Scientific and Social Research, 2024, Volume 6, Issue 5
https://ojs.bbwpublisher.com/index.php/SSR

# Non-destructive Banana Quality Assessment and Quality and Safety Monitoring using Spectral Imaging Technology

**Dongmei Zou***

Analysis and Testing Center, Chinese Academy of Tropical Agricultural Sciences/Key Laboratory of Quality and Safety Control for Subtropical Fruit and Vegetable and Laboratory of Quality and Safety Risk Assessment for Tropical Products of Ministry of Agriculture and Rural Affairs, Haikou 571101, China

***Corresponding author:** Dongmei Zou, 1548801248@qq.com



**Abstract:** This thesis discusses a method to realize non-destructive banana quality assessment and quality and safety monitoring using spectral imaging technology. As one of the important agricultural products in China, the quality and safety of bananas have always attracted much attention. Traditional quality assessment methods often require destroying bananas, but this method uses spectral imaging technology to realize the assessment of banana quality by measuring and analyzing the spectral characteristics of bananas. At the same time, this method also utilizes spectroscopic technology to detect harmful substances in bananas to realize the safety monitoring of banana quality. The experimental results show that the method has high accuracy and reliability, and can be used as a rapid, efficient, non-destructive means of banana quality assessment and quality and safety monitoring.

**Keywords:** Spectral imaging technology; Banana; Quality assessment; Quality and safety monitoring; Spectral characterization; Harmful substances detection

**Online publication:** June 7, 2024

## 1. Introduction

Banana is a widely consumed fruit, and its quality has an important impact on consumers' taste and health. However, traditional methods of banana quality assessment often require destroying bananas, which causes a lot of inconvenience to the conservation of banana resources and the safe monitoring of quality. In recent years, spectral imaging technology has been widely used in the field of agricultural quality inspection as a non-destructive, rapid, and accurate detection means.

## 2. Spectral imaging techniques and their application to banana quality assessment

### 2.1. The basic principle of spectral imaging technology

Spectral imaging technology is a kind of imaging technology that uses spectral sensors to obtain the surface or internal structure of an object. By analyzing the spectral information, the nature, composition, structure, and other information of the object can be obtained, and this technology has been widely used in agriculture, food, medicine, and other fields [1–2].

## 2.2. Application of spectral imaging technology in banana quality assessment

### 2.2.1. Visible spectrum imaging

Visible spectral imaging technology can analyze the color, texture, shape, and other characteristics of bananas by obtaining the banana spectral information, to realize the assessment of quality. It is specifically manifested in the following aspects.

Color and luster analysis: the color and luster of bananas is an important index for evaluating quality. Spectral imaging technology can obtain the visible spectral information of bananas, and through the analysis of the spectral data, the chromaticity, brightness, and other parameters of bananas can be calculated, to assess their color quality.

Texture analysis: the texture of the banana surface is also an important factor affecting the quality. Spectral imaging technology can capture detailed information on the banana surface, and by analyzing the texture, the ripeness and disease degree of the banana can be assessed.

Shape analysis: the shape of the banana is also an important factor in evaluating quality. Spectral imaging technology can obtain the shape characteristics of bananas, and through the analysis of the shape, the uniformity, size, and other characteristics of bananas can be evaluated.

### 2.2.2. Near-infrared spectral imaging

Near-infrared spectroscopy and imaging detection have the advantages of high efficiency, rapidity, and non-polluting compared to traditional detection methods [3]. Near-infrared spectral imaging technology can pass through the banana skin and obtain its internal spectral information, so it can be used to assess the internal quality of bananas. It is specifically manifested in the following aspects.

Moisture content analysis: the moisture content of a banana has a great influence on its quality. Near-infrared spectral imaging technology can obtain the near-infrared spectral information of bananas, and through the analysis of the spectral data, the moisture content of bananas can be calculated to assess their freshness.

Brix analysis: Brix is an important indicator of banana quality. Near-infrared spectral imaging technology can obtain the near-infrared spectral information of bananas, and through the analysis of the spectral data, the sugar content of bananas can be calculated to assess their quality.

## 2.3. Advantages of spectral imaging technology in banana quality assessment

### 2.3.1. Non-destructive

Spectral imaging technology does not require the destruction of bananas and allows non-destructive testing of the whole fruit, which is conducive to the preservation of the quality and nutrient content of bananas. This is very important for perishable fruits like bananas.

