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SPECTRA OF THE MONTH

SPUD SPECTROSCOPY: DETERMINING DIFFERENCES BETWEEN POTATOES AND SWEET POTATOES

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INTRO

BACKGROUND OF APPLICATION

Every year on the fourth Thursday of November, Americans celebrate one of the country's biggest holidays of the year: Thanksgiving. This event has been celebrated as a holiday nationally on and off since 1789 and was officially recognized as a federal holiday in 1870. Some of the most common Thanksgiving traditions include watching the Thanksgiving Day Parade or an American football game, gathering with family and friends, and eating a traditional Thanksgiving meal. This meal is centered around a whole turkey that is accompanied with sides such as stuffing, cranberry sauce, various casseroles, mashed potatoes, and sweet potatoes, which are often mislabeled as yams. While the two potato varieties can be clearly differentiated by appearance, differences can also be determined through composition. Sweet potatoes contain slightly more sugar, more water, and less starch compared to their more common counterpart, and also contain a significant amount of vitamin A, whereas regular potatoes contain only trace amounts. With these differences in mind, we hope to quantify these differences through multiple spectroscopic techniques.

This experiment aims to determine differences between potatoes and sweet potatoes using absorbance and fluorescence spectroscopy. A small russet potato was used for the potato sample, and a small Beauregard sweet potato for the sweet potato sample. Absorbance spectra were taken of each sample to determine differences in sugar and water content, and fluorescence spectra were taken of each sample to determine differences in vitamin A content.

FIGURE # 1 Potato samples used for this experiment (from left to right: russet potato and Beauregard sweet potato). The potato samples were measured as-is for the NIR measurements, while slices of each potato were measured for the fluorescence measurements.

DESCRIPTION OF SPECTROSCOPY SETUP

Two setups were used for this experiment, one for the absorbance measurements and the other for the fluorescence measurements. The setup for the absorbance measurements utilized our AvaSpec-NIR256-2.5-EVO spectrometer. Specifically for measurements in the NIR range up to 2.5 µm, this model pairs our high-sensitivity optical bench with next generation electronics for exceptional performance, including 0.53 ms/scan sample speed and integration times as fast as 10 µs. The AvaSpec-NIR256-2.5-EVO is equipped with our trusted InGaAs (Indium-Gallium-Arsenide) array detector and our ultra low-noise electronics board with both USB3.0 and Giga-Ethernet connection ports onboard. The instrument used in this experiment had a wavelength range of 1000-2500 nm and a 25-micron slit installed.

The fluorescence measurement used our new AvaSpec-PCT2048CL compact spectrometers. This instrument is built using our new semi-automated manufacturing technique that ensures higher levels of consistency and reproducibility unit-to-unit. The compact spectrometer offers USB2.0 communication as well as RS232 and SPI communication protocols, a CMOS linear array detector, ultra-low stray light as low as 0.1%, and a signal/noise ratio of 375:1. Furthermore, this spectrometer can be customized with a wide range of gratings, and the replaceable slit option is now standard for non-OEM units, which provides even more flexibility for a variety of application needs. This unit was configured with a wavelength range of 480-800 nm and a 200-micron slit.

