for the measurement of chlorophyll in the leaves of rice plants¹. Chlorophyll has a very strong and well documented correlation to nitrogen content, a primary indicator of plant health.

Employing an older version of the [AvaSpec-ULS2048CL-EVO](#), these researchers explored the use of the Yellow Edge Reflectance Index (YERI) and Red Edge Reflectance Index (RERI) for

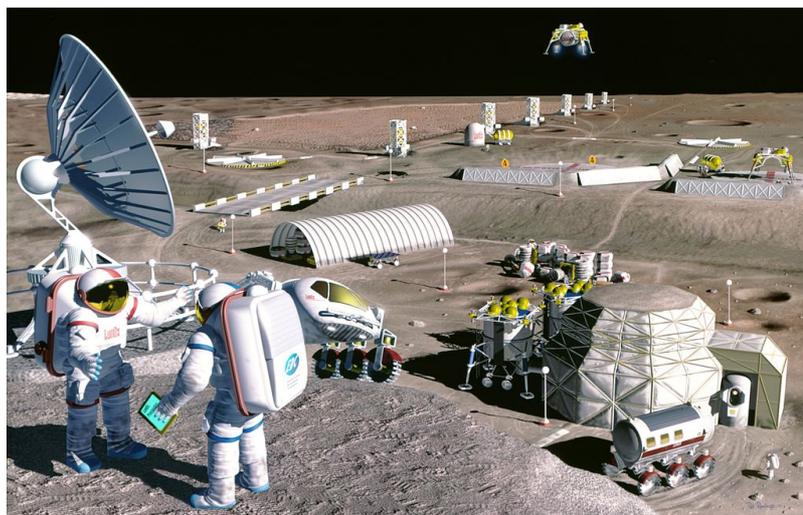
calibrating nitrogen and chlorophyll values to reference spectra at each stage of plant development and varying states of plant health². The theoretical work behind this study is applicable to other crops, once reference spectra can be correlated^{3,4}.

Fertilizer Automation Application

The principles used by the Zhejiang researchers are employed in commercial applications in use today. Yara, the UK agricultural giant founded in 1905 and committed to technological advancement in the agricultural industry, has developed the [N-sensor](#). This real-time, variable-rate nitrogen sensor works in concert with fertilizer spreaders to monitor plant conditions and adjust fertilizer application accordingly at the point of application. This means that the optimal amount of fertilizer is always used, both maximizing crop yield and reducing waste and environmental impact from over application of fertilizer.

Wheat in the Pacific Northwest

Wheat prices are set based on protein content and falling wheat prices have hurt farmers in this region in particular. The soft white winter wheat that is well suited to the climate in the PNW, has a lower protein yield than other varieties. Other varieties that are adapted for the region and have a higher protein yield also require more nitrogen fertilizer. Spectroscopy instruments were used to define a standard for measuring protein levels and the equivalent nitrogen values. This is the critical first step to developing variable-rate fertilizer technology for commercial application in the Pacific Northwest for wheat farmers⁵.



Food of the Future

Long term space missions and Mars colonization projects will require humans to produce food in environments that are less than optimal for plant growth. This has important ramifications for planning to meet the dietary needs of these future colonies. The Laboratory of Environmental Biology and Life Support Technology, in partnership with the International Joint Research Center of Aerospace Biotechnology & Medical Engineering at Beihang University, Beijing, China are studying the effects of low-intensity light on growth, photosynthesis and yield of wheat⁶. The researchers used an [AvaSpec-](#)

[ULS2048](#) spectrometer to control the light intensity of different test groups at the various growth stages. They discovered that low light at early growth stages had little effect in the ultimate yield, so long as adequate light was available during the later grain filling stages.

Applications during Harvest

Maximizing harvest and monitoring produce quality on the way to market is an important piece of the puzzle in ensuring the future food supply. Spectroscopy is used at this stage of the food stream as a non-destructive method to assess produce ripeness and quality.

There are researchers around the world working in the NIR range to devise indices for standard qualitative assessment of various produce. These indices can be used in-line to automate sorting and grading at the point of harvest and after.

