

# Rapid and Noninvasive Sensory Analyses of Food Products by Hyperspectral Imaging: Recent Application Developments

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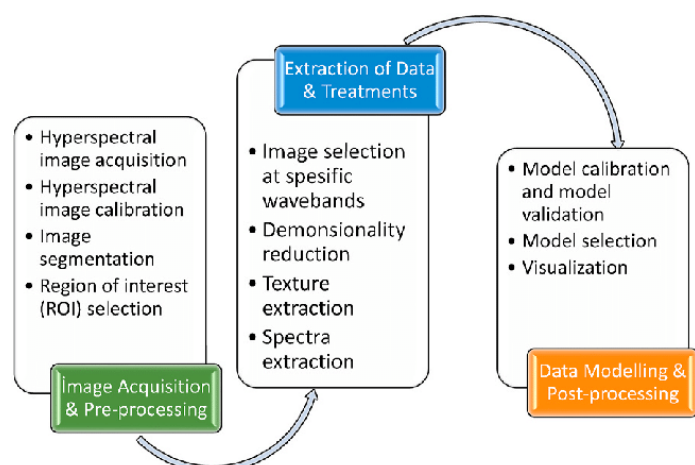
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Sensory analysis is the evaluation of the signals received through senses of sight, sound, taste, smell, and touch. The traditional methods for the analysis of sensory properties including trained sensory panels, colorimeters and texture analyzers are invasive, laborious, and small-scale procedures. Hyperspectral imaging systems (HSI) have emerged as a less time-consuming and non-destructive method to determine the sensory properties of a diverse range of food products.

## Fundamentals of hyperspectral imaging technology

Hyperspectral imaging systems integrate imaging and spectroscopy to obtain spatial and spectral data in one system. A hyperspectral imaging system produces three-dimensional (3-D) hypercubes including two-dimensional spatial data and one-dimension spectral data, forming a stack of images at continuous wavelengths, and every image at a specific wavelength is called sub-image and can be defined as  $I(x, y, \lambda)$ , i.e., a spatial image  $I(x, y)$  at different wavelengths ( $\lambda$ ).

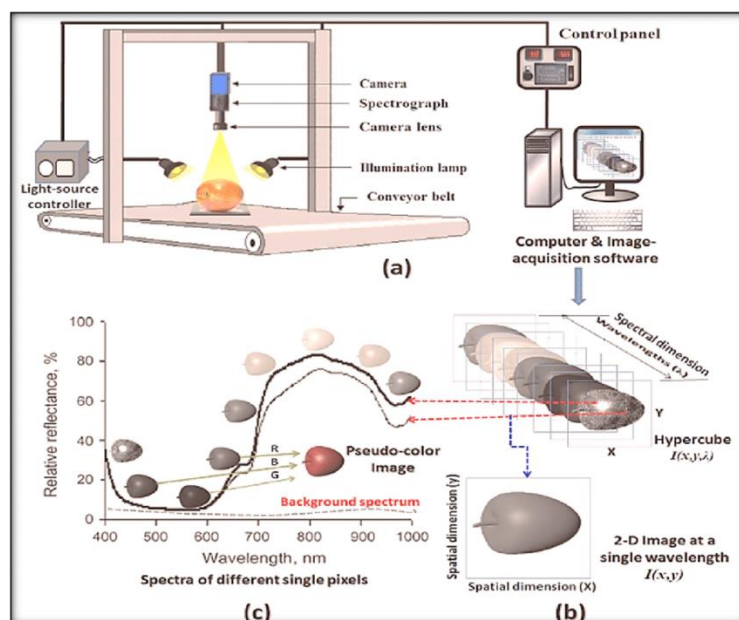


**Fig. 1: General steps of hyperspectral imaging process (Özdoğan et al., 2021)**

HSI image acquisition, there are four different approaches available, including point scanning (whisk-broom), line scanning (pushbroom), area scanning, and the single shoot procedure. Among

these methods, line scanning is the most used tool in the food industry, since it can scan continuously in one direction, and thus suitable for conveyor belt systems.

A hyperspectral system consists of a computer with proper software, a spectrograph, a camera, and an illumination the dimensionality of the data since hypercubes have a considerable amount of data. There are three main steps in the processing of hypercubes: image acquisition and pre-processing, extraction of data and treatments, data modelling and post-processing (Özdoğan et al., 2021).



**Fig. 2: (a) A schematic diagram of hyperspectral imaging (b) an example of 2-D sub-images (c) spectra of any pixels in the hypercube (Özdoğan et al., 2021)**

## Evaluation of visual sensory features of food products

### Colour

Colour is the first feature noticed by consumers, it is one of the most vital sensory quality characteristics, which has a significant impact on the purchasing decision of consumers by indicating some information about the physical, chemical, or

microbiological quality of food products (Su Z et al., 2021).

### **Bruises**

Bruising is mechanical damage in fruits and vegetables, which can occur during harvesting, packing, and transporting, affecting not only the appearance of foods but also its taste, texture, nutritional value, and consumer acceptance. Traditionally, bruises are classified by manual grading in the food industry, consequently, researchers have focused on finding self-regulating sorting systems for the early detection of bruises to decrease economic and nutritional value losses, and HSI has been investigated to detect bruises in apples, potatoes, pears, blueberries, kiwifruits, and mushroom.

