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Exploring the Spectral Database of Food Samples Using ASD Field Spec 4 Spectroradiometer

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Abstract: ***Accurate and precise spectral measurements reflect the inherent properties of the material being analyzed. However, certain factors contributing to changes in spectral signatures can adversely affect the quality of spectral measurements. In this study, we utilized the ASD FieldSpec4 Spectroradiometer, which offers an extensive spectral range spanning from 350 to 2500 nanometers, along with its associated software, to construct a spectral library of food samples. This paper defines a method for standard spectral reflectance measurements and the process for data collection.***

Keywords: ***Spectral measurement, FieldSpec, ASD, Spectroradiometer, Hyperspectral data, Remote Sensing, Field of View (FOV).***

I. INTRODUCTION

Hyperspectral remote sensing can derive data from diverse materials using the spectra gathered by the ASD FieldSpec spectroradiometer [1]. This tool provides band details spanning from 350 nm to 2500 nm, encompassing the visible, near-infrared (NIR), and shortwave-infrared (SWIR) regions, thereby yielding a comprehensive dataset. Researchers encounter significant obstacles when gathering spectral reflectance data, whether in the field or under controlled laboratory conditions. Accurate spectrum acquisition is imperative for effective data extraction. Several factors influence the collection of spectral data, which can be summarised as follows: Due to the absence of a standardised document outlining measurement procedures, we have endeavoured to outline standard data collection techniques for the ASD FieldSpec Spectrometer.

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A. Specifications of ASD FieldSpec4

ASD (Analytical Spectral Devices) A spectroradiometer measures the interaction between the physicochemical features and spectral signature features of an object. The ASD Field Spec 4 spectroradiometer provides more information and is considered the best spectroradiometer in the Field Spec line, tailored to meet specific needs. ASD spectroradiometers have been used in the detection, identification, verification, and quantification of objects. This device features three distinct detectors: the UV/VNIR range (300–1000 nm), the SWIR1 range (1000–1800 nm), and the SWIR2 range (1800–2500 nm). The technical specifications of the ASD FieldSpec 4 are detailed in Table I.

Table 1. ASD FieldSpec 4 Spectroradiometer Specifications [2]

Specification of Field Spec 4 Spectrometers		
Sr. No.	**Performances**	**Value**
1	Spectral Range (nm)	350-2500nm
2	Sampling Interval (nm)	1.4nm@350-1000nm
		1.1nm@1000-2500nm
3	Spectral Resolution (nm)	3nm@700nm,
		10nm@1400/2100nm
4	Scanning Time (ms)	100ms

Figure 1: ASD FieldSpec 4 Spectroradiometer

The systematic approach to data collection involves using a standard measurement. The procedure for acquiring a spectral database is outlined in the subsequent sections. The database is gathered by utilizing the RS3 software, accompanied by the ASD FieldSpec4 spectroradiometer [3]. In laboratory settings, it is essential to have a dark room to prevent interference from other colours and light sources that could impact the spectral signature. The configuration of the spectrometer setup is illustrated in Figure 2.

Figure 2: Spectrometer Configuration in a Laboratory

A. The ASD FieldSpec4 spectroradiometer, developed by ASD over 25 years ago, initiated the field and laboratory spectroscopy science, establishing itself as the premier choice for spectrometers worldwide. These instruments are utilised across various remote sensing applications, encompassing crop analysis, vegetation studies, climate research, snow analysis, soil examination, mineral analysis, defence applications, environmental condition assessment, material quality analysis, and more. The ASD FieldSpec4 spectroradiometer is capable of measuring radiant energy, including radiance and irradiance.

B. Spectrometer Initialization

It is advised to allow the ASD FieldSpec 4 to undergo a warm-up process before usage, with the duration of the warm-up varying depending on the environmental conditions. This warm-up period is necessary to ensure that the three spectrometer detectors—the VNIR silicon photodiode, SWIR1, and SWIR2 detectors—reach thermal equilibrium. ASD recommends a 90-minute warm-up period, while NERC FSF suggests a 30-minute warm-up period for the spectrometer. Following the warm-up period, spectral signatures of materials can be collected using the RS3 software. Upon starting RS3, a splash screen will appear, as depicted in the following figure. It is essential to have either Wi-Fi or Ethernet connectivity during this process.