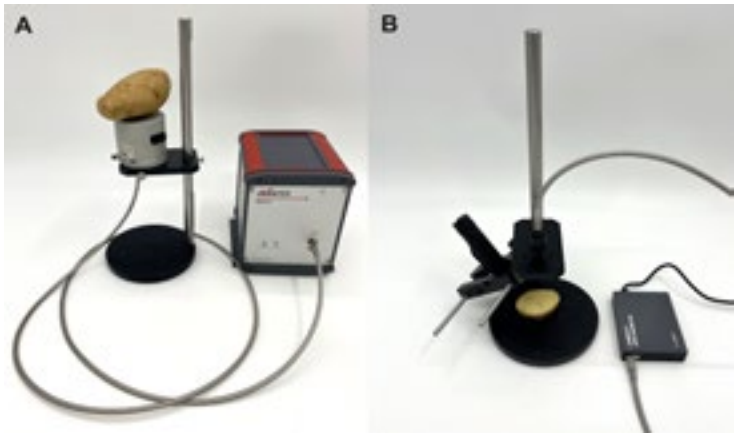

FIGURE # 1 Setup for potato sample measurements. (A) For the absorbance measurements, the potato samples were placed directly over the port of the integrating sphere, and the integrating sphere was connected to the NIR spectrometer via a fiber optic cable. (B) For the fluorescence measurements, a slice of each potato sample was illuminated with the UV flashlight at an angle and was measured with a collimating lens attached to a fiber optic cable along with an in-line long-pass filter.

The light source used for the absorbance measurements was a built-in halogen light in our AvaSphere-50-LS-HAL-12V integrating sphere. While specifically designed for reflection applications, this integrating sphere is also useful for low reflecting materials and NIR spectral measurements, where signal strength can be limited. The built-in halogen light source provides diffused halogen light on the sample without the losses associated with fiber-optic coupling, with up to 160 times more light on the sample compared to our standard reflectance integrating sphere. The AvaSphere-50-LS-HAL-12V has an internal diameter of 50 mm, a 10 mm sample port, an SMA-terminated reference port, and a direct collimated SMA-port for collection of the signal with any of our AvaSpec spectrometers. The light source used for the fluorescence measurements was a commercially available UV flashlight with a 365 nm peak. Other accessories used for this experiment included a 400-micron core fiber optic cable (FC-UVIR400-1-BX) to connect the integrating sphere to the NIR spectrometer and to connect to the compact spectrometer during the fluorescence measurements, a WS-2 white reference tile (not pictured) for the absorbance reference measurement, a collimating lens (COL-UV/VIS) for the fluorescence measurements, an in-line filter holder (FH-INL) and a 485 nm long-pass filter to isolate the fluorescent signal from the UV light, and a mounting stage to hold the integrating sphere in place for the absorbance measurements and the fiber optic cable and UV flashlight in place for the fluorescence measurements.

DESCRIPTION OF METHODOLOGY

The potato samples used for this experiment were a small russet potato and a small Beauregard sweet potato. For the absorbance measurements, dark and reference spectra were taken using our WS-2 white reference tile with the internal halogen light of the integrating sphere turned off and on, respectively. Each whole potato was then individually placed over the opening port of the integrating sphere and measured. For the fluorescence measurements, a slice of each potato sample was taken to provide a more uniform measurement surface and better comparison between the samples. This did not have to be done with the absorbance measurements since the measured NIR spectrum penetrates past the surface of the samples. The fluorescence measurements were performed in a dark room to minimize the presence of ambient light, and the light illuminated the samples at an angle to exclude specular reflection in the measured spectra. To further isolate the fluorescence of the sample from the UV light, a 485 nm long-pass filter was used to block the majority of the light from the UV flashlight from being measured by the spectrometer.

For data analysis, we used both Absorbance and Scope-Minus-Dark mode in AvaSoft. As the name suggests, Absorbance mode is designed for absorbance applications, where the reference measurement will report 0 A.U. (absorbance units) and 5 A.U. when the light source is turned off. In this experiment, the WS-2 white reference tile was used as the reference. For the fluorescence measurements, Scope-Minus-Dark mode was utilized. This is a common mode for fluorescence measurements, as it subtracts the dark spectrum (what the spectrometer measures with no light source) from the raw counts (i.e., scope mode) over the whole spectrum. This helps minimize noise in the spectrum and better isolate and identify the fluorescence peaks. For the absorbance measurements, we used an integration time of 15 milliseconds and set averaging to 35 for more consistency between measurements. For the fluorescence measurements, the integration time was set much longer at 500 milliseconds due to less light being available for measurement. Averaging for these measurements was set to 4 to provide a more consistent measurement but also not create too long of a timeframe between measurements.