Among the fruits that have been studied for this type of spectroscopy measurement are Jonagold apples, sweet cherries in Hungary, peaches in Spain, and several varieties of grapes in Italy.

Jonagold and Fuji Apples



Avantes has previously reported on researchers working to develop standards for [evaluating the ripeness and quality of Jonagold and Fuji apple varieties](#). Working in red, and near infrared range (600-1100nm), these studies developed several objective indices for the qualification of apple ripeness and quality based on water and soluble sugar content, as well as color.

Sweet Cherries

Researchers in Hungary, which produces roughly 10-12 thousand tons of cherries annually, investigated the absorption characteristics of anthocyanin, a water soluble plant pigment that appears red, blue or purple depending on minute changes in the pH of the plant. The [AvaSpec-ULS2048L](#) proved to be an optimal instrument for working in the red spectra (570-730 nm) and in the NIR (900-970 nm), and with samples at various stages of the life cycle and varying health status. This project ultimately developed four spectra indices to objectively qualify cherry fruit. In addition to anthocyanin, color and water content indexes were important factors⁷.

Peaches

Perceived ripeness is the most important quality indicator for customers, therefore it is the primary consideration after harvest. But, how ripeness is qualified has mostly been subjective because objective tests were destructive in nature. We do know that soluble sugar content (SSC) and water content (which affects firmness) are highly correlated with fruit quality. NIR spectroscopy has been proven an effective means to measure SSC and water content due to their spectra absorption properties.

Italian researchers using an early model equivalent to the [AvaSpec-NIR256-1.7](#) worked on the development of an index standard for correlating the results of NIR spectroscopy to perceptions of ripeness allow this technology to be utilized in commercial applications to put this technology to use in the field⁸.



Grapes and Wine Production

Wine production is a very important industry in many parts of the world, especially in Italy. Researchers from the department of Agricultural Engineering at the University of Milan, Italy applied Vis/NIR spectroscopy to characterization of grape composition at harvest. They sampled an astonishing 156 grape varieties throughout 2005 and 2006 while working toward a rapid in-line means of predicting ripening parameters identified to affect wine quality⁹.

Grape composition at harvest is the primary determinant of future wine quality. Several factors are considered in grape composition including familiar ripeness indicators such as soluble sugar content and acidity as well as phenolic compounds anthocyanins (as in the cherries study) and polyphenols.

This study conducted with the aid of the [AvaSpec-ULS2048L](#) showed promise for the development of a portable VIS/NIR optical measurement system working in the 450-980 nm wavelength range for quick, non-destructive grape quality measurements with a 95% validation rate at the time the study was completed in 2010. Since that time, spectrometer technology has advanced to the point that these applications are a "ripe"



opportunity for the development of commercial systems.