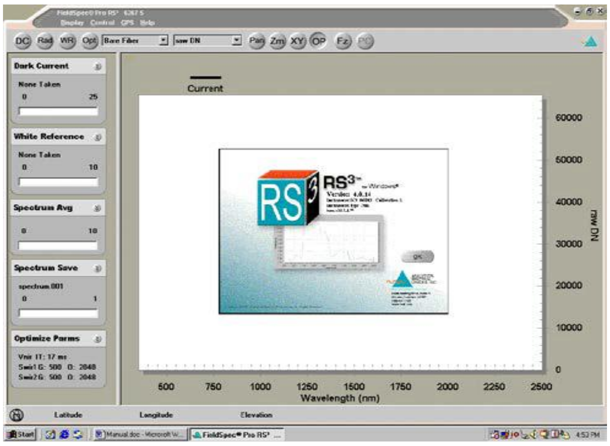

Figure 3: Splash Screen of the RS3 Software

C. Optimization

Before data collection, it is essential to optimize the spectroradiometer, a process that establishes the appropriate settings for the light source used to gather spectra. If the light source remains consistent and the instrument is adequately warmed up, re-optimization is generally unnecessary. However, if the measurement drifts towards saturation, re-optimization becomes imperative. The RS3 application issues a warning in such cases. Unlike optimization, performing a white reference should be done frequently, ideally every ten to fifteen minutes under solar illumination and every thirty minutes with artificial light sources. Depending on the specific illumination conditions during spectral data collection, the instrument's sensitivity is adjusted, typically taking one minute for the ASD FieldSpec. Therefore, regular optimization of the detectors is necessary to minimize saturation levels.

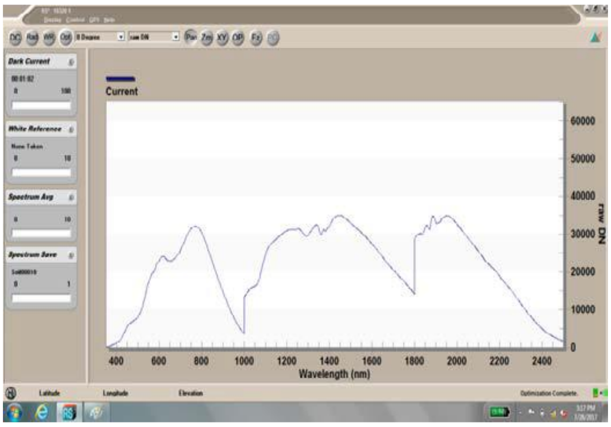

Figure 4: Optimization

D. Dark Current

Dark current (DC) refers to the inherent electrical current present in the electrical components of the spectroradiometer, which interferes with the detection and measurement of light signals. It is a characteristic of the detector and its associated electronics, exhibiting variations due to factors like temperature changes and time fluctuations. To ensure accurate data acquisition, the DC for each channel must be subtracted from the total signal in that channel. The electrical current generated by electrons within the ASD is consistently added to incoming photons of light, resulting in a false signal known as dark current. This dark current stabilizes the incoming current, and during each optimization process, it is automatically collected, stored in memory, and applied to every spectral measurement. Proper execution of dark current (DC) measurement is crucial during data collection sessions, particularly while the spectroradiometer is warming up, to maintain data accuracy.

E. White Reference

The term "baseline" is another name for white reference. White surfaces have the property of reflecting all incident energy into the environment. Therefore, the white reference serves as a calibration or reference panel that reflects 100 percent of the incident illumination, allowing for the calibration of target reflectance. During the collection of spectral data in laboratory or field settings, it is essential to take white reference readings every 10 to 15 minutes to ensure more accurate reflectance spectra.