TEST DATA AND RESULTS

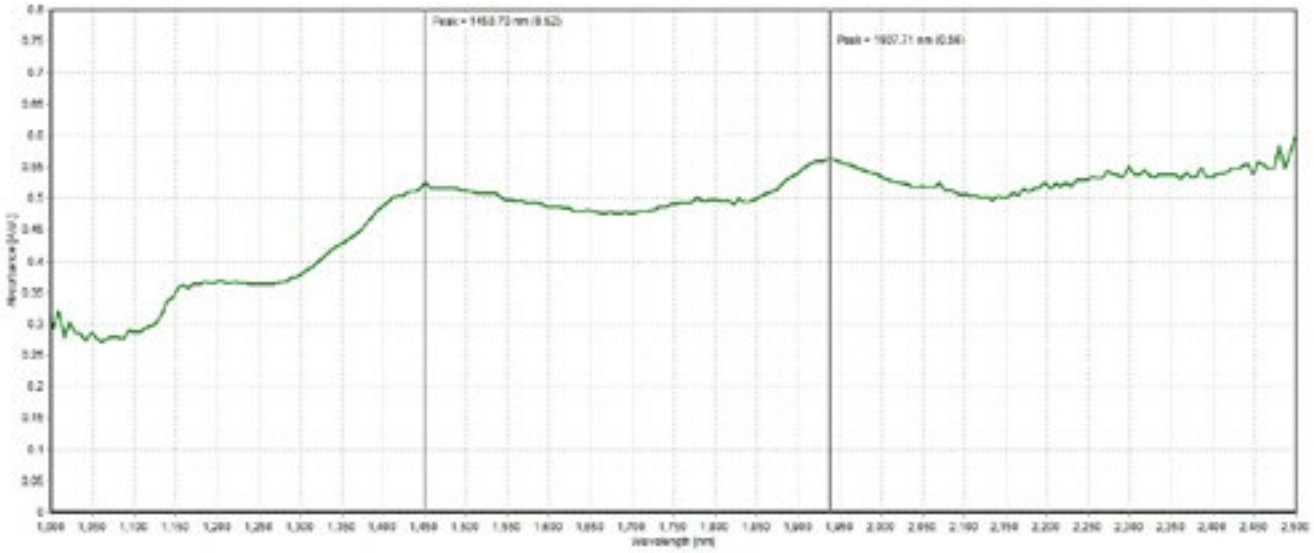

FIGURE #3: Absorbance Spectra of Potato Sample

TEST DATA AND RESULTS

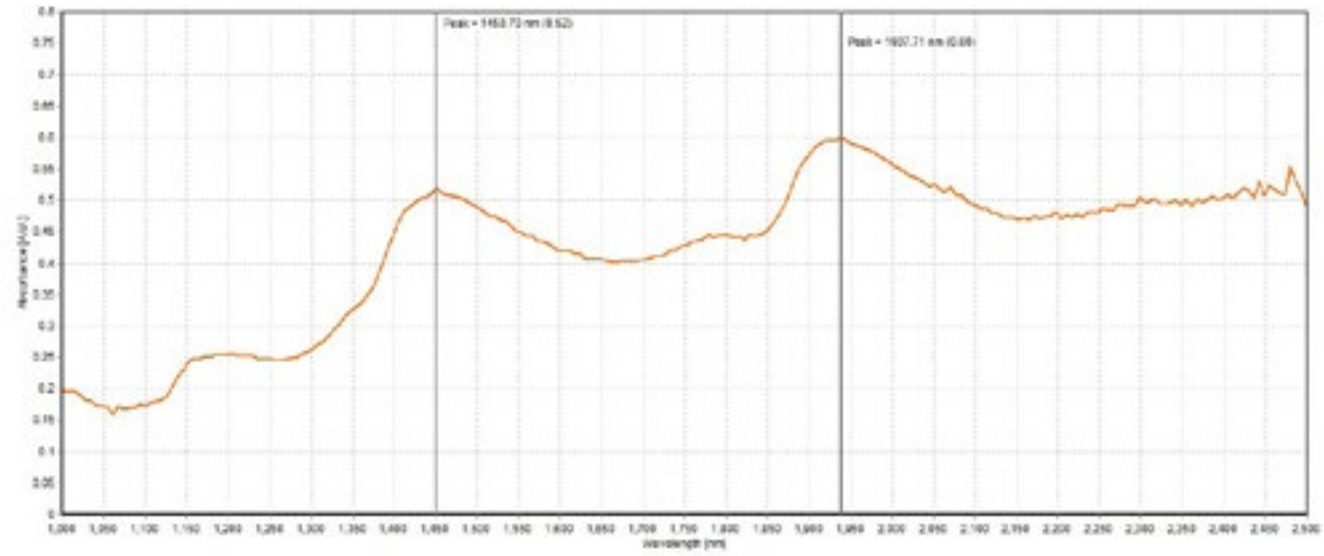

