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A Non-Invasive Technique for the Detection of Food Quality

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The global food processing industry is frequently confronted by new technological challenges to meet the increasing demand for quality-assured processed products. Consequently, over the last decade, the food processing industry has shifted the way it performs quality measurement from subjective assessment to the widespread adoption of objective non-invasive technologies that provide faster and more reliable results. The non-invasive technologies are now commercially available for quality control as either small desktop or online grading units. Several studies have highlighted the potential of different non-invasive approaches and methods applied to processed horticultural products and have promoted its use as a rapid and non-invasive analytical method for quantitative or qualitative analysis. These include infrared spectroscopy, hyperspectral imaging, and X-ray computed tomography. Several of these techniques have been successfully employed in the classification, authenticity, and quantification of commercial juices, oils, powders, and dried products.

Types of Non-invasive Techniques

1. Hyperspectral imaging
2. Thermal imaging
3. X-ray imaging
4. Infrared Spectroscopy

Hyperspectral imaging

Hyperspectral imaging (HSI) is a non-invasive technique that integrates spectroscopic and imaging into one system. It is often used to gather images with spatial and spectral data and has been widely used for the studied food technique. HSI simultaneously acquires large amounts of monochromatic images with wavebands, and a full spectrum is extracted for each pixel in an image. The data obtained from HSI systems are 3-dimensional (3D) structures that consist of two spatial and one spectral dimension. The process usually requires a significant amount of time for image acquisition under laboratory conditions and relatively complicated procedures for offline image analysis. This process involves fast image acquisition and simple algorithms for image processing and decision making. HSI makes use of one of three methods to generate 3D hyperspectral cubes [hypercubes (x, y, k)]; these include point (whiskbroom) scanning, line (pushbroom) scanning, and area scanning (tunable filter or staredown). A block diagram illustrating the basic steps of HSI spectral acquisition and model development is presented in Figure 1.

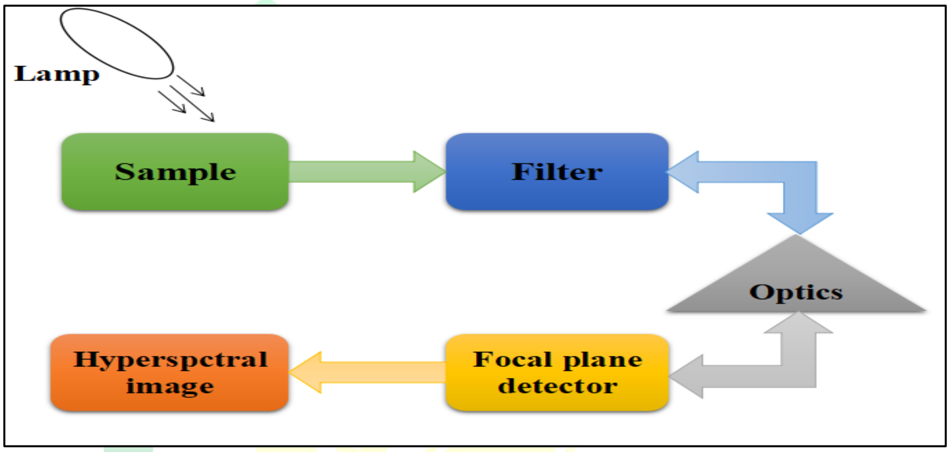

Figure 1. Block diagram of basic steps for hyperspectral imaging.

(a) The sample is radiated with NIR radiation, (b) the reflected radiation is captured by a filter and optics which is responsible for wavelength selection, separation, and measurement, (c) the spectrum of each pixel is captured and is recorded by a detector, (d) the image of the sample at each wavelength is recorded resulting in image slices.

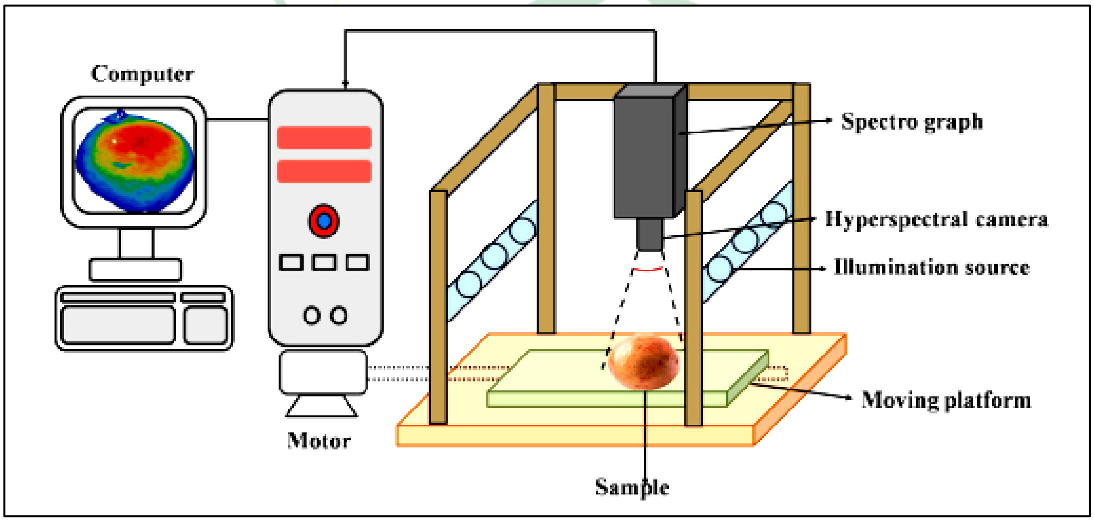

Figure 2. Hyperspectral imaging system and components

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Components, configuration, and acquisition of hyperspectral images