### 2.3.2. Fast and accurate

Spectral imaging technology can rapidly obtain the image of banana fruits, and by analyzing the spectral information in the image, many quality indicators of bananas, such as the color, shape, and texture of fruits, can be obtained. At the same time, this technique has high accuracy and can help to accurately assess the quality of bananas [4].

### 2.3.3. Multi-indicator analysis

Spectral imaging technology can obtain the spectral information of banana fruits, which includes spectral information of different wavelengths such as visible light, near-infrared light, red light, and so on. This spectral information contains quality-related information about banana fruits, such as color, moisture, sugar, acidity, and so on. Through the analysis of multiple indicators, the quality of bananas can be assessed more comprehensively.

### 2.3.4. Real-time monitoring

Spectral imaging technology can realize real-time monitoring of banana fruits, which helps to discover quality problems in time, so corresponding measures can be taken to improve and deal with them. This is of great significance to ensure the quality and safety of bananas and food safety.

# 3. Preprocessing and analysis of banana spectral imaging data

## 3.1. Preprocessing of spectral imaging data

Spectral imaging is a widely used method in agriculture for non-destructive quality assessment and quality and safety monitoring of fruits such as bananas. To extract useful information from spectral imaging data, data preprocessing is required.

## 3.2. Spectral imaging data preprocessing methods

### 3.2.1. Data Acquisition

First, spectral imaging of bananas is needed. Usually, spectral imaging equipment is configured with different bands, such as visible light, near-infrared light, and red light. According to the ripening degree and quality requirements of bananas, the appropriate waveband for imaging is chosen. In practice, multi-band spectral imaging technology can be used to improve the completeness and accuracy of data information.

### 3.2.2. Data preprocessing

Spectral imaging data usually contain multiple bands, each of which has its unique information. To eliminate the interference of environmental factors and improve the correlation between the spectral data and the attributes to be measured, it is necessary to preprocess the raw spectral data [5]. The preprocessing methods include filtering, denoising, and normalization.

Filtering: in spectral imaging data, there may be some noise and outliers. Filtering can effectively remove these noise and outliers. Common filtering methods include the Butterworth low-pass filter and Hamming filter.

Denoising: There may be some isolated points or spots in the spectral imaging data, and these points cause interference in data analysis. Denoising methods can effectively eliminate these isolated points or spots [6]. Common denoising methods include median filtering.

Normalization: normalization is the process of converting spectral imaging data to a certain range. This can eliminate the effect of data magnitude and numerical size so that the data of different bands can be compared on the same scale. Common normalization methods include linear normalization and logarithmic normalization.

### 3.2.3. Feature extraction

After completing the preprocessing, useful features need to be extracted from the spectral imaging data. There are various subcategories of this type of method according to the different transformation methods and extraction criteria, and these features can reflect banana ripeness, sugar level, acidity, and other indicators [7].

Common feature extraction methods include correlation analysis, principal component analysis, and cluster analysis.

#### 3.2.4. Model building and validation

Based on the extracted features, a model for assessing banana quality by spectral imaging technology can be built. Commonly used models are support vector machines (SVM), decision trees, artificial neural networks, and so on [8]. After the model is established, it needs to be validated to assess the accuracy and stability of the model.

### 3.3. Methods of analyzing spectral imaging data

#### 3.3.1. Preprocessing of spectral data

Before analyzing the spectral data, this interfering information affects the stability and reliability of the classification model and needs to be preprocessed to remove noise and outliers [9]. Filtering and removal of interfering signals such as scattering and reflections can be used to improve the quality and accuracy of the data.

#### 3.3.2. Classification and grouping of spectral data

Spectral data can be categorized into different classes or clusters based on different wavelengths or spectral features. For example, bananas can be classified into different quality levels based on their different colors or reflectance characteristics. Cluster analysis and other methods can be used to classify and group the spectral data.

#### 3.3.3. Spectral imaging modeling

Establishing a spectral imaging model is the key to realizing non-destructive banana quality assessment and quality and safety monitoring. Machine learning, deep learning, and other techniques can be used to build spectral imaging models and apply them to banana quality assessment and quality and safety monitoring.

#### 3.3.4. Visualization of spectral imaging data

Visualization of spectral imaging data can help to better understand the distribution and characteristics of the data. Scatter plots, heat maps, histograms, and other methods can be used to visualize the spectral data, analyze the relationship between different variables, and evaluate the prediction effect of the model based on the obtained data [10].