FIGURE #4: Absorbance Spectra of Sweet Potato Sample

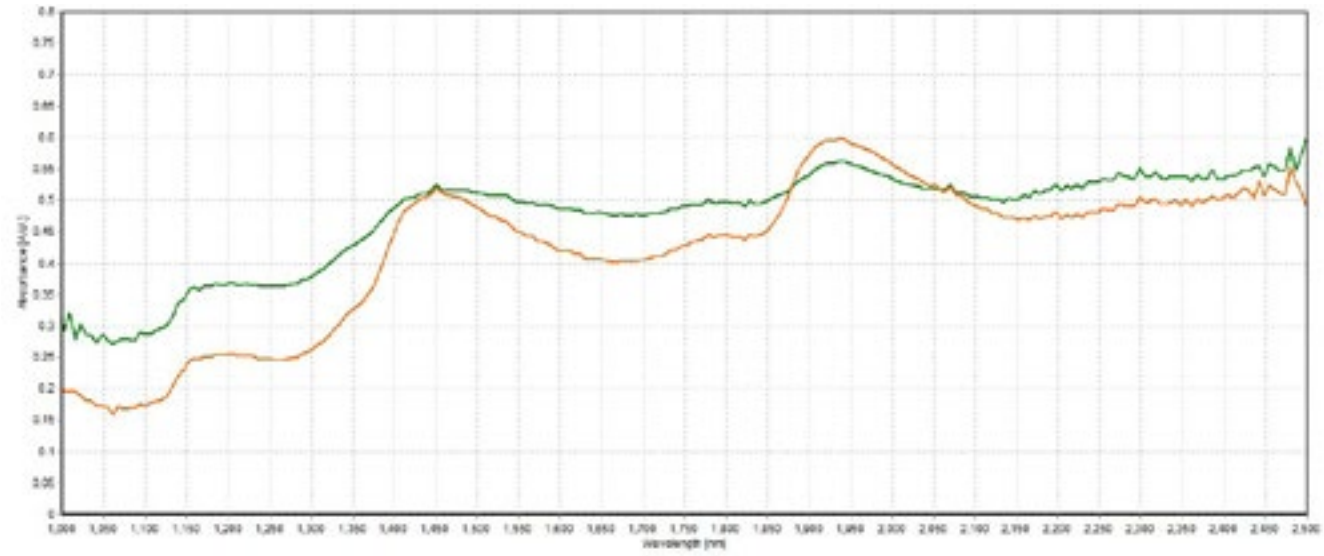

FIGURE #5: Absorbance spectra of both potato (green) and sweet potato (orange) samples, shown together for comparison.