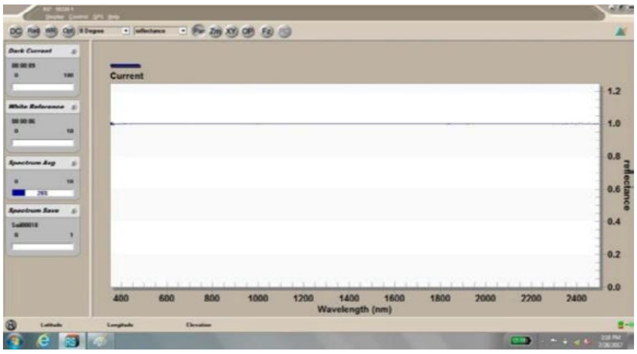

Figure 5: Reading of the White Reference

In the figure, the straight line indicates that 100% of the light is reflected, and the spectroradiometer records this reflected energy.

II. CALCULATION OF FIELD OF VIEW (FOV)

Field of View (FOV) refers to the solid angle through which light reaches the target material. Typically, spectral signatures are obtained from the nadir position. When collecting spectra of any material, it is crucial to configure parameters such as FOV, height, distance, and angle. FOV represents the solid angle of light reaching the target and entering the spectroradiometer. The FOV options available with the ASD FieldSpec4 spectroradiometer are circular, including 1°, 8°, and 25° (bare fibre). In laboratory measurements, one and 8-degree FOVs are used for spectral signature collection, while a 25-degree FOV is employed for field measurements. The following figure shows the FOV geometry, in which the tangent of α and δα, the angles of the instrument's FOV, gives the diameter D [4].

A. For Slanted Position

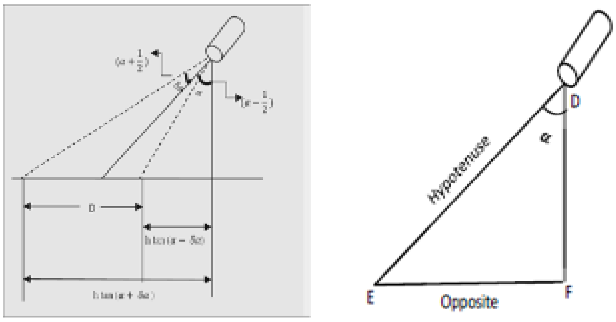

Figure 6: Geometry of Field of View (FOV)and Angle (α) calculation of Field of View (FOV)[4]

B. For Nadir Position

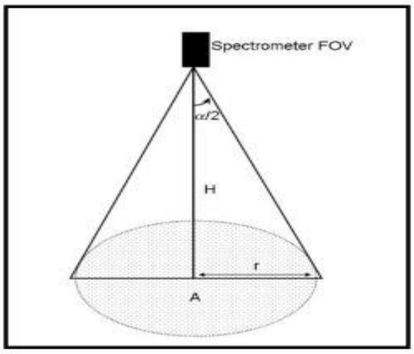

Figure 7: Obtaining FOV at Nadir Position [4]

III. DATASET PREPARATION

A dataset experiment consists of 21 samples, where each sample was tested 10 times. Using an ASD spectroradiometer, as shown in Tables 2, 3, and 4, the standard sample is stored as labels 1, 2, 3, 4, and so on. All the samples were stored in comma-separated value (CSV) format.

Table 2: Chilly Sample

Label	Sample _name
Chilly_1	Chilly Market
Chilly_2	Chilly Market
Chilly_3	Chilly_Market
Chilly_4	Chilly Market
Chilly_5	Homemade
Chilly_6	Homemade
Chilly_7	Homemade

Table 3: Turmeric Sample

Label	Sample _name
TP_1	Turmeric Home
TP_2	Turmeric Home
TP_3	Turmeric Home
Tp_4	Market
TP_5	Market
TP_6	Market
TP_7	Market

Table 4: Tea Sample

Label	Sample _name
Tea_1	Tea Market
Tea_2	Tea _Market
Tea_3	Tea _Market
Tea_4	Tea Market
Tea_5	Tea Market
Tea_6	Tea Market
Tea_7	Without brand

We experimented with a total of 21 samples, including some homemade and others from various market brands. Available market brands of chilly powder, tea, and turmeric were collected and kept in airtight bags with proper labelling.