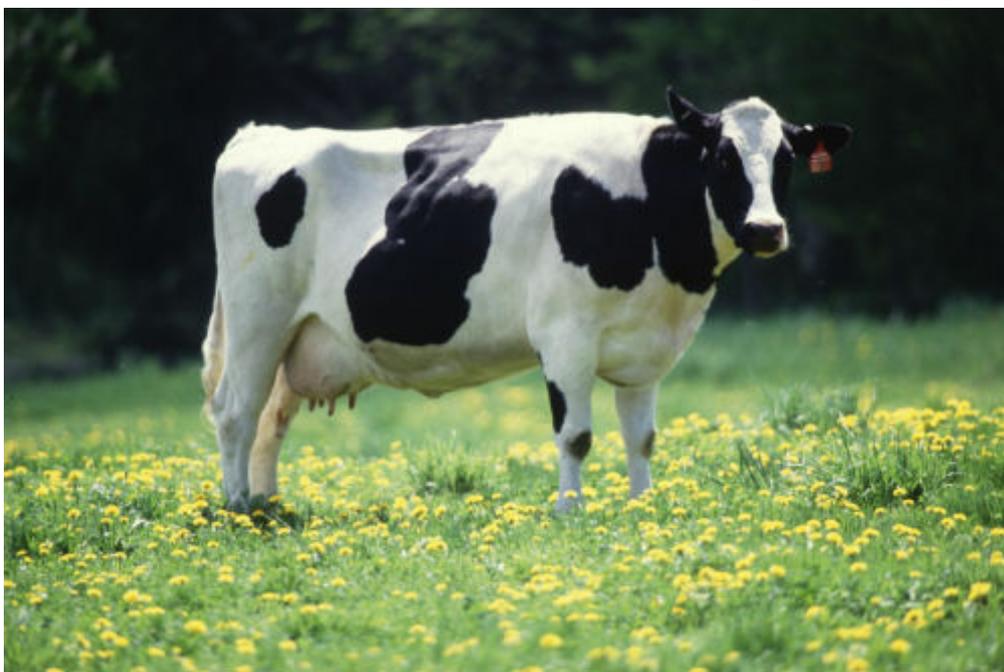
Food Product Applications

Milk Production

There are several uses for spectroscopy in the dairy industry. Fluorescence spectroscopy is used to analyze milk content for proteins, fat, water content, carbohydrates and minerals. The traditional chemical methods of analysis require specialized personnel, laboratory equipment and are often destructive in methodology. The constituents of milk products are typically studied in the UV (185-210 nm) and NIR (800-2500 nm) wavelength ranges.

Research by a team at the University of Food Technologies in Plodiv, Bulgaria is aimed, in part, at giving inspectors a tools to curb the proliferation of milk products adulterated with the addition of vegetable fats, sugars, and foreign proteins¹⁰.

The French company Spectralys Innovation, in partnership with Actalia, the center of expertise for the food industry, has developed the [Amaltheys, a commercial fluorescence analyzer for assessing denatured whey proteins in cheese milk](#). This systems allows cheese producers to monitor curd coagulation and standardize cheese production yields¹¹.



Egg and Beef Quality

Work is underway to develop methods for quality

assessment of numerous other food products. Among the more interesting recent examples are the use of VIS/NIR spectroscopy to assess egg freshness and beef tenderness.

Researchers working with Beef from China Agricultural University, College of Engineering, Beijing, China are working with the [AvaSpec-NIR256-2.5](#) spectrometer to measure characteristics of meat quality, among them: water content, fat content, color, pH, and tenderness. In addition to studying the constituent macronutrients, this team also considered the use of NIR spectroscopy to look for common contaminants such as total volatile basic nitrogen¹².

Eggs are another popular source of protein, and monitoring freshness from inside the shell was problematic, however, researchers from the Egg Quality and Incubation Research Group studied the NIR and visible light transmission spectra obtained from eggs. Using the [AvaSpec-ULS2048L](#), the EQIRG discovered a strong connection between the transmission spectra collected and traditional measurements of egg freshness, such as pH and Haugh Units which measure protein quality based on the height of the albumin, or egg white¹³.

Catching Food Counterfeits

There are several food products that, due to demand or price, are frequently counterfeited. Honey and Olive oil are two examples of products that are frequently adulterated or “counterfeit.” Honey is one of the world’s most faked foods. Adulterated alcohol has also been a topic in the news recently with resort areas in Mexico trying to prevent the sale of these potentially deadly counterfeits. Wendy Meulebroeck and a team from the Vrije University Brussels, Belgium published a series of studies on photonics enhanced sensors in food monitoring in IEEE Instrumentation and Measurement magazine. This research employed the [AvaSpec-ULS3648 spectrometer](#) with resolution possible down to 0.1 nm, and made great strides in demonstrating the suitability of NIR spectroscopy for identification and authentication of solid and liquid food products¹⁴.

The Royal Society of Chemistry has also studied the issue of food frauds and is working on the development of a point-and-shoot rapid detection method for in the field analysis of the food chain¹⁵. They evaluated the [AvaSpec-NIR256-2.5-HSC](#) for use in a system that takes rapid food analysis out of the lab and puts it on the front lines of

Avantes in Agriculture and Food

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