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ANALYSIS

For the absorbance measurements, both the potato and sweet potato samples showed absorption peaks around 1450 nm and 1937 nm. Both peaks have been correlated to both sugar and water content, so neither peak can be definitively tied to one constituent in these measurements. It is worth noting that the peak at 1937 nm is higher in the sweet potato sample than the potato sample, which could be correlated to either the higher water or sugar content seen in sweet potatoes compared to regular potatoes. While the peak magnitude at 1450 nm is similar for both samples, the slope around this peak is sharper for the sweet potato sample. This could indicate a relatively higher sugar content compared to overall starch for the sweet potato sample compared to the potato sample. For the fluorescence measurements, different peaks were seen in each sample, with a sharp fluorescence peak seen around 680 nm in the potato sample and a broader fluorescence peak seen around 575 nm in the sweet potato sample. These fluorescence peaks did not seem to correlate with vitamin A content or any other nutritional values. The common constituent with a fluorescence peak at 680 nm would be chlorophyll, which could potentially indicate that the potato sample was fresher than the sweet potato sample since this peak was significantly higher in the potato sample. A potential source of the 575 nm fluorescence peak seen in the sweet potato sample could be manganese, which has an emission peak around 580 nm and is found in a much higher concentration in sweet potato than regular potatoes. Besides these findings, we could not unfortunately measure any vitamin A fluorescence with the presented setup. It should be noted that what appear to be peaks in both spectra around 510-520 nm is remnant light from the UV flashlight, not additional emission peaks.

CONCLUSION

In conclusion, the present experiment highlights the use of both absorbance and fluorescence measurement techniques in determining differences between potato and sweet potato samples. The absorbance spectra showed clear differences in water and sugar content between the samples. While the fluorescence spectra did not demonstrate differences in vitamin A content, potential differences in manganese content and sample freshness in terms of chlorophyll content could be interpreted. The AvaSpec-NIR256-1.7-EVO is a highly versatile NIR spectrometer with plenty of available options to match the bandwidth and requirements fitting your application. The AvaSpec-PCT2048CL is an equally versatile UV/VIS spectrometer produced utilizing our new semi-automated manufacturing technique that ensures a high level of consistency and reproducibility from unit to unit. The AvaSphere-50-LS-HAL-12V is specifically designed for reflectance measurements but is effective for any applications where limited signal strength may be an issue, such as NIR measurements. Please contact Avantes for more information on the configuration that is best suited for your data collection.

TEST DATA AND RESULTS

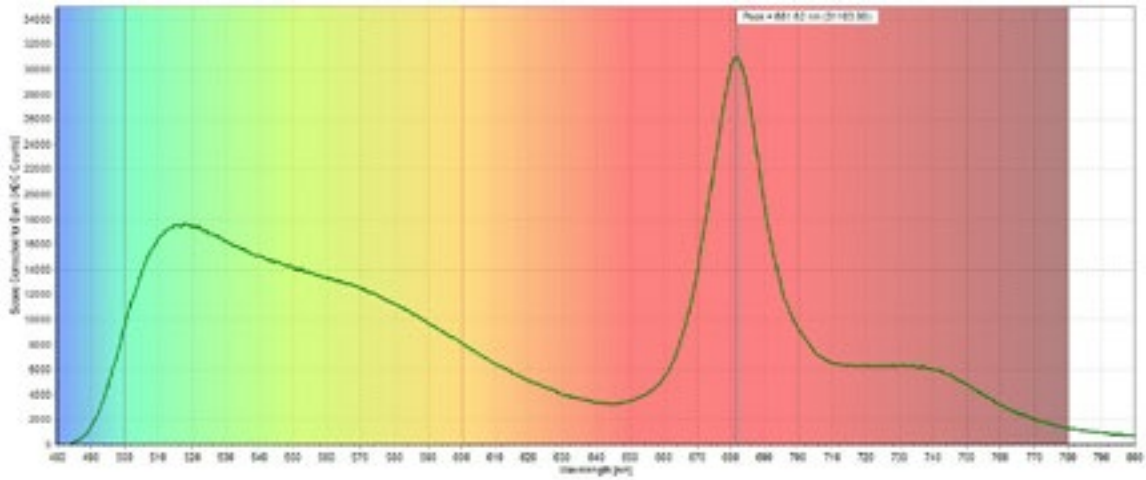

FIGURE #6: Fluorescence spectra of potato sample.

