1. **Detection of early decay on citrus using hyperspectral transmittance imaging technology coupled with principal component analysis and improved watershed segmentation algorithms**
   (Link: https://www.sciencedirect.com/science/article/abs/pii/S0925521419309512 )

**Summary**
Early detection of decaying citrus fruits are essential for preserving in cold storage and ensuring sound state at the time of transportation. Spots on surface peel are created by soaking water from dead cell tissues caused by different fungus. Therefore, previously different methods were used to detect citrus fruits decaying caused by Penicillium Spp. (fungi) and defects on fruit skin such as canker spot, wind scarring etc. These methods include Machine Learning with color detection camera, RGB images, UV induced fluorescence imaging technology which only could reach up to 65% in detection accuracy rate. In this research, the contributors observed a new technology known as hyperspectral transmittance image within 325-1100 nm spectral region with watershed segmentation algorithm to differentiate between stem end tissue (used PC2 image) and decayed tissue (used PC3 image) using pseudo color image transformation and accuracy rates are 93% and 96% respectively for orange.

**Methodology**
In this paper, the researchers used a novel approach for detecting decayed region in orange and these methods are as follows:

- Hyperspectral transmittance image within 325-1100 nm for higher accuracy rate.
- Principle component (PC) images for decay detection
- Principle component analysis (PCA) for stem end identification
- Improved watershed segmentation algorithm

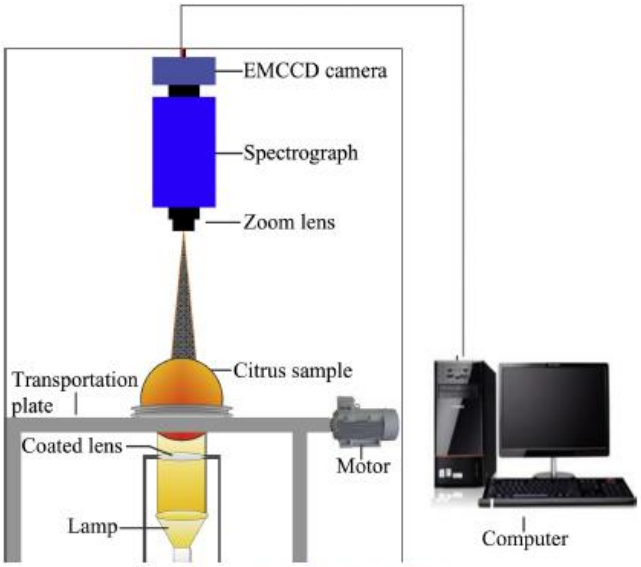

Fig. 1. Hyperspectral transmittance imaging system.

**Equations**

There are some equations which are used during the analysis of hyperspectral transmittance images. These are given below:

- The calibrated image T, for hyperspectral transmittance image,
  T = RawDark / WhiteDark
- Morphological geodesic dilation,

$$\begin{cases} D_b^1(\nabla f(x,y), r) = min(\nabla f(x,y) \oplus b, r) \\ D_b^{i+1}(\nabla f(x,y), r) = min(D_b^i \oplus b, r)(i = 1,2,3, \ldots) \end{cases}$$

- Morphological geodesic erosion,

$$\begin{cases} E_b^1(\nabla f(x,y), r) = max((\nabla f(x,y) \Theta b), r) \\ E_b^{i+1}(\nabla f(x,y), r) = max(E_b^i \Theta b, r)(i = 1,2,3, \ldots) \end{cases}$$

- Morphological gradient of image,

$$\nabla[f(x,y)] = (f \oplus b)(x,y) - (f \Theta b)(x,y)$$

- C= 4πA / P2

**Findings**

Previously using other methods could only get around 65% accurate decay detection, but combining hyperspectral transmittance image with image processing provides 93% and 96% accuracy rate for stem end identification and decay detection in citrus fruit respectively.

**Novelty**

- The novelty of this paper is using hyperspectral transmittance image, improved watershed segmentation algorithm and pseudo color image transformation at the same time.
- The researchers also found out the difference between stem end image and decay detection image of citrus fruits like oranges so that the accuracy rate of decay detection increased more than previous findings.
- Also they used PC2 image for stem end detection, PC3 image for decay detection, R component, G component,B component for better observation in image processing.

**Algorithm Used**
They have used here improved watershed segmentation algorithm, stem end identification algorithm,

**Analysis**
In this paper, they have analyzed PC2 image, Pseudo color image, R component, G component, B component images for better identification of decayed region and stem end region.

**Problems Faced**
While writing these segments, I have to search about IWSA, PC2,PC3 and hyperspectral transmittance images for better observation.

**Future Work**
Usage of image processing along with the collaboration of hyperspectral transmittance image can give us relatively accurate decay detection information which is not that much familiar in our research areas.