The following items are used for sample preparations.

•A Petri dish is used to hold the sample for experiments

• A spatula is used to transfer the powder from the bags to the petri dish

IV. DATA COLLECTION PROCESSING

For this research, typical food samples, including homemade chilli powder and turmeric powder, were collected alongside equivalent samples acquired from local markets.

The food sample was enclosed in a 10-gram airtight bag. A spectroradiometer, specifically the ASD FieldSpec 4, was used to analyse the food samples. In the Multispectral Research Lab at the Department of Computer Science and IT, Dr. B.A.M. University, Aurangabad (MS), India, the sample scanning was conducted in reflectance mode within a fully equipped dark room to eliminate external light interference. A tungsten halogen light, coupled with a spectroradiometer, served as the light source at a 45-degree incident angle.

To optimise device signals, calibration accuracy, and sensor response, a standardised spectral panel was used alongside a petri dish and black paper measuring 10 mm by 90 mm as the sample holder. Food samples were individually placed in petri dishes, and their spectral signatures were captured using a spectrometer. Each sample spectrum was scanned 20 times within the wavelength range of 350–1000 nm, with a sampling rate of 1.4 nm and 1.1 nm for wavelengths between 100 and 1500 nm. The ASD FieldSpec4 device required 100 milliseconds to scan each sample. We use a nadir (8-degree FOV) for collecting the spectral signature.

Figure 9: Sample Collection using ASD FieldSpec4 Spectroradiometer.

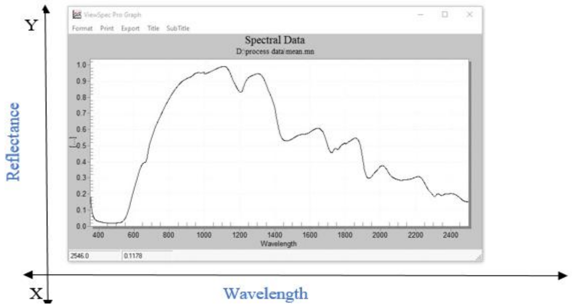

Figure 10: Spectral Data of Food Sample

The ASD FieldSpec4 Spectroradiometer was employed to scan all food samples, and the spectral signature of each sample was acquired using RS3 software. Twenty scans were conducted for each sample, and these were combined into a single mean file for further analysis. Initially, food samples were collected for preprocessing and statistical analysis. In the laboratory, twenty spectral signatures of food samples were recorded and assessed using ViewSpecPro software. However, the signatures did not indicate the locations of absorptions and reflectance in bands. Subsequently, all spectral signature files were loaded into ViewSpecPro software and merged into a single file, representing the average of twenty scan files. This consolidated file was then reexamined in the ViewSpecPro software.