Components of hyperspectral imaging system are the basis the guarantee to obtain high quality hyperspectral images for quality assessment and evaluation of a tested object and also to give detail information for further experiment. Typical hyperspectral imaging system contains the following components; objective lens, spectrograph, camera, illumination and a computer system as shown in Fig. 2. The camera, spectrograph and illumination components are the key components factors that determine the spectral range of the system. Typical hyper spectral imaging system normally consists of Silicon (Si) – based charge-coupled device (CCD) or CMDS (Complementary Metal Oxide Semi-conductor) camera, to simultaneously collect the spectral and spatial information, the spectrograph plays the role of wavelength dispersion to distribute wide band of light into various wavelengths. LED lamps or tungsten halogen lamps are commonly used as light sources in hyperspectral imaging system for the illumination of the sample test, and in addition the computer system to compose and store the three-dimensional hypercube. Specifically, a beam of light reflected from the sample object enters the objective lens in front of the spectrograph and is divided into its component wavelengths by diffraction optics contained in the spectrograph given a two-dimensional image; one containing dimension represents the spectral axis (λ) and the other contains one spatial dimension (X) of the scanned line.

Acquisition of hyperspectral images

There are three techniques to build hyperspectral images as shown in Fig.3:

1. Point spatial scanning (whiskbroom method).
2. Line scan pattern (Push-broom imaging system).
3. Area scanning (wavelength tunable imaging system).

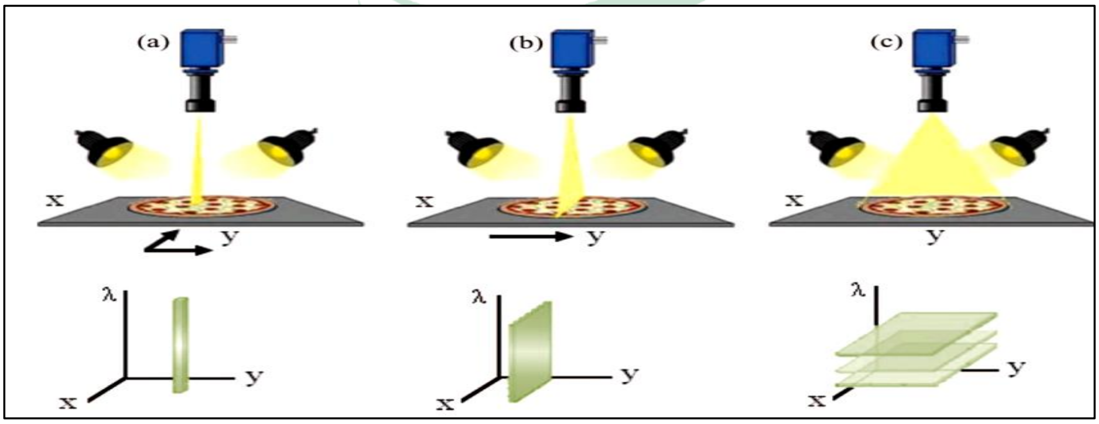

Figure 3. Three approaches to generate hyperspectral images:

(a) whiskbroom imaging (point scanning): image is acquired point by point; (b) push-broom imaging (line scanning): mage is scanned line by line along one axis and (c) area imaging (wavelength scanning): the image of the whole object/area is acquired at a single wavelength at a time. Arrows indicate the direction of movement.

Advantages of hyperspectral imaging:

The advantages of using hyperspectral imaging for quality assessment of food materials are as follows:

1. It is a non-destructive, non–contact, and non-invasive tool and technology; which therefore ensures the safety and quality of food materials.
2. Safety of the environment, as no chemicals are used in the experiment.
3. It gives a better understanding of the chemical elements of the food materials and is commonly termed chemical imaging.
4. Its safes times compared to the traditional or chemical method of food grain storage control and quality evaluation.

Limitations of hyperspectral imaging:

1. A hyperspectral imaging system is highly priced in comparison to other image processing techniques. It is a non-destructive, non – contact, and non-invasive tool and technology; which therefore ensures the safety and quality of food materials
2. Safety of the environment, as no chemicals are used in the experiment.
3. It gives a better understanding of the chemical elements of the food materials and is commonly termed chemical imaging.
4. Its safe times compared to the traditional or chemical method of food grain storage control and quality evaluation.

Conclusions

This article explores non-invasive technology for assessing the quality of processed food products. Challenges to commercial adoption include high equipment costs, long processing times, and required technical expertise. Near-infrared and mid-infrared spectroscopy have been successful for measuring physical and chemical properties, but require improvements for commercial adaptability. Future research for imaging techniques such as HSI, MSI, and X-ray CT systems should focus on improving data acquisition and processing times and developing smaller and less expensive devices. Adoption of these technologies would reduce time and costs and improve quality control of food products.