**Research Gap**
Although they have mainly used hyperspectral transmittance image and pseudo color image transformation technology, they haven't recognized these as a part of image processing.

2. **Food Quality Inspection and Grading Using Efficient Image Segmentation and Machine Learning-Based System**
   ( Link: https://www.hindawi.com/journals/jfq/2022/5262294/ )

**Summary**
In recent years, inspecting quality of food is extremely important for ensuring a good product, at the same time detecting rotten foods so that spoiled food can not contaminate fresh foods. Therefore, in this paper, for ensuring food quality inspection, the authours used image processing techniques with k means clustering and added Gaussian elimination method for removing noise from collected photos. Then in order to enhance the size of noise less photo, they used here

histogram equalization and photos are being segmented using k means clustering and some other algorithms. From there, the researchers can identify which food is spoiled.

**Methodology**

Im this paper, first of all, they collected variety of datasets of foods. Then using Gaussian elimination, they remove noise from the photoes and then the size of these photos are being emhanced by equalizing the histogram. K means clustering is used here for breaking a photo into several segments to detect disease or other signs of spoiled food. After that, photos are classified using support vector machine (SVM) and KNN.

**Equations**

- Standard deviation using Gaussian function is,

$$\mathbf{G}(\mathbf{x}) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{(x^2/2\sigma^2)},$$

$$\sigma = \sqrt{\frac{\sum_i \left(X_i - \overline{X}\right)^2}{n-1}},$$

- The detection of  sensitive negative results,

$$\text{sensitivity} = \frac{\text{TP}}{(\text{TP} + \text{FN})}.$$

- Analyzing specificity using TP/TN,

$$\text{specificity} = \frac{\text{TN}}{(\text{TN} + \text{FP})}.$$

- Analyzing accuracy  using TP/TN,

$$\text{accuracy} = \frac{\text{TN} + \text{TP}}{(\text{TN} + \text{TP} + \text{FN} + \text{FP})}.$$

**Findings**

In this paper, they found a clear image dataset since they used Gaussian elimination method and histogram equalization. Moreover, by doing mathematical calcuation, they found the accuracy, sensitivity and specificity while inspecting a food quality.

**Novelty**

The novelty of this paper is, the authors implemented Gaussian elimination method along with histogram equalization for reducing noise and increasing image size respectively for image dataset.

**Algorithm Used**
They have used here k means clustering which is basically a machine learning algorithm.

**Analysis**
In the analysis segment, they analyzed pictures using image processing and then all these pictures are categorized using KNN (a classification algorithm that can detect an object using the closest training example).

**Research Gap**
The authors did not include any smartphone based system which people can use easily inside or outside of the cold storage.

**Problems Faced**
This paper doesn't provide any idea about which components are used during the research.

**Future Work**
If the researchers can integrate this system by using smartphones and if we can use this technology inside or outside of a cold storage, then there is a vast area for conducting more researches.

3. **IOT Based Food Freshness Detection Using Deep Learning Techniques**
   ( Link: https://www.irjweb.com/IOT%20Based%20Food%20Freshness%20Detection%20Using%20Deep%20Learning%20Techniques.pdf )

**Summary**
Since today's era is more concerned about food quality and obtaining the nutritious values from fresh fruits and vegetables, so the researchers of this paper has added some innovation to provide more accurate results in terms of food. They enclosed here Convolutional Neural Network (CNN) and Object Detection Algorithm YOLO for identifying spoiled areas on food skin. Moreover, they added some specifications including checking emitting gas level detection from rotten food and spilage level using Artificial Neural Network and taking the spoilage food identification to the next level.

**Methodology**

Some of the major methods that is being used are as follows:

- First of using IoT based 360° gyro camera, the pictures of different foods were taken.
- Then, at the same time MQ2 Gas Sensor and MQ135 Gas Sensor detected the emmited methane and ethane gas respectively from the food.
- Then image processing segmentation was completed using CNN ImageNet and YOLO architecture algorithm.
- After merging infos, the output is analyzed for better accuracy rate of rotten food detection using MobileNetV2, DenseNet121 and EfficientNetB2.

**Components Used**

The components used here are given below:

- Raspberry Pi Model B
- MQ2 Gas Sensor (for detecting methane)
- MQ135 Gas Sensor (for detecting ethane)
- MG90S
- SD Card
- ESP 8266
- 360° Gyro Camera
- Web camera

**Findings**

In this research, the authors could calculate the amount of methane and ethane emission from a food using gas sensors. Also using improved CNN and YOLO algorithm helped to accurately identify defective fruits and vegetables

**Novelty**

The novelty of this paper is the implementation of MQ2, MQ135 gas sensors for methane and ethane emission, and using Object Detection Algorithm YOLO identified the defective parts from images.