V. RESULT AND DISCUSSION

The data acquired by spectroscopy was continuous-wavelength band data. To analyse this vast amount of data, chemometrics techniques are employed in a multidisciplinary manner to interpret complex chemical data obtained from spectroscopic devices. Chemometrics techniques extract information from spectral data obtained by NIR spectroscopy using mathematical methods, multiple statistical techniques, computational approaches, and machine learning and deep learning algorithms. Food samples, i.e., chilli powder, turmeric powder, and tea powder, were analysed by an ASD FieldSpec 4 spectroradiometer, and the spectral signature of each sample was acquired with the help of RS3 software. The ASD FiledSpec4 device is controlled by RS3 software and comes with the device for developing the spectral signature of any material. After acquisition, the spectral signature can be viewed and processed using various chemometric and statistical techniques with the aid of ViewSpec Pro software, which is also included with the ASD FieldSpec 4 spectroradiometer. For each sample, 10 utterances or scans were taken, and these ASDF files were combined into a single mean file using ViewSpec Pro software. These mean files were then used for further processing. At first, the Pure homemade samples and files were taken for preprocessing and statistical analysis. All 10 pure homemade samples are opened in ViewSpec Pro software and converted into one Mean file. Figure 11 shows the Mean of the Spectral signatures of the samples. The initial phase of data preprocessing focuses on data cleaning to mitigate existing noise. Specifically, measurements within the spectral range of 350-400 nm and 2400-2500 nm were excluded to minimise potential edge effects. This refinement yields a near-infrared region spanning from 500 nm to 2300 nm. The absorbance, or spectral signature, corresponding to each wavelength is then leveraged for subsequent processing. Commonly employed preprocessing techniques in ASD spectroscopy encompass smoothing, mean centring, derivatives, normalisation, standard normal variate, and multiplicative scatter correction. Splice correction and Smoothing are required to explore the information of Spectral bands. For this, the Savitzky-Golay filter is applied, along with the first and second derivatives, as preprocessing techniques. Figure 12 shows the second derivative spectral signature of the sample. The above process is applied to all remaining samples.

Table 5: Preprocessing Algorithms Were used in This Study

Preprocessing algorithm	Impact	Equation
1st Derivative	Reduce the drift of the baseline &Highlight some parts of spectral information	$FD(R) = \frac{Rn+1 - Rn}{\lambda n+1 - \lambda n}$
2nd Derivative	Reduce the drift of the baseline and liner trend. Also highlight some parts of the spectral information	$SD(R) = \frac{FDn+1 - FDn}{0.5(\lambda n+2 - \lambda n)}$
Savitzky-Golay	Remove the high-frequency noise from samples	$R_{i,SG} = \frac{1}{f_{norm}} \cdot \sum_{j=-m}^{j=m} C_j \cdot R_{i+j}$

