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A Review on Detection of Black Pepper Adulteration

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Abstract: Food fraud costs a lot of money and erodes consumer and merchant confidence. One of the most expensive spices in the world, black pepper is prone to adulteration for commercial gain. Adulteration is frequently caused by economic fraud, negligence, a lack of basic sanitation, or intentional tampering with food. Pepper, once worth its weight in gold, today makes up around 35% of the global spice trade. Because they are readily available, inexpensive, and morphologically like black pepper, papaya seeds are frequently employed as an adulterant in black pepper. Black peppercorns and papaya seeds almost appear identical to the unaided eye, but we can tell them apart using picture processing.

Keywords: Food Adulteration, Black Pepper, Image Processing, Accuracy

I. INTRODUCTION

Food Adulteration is defined as the "addition or subtraction of any substance to or from food, so as to modify the natural composition and quality of food substance". The risk of food adulteration is increasing for buyers, sellers, and producers everywhere. Adulterants, which can include chemicals, colors, pesticides, or even dangerous substances like poisonous metals, germs, and viruses, can be introduced to food items either knowingly or unknowingly. Each step in the food supply chain, from the creation of raw materials to processing, packaging, storage, and transportation, has the potential to result in food adulteration. Food theft costs the economy a fortune and erodes consumer and business confidence. Food adulteration is a crucial issue that affects both developed and developing nations worldwide. Depending on the nation and the location, many factors might lead to food adulteration. In some instances, it is because of a lack of policies and monitoring, while in other instances, it is because of manufacturers' and distributors' greed and unscrupulous business tactics.[1]

Black pepper is a widely used spice in many different cuisines throughout the world. It is manufactured from the dried fruit of the Piper nigrum plant, which is indigenous to India and Southeast Asia. Yet, the strong demand for black pepper has resulted in the widespread practice of black pepper adulteration, which is the act of adding additional chemicals to the spice to enhance its amount or profit. Adulteration of black pepper can entail the addition of cheaper ingredients to the spice, such as papaya seeds, juniper berries, and even sawdust or dirt. Some manufacturers combine black pepper with other spices, such as chilly powder or cumin, to boost volume and save prices. In addition to these adulterants, black pepper may be infected with microbiological infections, which can endanger consumers' health.

The present methods for detecting various adulterants are quite sophisticated, and expensive, and demand a piece of laboratory-based equipment. They are also not portable for real-time testing. Additionally, these methods employ destructive sensing. The fact that black peppercorns and papaya seeds have morphic similarities to the naked sight, it is essential to detect such adulterants to ensure safe and quality food products are delivered to the market.[2]

II. LITERATURE SURVEY

A. Geo-tracing of black pepper using metal oxide semiconductor (MOS) gas sensors array

This study has demonstrated that geo-tracing of Malaysian and Indian black peppercorns can be achieved with an overall accuracy of 92.5% employing TGS2600, TGS2602, and TGS2620 MOS (metal oxide semiconductor) gas sensors, the pneumatic system design, and PCA analysis. In addition, compared to traditional GC-MS equipment, sampling using MOS gas sensors is substantially quicker, portable, less expensive, and non-invasive. While tweaking the variable resistors to get the optimum baseline voltage prior to the sampling phase does not adversely influence the sensor's responses. Figure 1 shows the representation of the pneumatic system consisting of (1) an air filter containing active carbon, (2) a 12V DC vacuum solenoid valve (normally closed) (3) a sensing chamber with MOS gas sensors, (4) 12 VDC air pump. (5) relay module and (6) Arduino UNO microcontroller for gas sensors' analogue reading measurement. Fewer MOS gas sensors would reduce the internal volume of the detecting chamber since they would be put inside it.

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As the VOC concentration would approach saturation within the chamber more quickly with a lower internal capacity, a faster sensor response would be achievable. To reduce sensor numbers while still providing enough sensor data for VOC profiling of black pepper, three MOS gas sensors are added to the gas sensors array. The three distinct MOS gas sensor types considered are VOC-sensitive. The resistance of the output load may be changed at baseline condition to get the required baseline output voltage prior to sampling by coupling the resistors to pin 2 of the sensors as the output load. In accordance with the PCA analysis and geo-tracing results, modifying the output load's resistance within baseline circumstances has no damaging consequences on the device's sensitivity or accuracy. The Arduino UNO microcontroller's analogue reading port is linked to pin 2 across each sensor to determine the output voltage.[3][14][15][16]

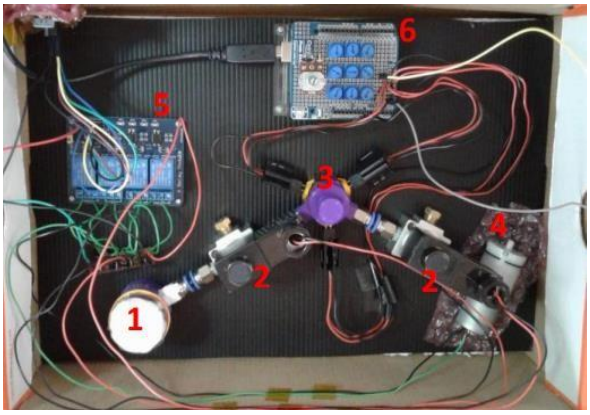

Figure 1: Structure of Pneumatic System

B. Hyperspectral imaging as a powerful tool for identification of papaya seeds in black pepper

This study of the identification of black pepper adulterants such as papaya seeds using hyperspectral imaging as a strong and promising tool revealed that NIR-HSI can identify papaya seeds in samples of berries, powder, and pure black pepper. SIMCA classification enabled identifying and categorizing berries, papaya seeds, powdered black pepper, and mixes with sensitivity levels greater than 90% and error rates lower than 8%. The PLS model has a strong capacity to predict the content of papaya seeds in samples of black pepper powder. It was tested with substantial wavelengths. This prediction map's pixel-by-pixel distribution of adulterants allows for an easy approach to estimating the number of papaya seeds in black pepper.