Detection of bruises of fruits such as apples with a pixel-based selection of the region of interest (ROI). Other classification methods such as SIMCA, logistic linear regression (LLR) and neural network (NN). Detected the early bruises of vegetables by HSI with image enhancement applications, including histogram equalization algorithm, mean smoothing and gradient algorithm.

### **Chilling Injury**

Chilling injury is one of the most common physiological disorders in fruits and vegetables, which can occur during low-temperature long term storage, and can cause various alterations such as internal browning, deteriorated texture, lack of juiciness, and off-flavour. Hence, it is important to detect chilling injury in fruits and vegetables before reaching the consumers (Su Z et al., 2021).

### **Evaluation of tactile sensory features of food products**

#### **Textural features**

Food texture are plays major important role in food quality the ability to resistance of food for deformation such as biting, chewing and grinding so it directly affects to consumer acceptability of food. Besides traditional work to check sensory analysis of food product on new novel method called NIR hyperspectral imaging method.

### **Marbling level**

Marbling is a meat quality characteristic to determine the size, number, and distribution of visible fat with lean in a muscle, which is closely related to textural properties such as tenderness and juiciness.

The uniform distribution of marbling is considered as an indicator of good quality meat by consumers. Traditionally, marbling is assessed visually by trained graders in accordance with marbling reference standards. On the other hand, HSI has been explored to be an alternative technique to determine the marbling level of meats such as beef and pork, showing good prediction results with coefficients of determination ranging from 0.92 to 0.99 (Aredo et al., 2017).

### **Water holding capacity**

Water holding capacity (WHC) or drip-loss (DL) of meat is identified as the capability of the meat sample to maintain the water inside against external factors such as gravity and temperature. Although it seems like a chemical property, WHC is a characteristic, providing information about the juiciness and tenderness of fresh or cooked meat and consequently, the total eating quality. Many methods have been used for evaluation of WHC, including external mechanical force, gravimetric and cooking procedures. However, a fast and less repeatable procedure is an urgent need for the meat industry, and thus, the availability of HSI for the estimation of WHC in the spectral range of 400–1000 nm (Kamruzzaman et al., 2013).

### **Evaluation of multisensory features of food products**

#### **Flavour**

Flavour is a sensory impression of food products, which is identified by the combined chemical senses of the taste and smell system and flavor perception can thus can followed all five taste classes, sweetness, saltiness, sourness, bitterness and umami perceived by the mouth (Caporaso N et al., 2021).

Different chemometrics compare their effects on prediction, including five different spectral pre-treatments (normalization, MSC, SNV, SG-1st, SG-

2nd), three-wavelength selection methods (RC, VIP, SPA), and two multivariate analysis (PLSR, LS-SVM).

### Maturity

Maturity or ripeness is a stage that can show the readiness of foods for eating, which can be defined by both the internal and external characteristics of the food products. Moreover, food products can gain the desirable sensory characteristics such as palatable taste, intended texture, and specific colour during ripening.

For instance, some products such as persimmon and bananas are unlikely to be consumed before they reach maturity because of their astringency taste and hard texture. Therefore, the determination of the maturity stage of foods can guarantee the sensory quality, leading to the maintenance of market share by ensuring consumer satisfaction. Generally, the ripeness assessment can be determined by trained panels or laboratory-based parameters such as colour, texture, and total solid content. However, it is obvious that online monitoring systems are needed in the industry, and thus HSI has been widely investigated for the classification and prediction of the maturity stages of foods (Zhu M et al., 2020).

### Application of hyperspectral on food quality and safety

Hyperspectral imaging technology has the advantage of union of imagery and spectrum. It can simultaneously detect the surface and internal information of objects, so as to realize the rapid and nondestructive detection of food quality and safety. Therefore, it has been widely used in the field of food. In this paper, from the perspective of agricultural classification, the research progress of hyperspectral technology in primary agricultural products and food in recent years was systematically reviewed. In addition, the deficiencies and key points of this technology in the research were discussed in depth. This work lays a solid foundation for peers to quickly grasp the application progress of hyperspectral technology in the field of agricultural products and food, contributing to the in-depth research and application of this technology.

- Hyperspectral Imaging plays important role in food industry
- HSI will help to develop new era towards food safety and quality control
- HSI will replaces the traditional sensory evaluation method
- Maturity of will be easy identified by using HSI
- All parts of sensory will same function as HSI

### Conclusion

The comprehensive overview of recent application developments for identifying sensory properties including texture, colour, defects, flavour, freshness, and maturity in various food products by hyperspectral imaging technology. For sensory evaluation, the most used spectral region is Vis-NIR used. Furthermore, combining spectral and spatial information of hypercubes for the evaluation of sensory properties can lead to better performances. In addition, some studies have proved the success of real-time hyperspectral imaging, which can encourage the early adoption of HSI technology by the industry.

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