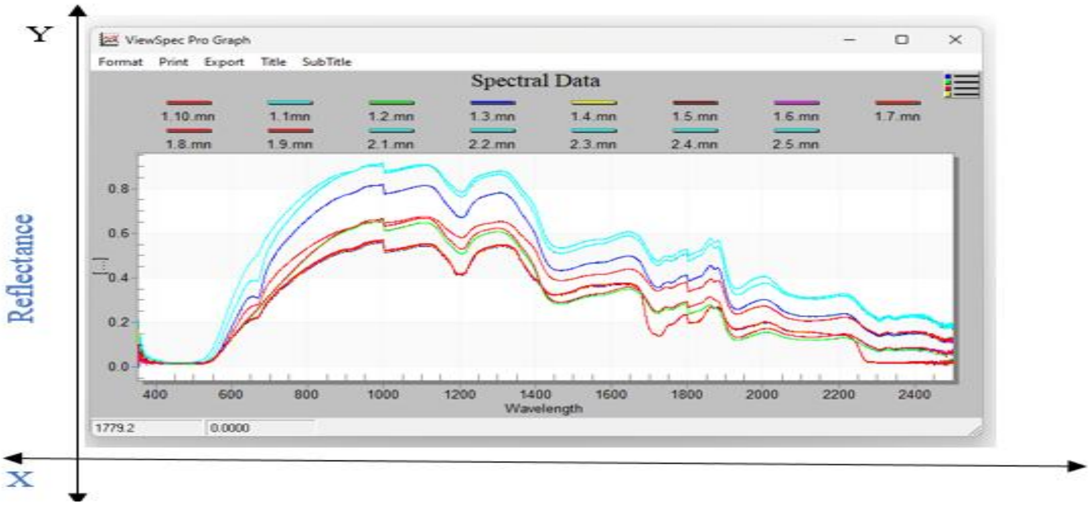

Figure 11: Mean of Chilly Powder

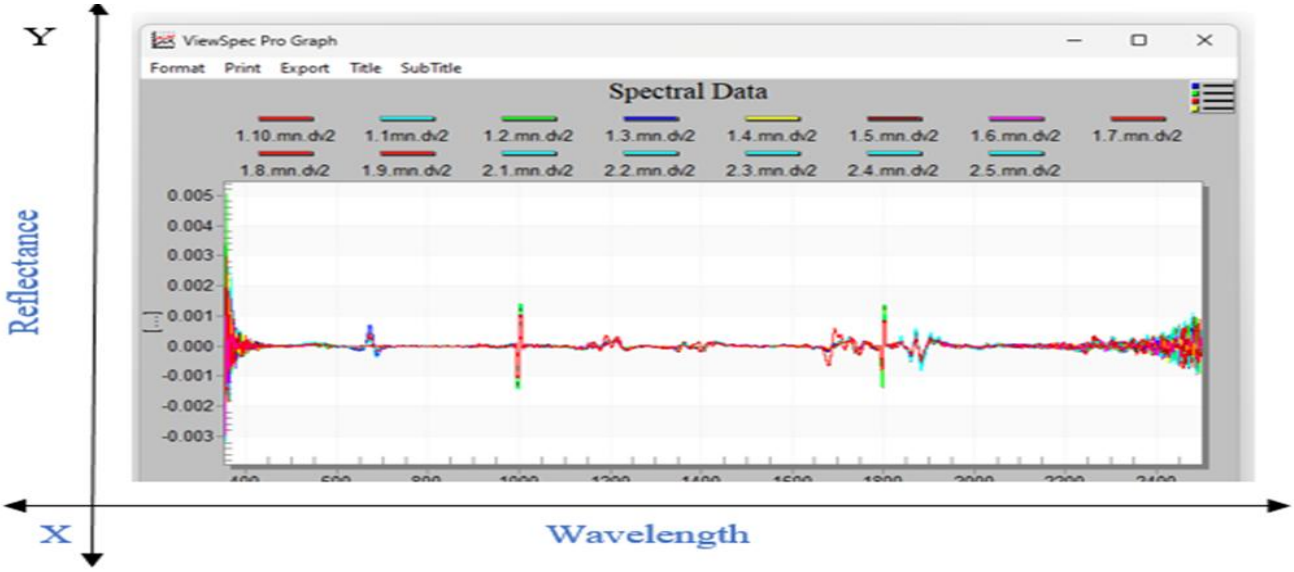

Figure 12: Second Derivative Spectra of Samples

The first and second derivatives are mathematical transformations utilized to address baseline effects in spectra, aiming to enhance the robustness of calibration models for estimating soil parameters. The first derivative (Der Ist) of a spectrum quantifies the slope of the spectral curve at each data point. Given that this slope remains unaffected by baseline offsets, Der Ist proves highly efficient in eliminating such offsets. However, it's essential to note that peaks in the original spectra often correspond to zero-crossing points in the IST spectra, posing challenges in interpretation. On the other hand, the second derivative (Der II) measures changes in slope along the curve. Beyond disregarding offsets, Der IInd is impervious to any linear slopes inherent in the data, rendering it an effective method for concurrently eliminating baseline offsets and slopes from spectra. Nevertheless, it's noteworthy that peaks in raw spectra typically change sign, manifesting as negative peaks in the second spectra [5][6].

VI. CONCLUSION

This study examines food samples and related products using spectral data responses of the specific materials in the View SpecPro software. To identify components within food samples, three different types of excipients have been utilized. The ASDFieldSpec4 Spectroradiometer and associated RS3 Spectra acquisition software are used to collect spectral data. The paper explains that it's essential to measure spectra correctly for any use, and it's also important to understand what the spectra show. We've put together a summary of all the calculations and standard methods for collecting data using RS3 software.

DECLARATION STATEMENT

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval or consent to participate, as it presents evidence that is already publicly available.
Availability of Data and Materials	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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