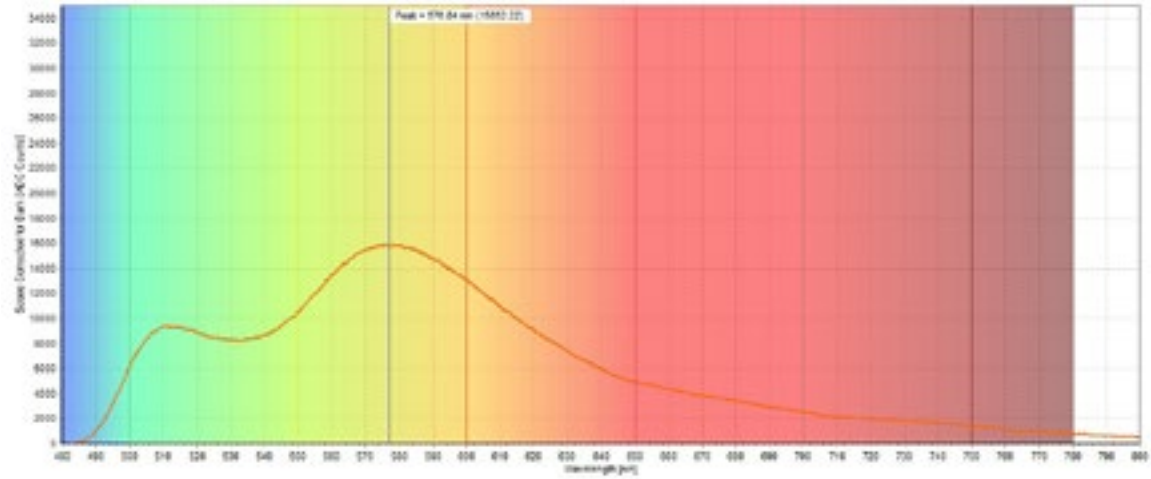

FIGURE #7: Fluorescence spectra of sweet potato sample.

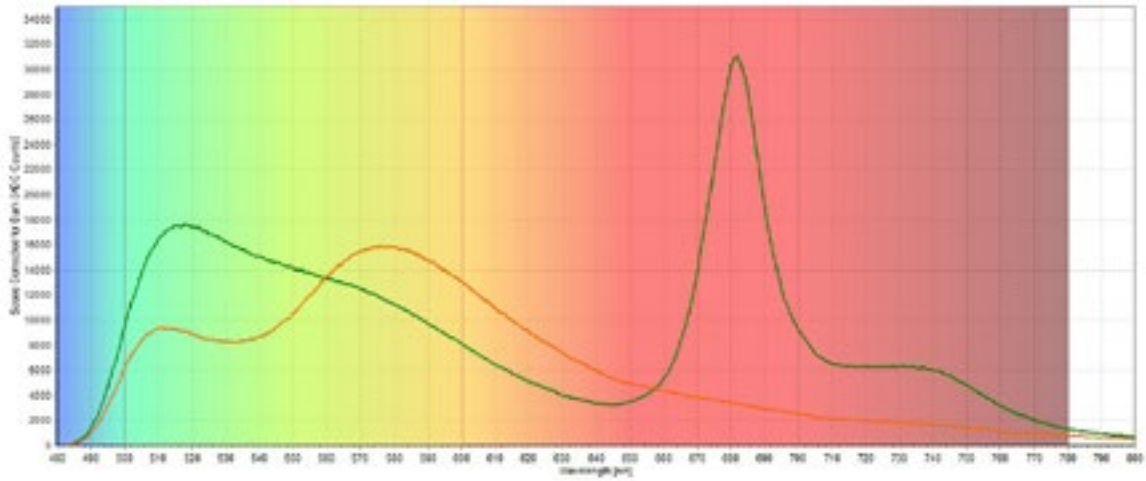

FIGURE #8: Fluorescence spectra of both potato (green) and sweet potato (orange) samples, shown together for comparison.

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