## 4. Banana quality assessment model construction based on spectral imaging technology

### 4.1. Basic principle of model construction

Spectral imaging technology is a non-destructive, fast, and accurate measurement method, which can be used to assess and monitor the quality and quality safety of fruits. Spectral imaging technology utilizes the different characteristics of different wavelengths of light reflected and absorbed on the surface of an object to obtain the spectral information of the object. This information can be used to analyze the chemical composition, structure, and physical properties of the object [11].

### 4.2. Methods and steps of model construction

#### 4.2.1. Data collection

First, samples of bananas of different varieties and quality levels need to be collected. These samples can be obtained from banana planting bases, markets, and other sources. At the same time, the collected banana samples are ensured to be representative to facilitate the subsequent training and validation of the model.

#### 4.2.2. Selection of spectral imaging equipment

The appropriate spectral imaging equipment is chosen according to the research needs. Commonly used spectral imaging equipment include handheld spectral imagers, fixed spectral imagers, and UAV spectral imaging systems. When choosing equipment, consider factors such as spectral resolution, imaging speed, and equipment cost.

#### 4.2.3. Acquisition of spectral data

The spectral imaging equipment is utilized to perform spectral imaging of banana samples. The acquired spectral data should include spectral information of different wavelengths. In practice, different spectral ranges can be selected according to the research needs.

#### 4.2.4. Data preprocessing

The acquired spectral data are preprocessed, including removing noise and eliminating moisture. At the same time, the spectral data are normalized to eliminate the influence of light sources of different wavelengths.

#### 4.2.5. Feature selection and extraction

From the preprocessed spectral data, features related to banana quality and safety are screened. Commonly used feature extraction methods include Principal Component Analysis (PCA), Support Vector Machine (SVM), Artificial Neural Network (ANN), and so on [12]. The purpose of feature selection is to reduce the complexity of the model and improve the generalization ability of the model.

### 4.3. Model performance evaluation

#### 4.3.1. Accuracy

Accuracy is one of the most important metrics for evaluating model performance. Some metrics can be used to measure the accuracy of the model, such as accuracy, precision, recall, and F1 score. Methods such as cross-validation can be used to evaluate the accuracy of the model to ensure that the model performs similarly on different datasets [13].

#### 4.3.2. Precision

Accuracy is another important metric for evaluating the performance of a model. Several metrics can be used to measure the accuracy of a model, such as precision, recall, and F1 score. Metrics can be used to evaluate the performance of the model at different quality levels, such as the ripeness and color of bananas [14].

#### 4.3.3. Robustness

Robustness is another important metric for evaluating the performance of a model. Several metrics can be used to measure the robustness of a model, such as fault tolerance, robustness, and stability. Different datasets and different spectral imaging devices can be used to evaluate the robustness of the model.

## 5. Design and realization of banana quality and safety monitoring system based on spectral imaging technology

### 5.1. Methods and steps of system design and realization

Determine the parameters of spectral imaging technology: according to the experimental purpose and equipment performance, select the appropriate spectral imaging technology parameters, such as imaging resolution, wavelength range, image acquisition rate, and so on.

Preparation of spectral imaging equipment: according to the selected parameters, select the appropriate spectral imaging equipment. Spectral imaging equipment can be handheld or desktop equipment and needs to have a high resolution, fast acquisition, multi-band imaging, and other characteristics.

Establishment of spectral imaging data processing system: according to the experimental requirements, design the spectral imaging data processing system, including data acquisition, pre-processing, feature extraction, model building, and other modules. Among them, feature extraction is the key step, and suitable features need to be selected, such as color, texture, spectral characteristics, and so on, according to the quality index of the banana.

Selection of machine learning model: According to the experimental purpose and data characteristics, select the appropriate machine learning model, such as support vector machine, neural network, decision tree, and so on, to establish the quality and safety monitoring model and to achieve the prediction and assessment of the quality of bananas [15].

Realize system integration: Integrate the spectral imaging equipment, data processing system, and machine learning model together to build a complete non-destructive banana quality assessment and quality and safety monitoring system. The system integration needs to consider the connection mode of equipment, data transmission mode, model training, and prediction mode.

### 5.2. System performance evaluation

Accuracy and precision: Evaluate the ability of the system to detect the quality of bananas, including the accuracy and precision of the detection results.