**Algorithm Used**

The algorithms used here are listed down below:

- ImageNet Convolutional Neural Network algorithm
- Object Detection Algorithm YOLO

**Analysis**

After training the machine over 350 times for banana and apple, they found the accuracy rate nearly 97.9%.

**Research Gap**

This research doesn't include any smartphone based image processing segment.

**Problems Faced**
While writing down the literature review of this paper, the steps are not clearly written in points.

**Future Work**
The future research can be done by integrating with smartphone based apps that can use such methods for detecting food spoilage.

4. **Disposable colorimetric geometric barcode sensor for food quality monitoring**
   ( Link: https://ieeexplore.ieee.org/document/7994325 )

**Summary**
Food quality inspection plays a vital role for detecting rotten foods. Current food quality detecting methods, for instance, electromagnetic interrogation, gas chromatography, chemical sensing etc. are not cost effective and efficient. Therefore, in this research, the researchers proposed a new approach of biodegradable and disposable colorimetric geometric fabricated barcode sensors which can be easily placed in the upper part of food or over raw chicken. Then using smartphones, the barcode can be scanned and after scanning, the system automatically extracts color information compared with a dataset and shows then the analytics whether the food can be consumed or it is time for discard. This new approach is extremely low in cost and environment friendly which can be a game changer for detecting food quality.

**Methodology**
- First of all, the barcode scanner is set on the upper part of the food.
- Then using a smartphone camera, barcode can be easily scanned like a QR code scanner.
- Then in the barcode sensing part, the entire process is done using image processing and photos clicked by smartphone are sent to MATLAB which uses Principle component analysis (PCA). It also works as an RGB recognition method.
- After analyzing the colors of the food, it provides a clear analytical overview of whether the food can be consumed or this is spoiled food.

**Findings**
The findings of this paper is that after observing different states of chicken in refrigerators and room temperature, the sensor can easily detect the color of spoiled areas using RGB recognition image processing technology.

**Novelty**

The novelty of this paper is to innovate biodegradable and disposable colorimetric geometric fabricated barcode sensors which is eco friendly and cost effective at the same time while using smartphones.

**Analysis**
At the time of analysis, 1st group of samples were kept under 20° C, 2nd group under 5° C and 3rd group of samples were kept both under 5° C and 20° C and changed temperature at an interval of 24 hours. After 5 days of observation, the analytics shows the detection of spoilage food.

**Research Gap**
In this research, the authors didn't give an idea of how much accuracy rate is provided by the geometric barcode sensor.

**Problems Faced**
They didn't provide the accuracy rate of the barcode sensor.

**Future Work**
Using other IoT based devices and precisely describing the accuracy rate will be extremely helpful in the near future.

5. **FPGA based Intelligent Food Spoilage Detection for Commercial Storage**
   ( Link: https://ieeexplore.ieee.org/abstract/document/9936415 )

**Summary**
Foods can be spoiled if they are stored in the refrigerator or cold storage. Moreover, when the foods are spoiled in a cold storage, it only only creates fungus or other diseases, but also spreads disease all over the storage foods. Therefore, in this paper, the authors proposed a new approach that can be easily implemented in our refrigerators as a detection method of rotten foods. Using deep machine learning algorithms (YOLOv5), image processing methods and FPGA based food spoilage detection methods can detect early levels of spoiled foods. Thus creating buzzers will alert users to discard that food immediately and this will also maintain the freshness of other foods while preventing food poison.

**Methodology**
- First of all, here the system uses an FPGA based food detection system where the MQ2 Gas Sensor is used for methane gas emission from spoiled food.
- Also moisture is being detected through sensors and Object Detection Algorithm YOLO version 5 is used here for detecting specific regions of spot or disease on food.

- When the system detects any mold or fungi on the food surface, the buzzer will automatically alert the user to discard the item from the refrigerator.

**Findings**
When they were observing the entire FPGA system, they observed every single fragmented image for better detection of rotten food.

**Novelty**
The innovative side of this paper is, they developed a new FPGA based rotten food detection in refrigerators which can be easily implemented in cold storage. Also the updated version of Object Detection Algorithm YOLO is used here.

**Algorithm Used**
During this experiment, the researchers used Object Detection Algorithm YOLO including machine learning algorithm for image processing.

**Analysis**
In the analysis phase, the researchers tested several image segments at the time of image processing using RGB recognition and they could detect the spoiled area over food surface.

**Research Gap**
If the research paper contains a smartphone based checking process of the system, then through smartphone, the user can see the analytics of segmented images color percentage and when the food is about to spoil.

**Future Work**
The FPGA based rotten food detection systems can also be connected through smartphones for better overview of the shelf of foods stored in refrigerators.