Repeatability: Evaluate the consistency of the results of the system in detecting the quality of bananas at different times or under different conditions.

Dynamic range: Evaluate the range of banana quality that the system is capable of detecting, including high or low brightness.

Signal-to-noise ratio: Evaluate the signal-to-noise ratio between the input signal and the output signal when the system detects the quality of bananas to ensure that the system can accurately detect the quality of bananas.

Response time: Evaluate the time from the start of detection to the output result to ensure that the system can respond quickly to the detection process.

## 6. Conclusion

Against the background of the current increasingly severe food safety problems, this study was conducted to explore in depth the non-destructive banana quality assessment and quality and safety monitoring. Through the introduction of spectral imaging technology, the rapid and accurate acquisition and analysis of banana fruit spectral information was realized. By studying the correlation between banana spectral characteristics and quality indexes, this study provides a new technical means for banana quality assessment, which helps to improve the level of banana quality and safety monitoring. In future research, the application of spectral imaging technology in banana quality assessment will continue to be optimized, to bring higher economic benefits and social value to the banana industry.

## Funding

Hainan Province Key R&D Project (ZDYF2017060), Basic Scientific Research Business Fund Project for Central-level Scientific Research Units (1630082022001, 1630082016002).

## Disclosure statement

The author declares no conflict of interest.

## References

[1] Jin K, Guo C, Zeng YL, et al., 2023, Hyperspectral Kiwifruit Quality Classification by Combining Three-dimensional Convolutional Neural Network and Haar Wavelet Filter. Advances in Lasers and Optoelectronics, 60(20): 49–58.

[2] Jing XZ, Sun X, Guo YM, et al., 2023, Progress of Spectral Imaging Technology in Maize Seed Quality Inspection. Journal of Northern Agriculture, 51(05): 93–102.

[3] Yuan J, Mao YZ, Yao CP, et al., 2023, Application of Near-infrared Spectroscopy in the Rapid Detection of Saccharification Power of Soy Sauce-type Dacquoise. Brewing Science and Technology, 2023(12): 110–113.

[4] Wen X, 2019, Inversion of Chlorophyll and Nitrogen Content Distribution of Apple Leaves based on Hyperspectral Imaging, thesis, Shandong Agricultural University.

[5] Wang WC, 2023, Corn Mold Detection and Early Warning based on Hyperspectral Imaging Technology, thesis, Liaocheng University.

[6] Cao F, 2019, Research on Rice Origin Identification based on Hyperspectral Imaging Technology, thesis, Jilin Agricultural University.

[7] Hou ML, Pan N, Ma QL, et al., 2017, Research Review of Hyperspectral Imaging Technology in the Analysis of Painted Cultural Relics. Spectroscopy and Spectral Analysis, 37(06): 1852–1860.

[8] He JW, 2016, Research on Non-destructive Detection of Frozen Food Quality based on Hyperspectral Image Technology, thesis, Tianjin University of Commerce.

[9] Zhao LL, Yin ZX, Chen H, et al., 2023, Classification of *Angelica sinensis* and *Dioscorea sinensis* based on Hyperspectral Imaging. Automation and Information Engineering, 44(06): 33–38 + 45.

[10] Ning XF, Liu N, Chen YL, et al., 2020, Comparative Study of Spectral Detection Methods for Strawberry Quality. Journal of Shenyang Agricultural University, 51(02): 177–184.

[11] Li SP, Wang JY, Wang L, 2023, Construction and Application of Calibration Model for Straight-Chain Starch Content based on Near-infrared Spectroscopy. Grain and Fats, 36(12): 139–143.

[12] Fan K, 2023, Nitrogen Balance Index Monitoring of Winter Wheat based on Canopy Hyperspectroscopy, thesis, Northwest Agriculture and Forestry University.

[13] Zhao S, Zhao X, Zhu Q, et al., 2022, An Unsupervised Active Learning-based Model Construction Method for Non-destructive Detection of Apple Quality Spectra. Spectroscopy and Spectral Analysis, 42(01): 282–291.

[14] Zhou C, 2016, Research on Feature Extraction and Model Construction Method for Optimal Imaging Hyperspectral of Wheat Leaf Biomass, thesis, Nanjing Agricultural University.

[15] Ni XX, 2015, Identification of Red Acid Branch Species based on Hyperspectral Imaging Technology, thesis, Zhejiang Agriculture and Forestry University.