Using a NIR-HSI system 1003B-00572 in the spectral range of 900-1710 nm at 5 nm intervals, pure and adulterated samples were scanned, resulting in an overall of 159 bands. The transport platform VT-80 250-DC with engine C 863, a hyperspectral camera StingRay optics, a lighting assembly with lamps at a 45° angle, a power supply of 21 DC, and a computer with Windows 7 Professional operating system Intel Core i7 with data acquisition and processing software HyperSpec III made up the system. Five grams each of pure and contaminated samples were prepared in Petri plates, placed one at a time on the translation stage, and sent to the camera's field of vision at a user-defined pace of five millimetres per second. Over the course of the experiment, the camera and light were positioned in relation to the sample to maintain a uniform picture size and control the illumination. Figure 2 depicts the distribution map of papaya seeds in black pepper powder at the pixel level.

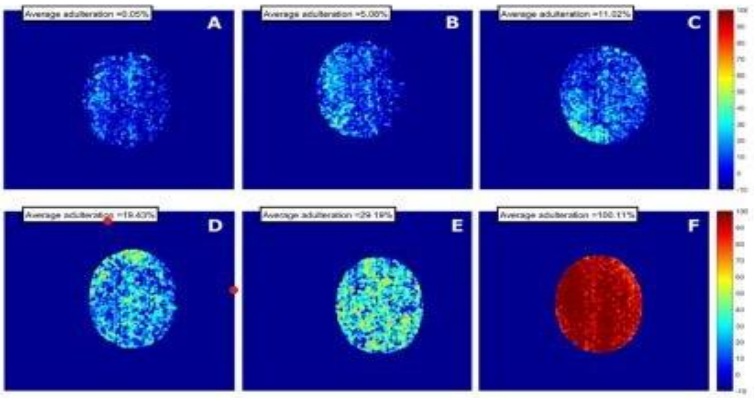

Figure 2: Detection of Papaya Seeds Through Hyperspectral Imaging

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The figures represent: A) Pure black pepper (0% adulteration level), B) 5% adulteration level, C) 10% adulteration level, D) 20% adulteration level, E) 30% adulteration level, and F) Pure papaya seeds (100% adulteration).[5][9][17][18][19]

C. Development of IoT Sensor for Pepper Adulteration Detection using Sensor Arrays

This work presents the working mechanism of the IOT monitoring system developed to detect black pepper adulterants. Pepper sample is used for the detection of volatile organic compounds which could be a source of adulterants and hinder the quality of the substance. Various gas sensors are used for detection as they spontaneously respond to the odour and gas sensors are highly portable and pocket friendly. Various gas sensors have a peculiar propinquity towards the mixture of volatile organic compounds and as a result, it is used to produce an odour identification that is unique and distinct for various food samples which are purely dependent on its quality. Various sensors deployed for the detection of volatile organic compounds are MQ3, MQ135, MQ138, and TGS2602. Arduino Uno's analogue reading is connected to each sensor to measure the output voltage. The microcontroller is given access to the wireless network by the WI-FI module, which also links it to the wireless router for network connectivity.

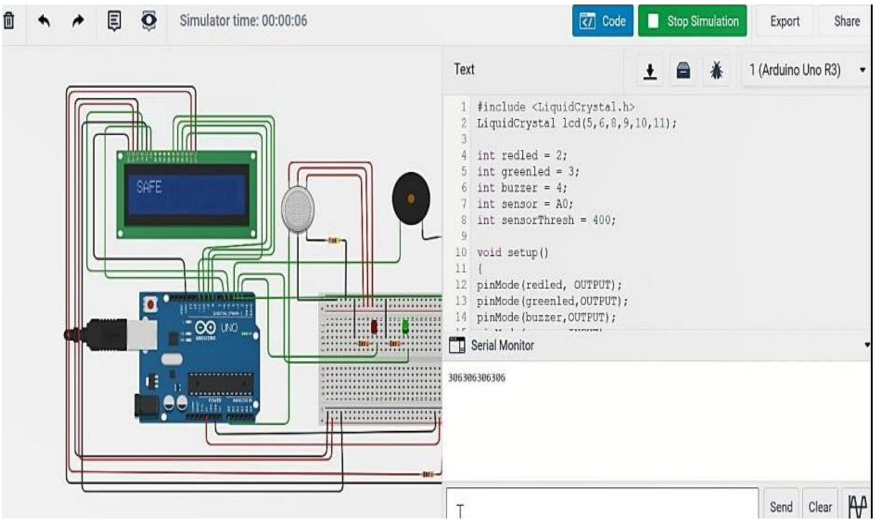

Figure 3a: Sensor output values prior to the detection of smoke

Figure 3a demonstrates how a virtual simulation of a circuit employing a gas sensor operates. The LCD will display "all clear" before the sensor begins to function, and the oscilloscope will show no wave. When the sensor detects smoke, however, the LCD will indicate "alarm," and the oscilloscope will display a square waveform, indicating a voltage change in the circuit. Additionally, the sensor value output is shown as 306V in this picture when the circuit is simulated without smoke.

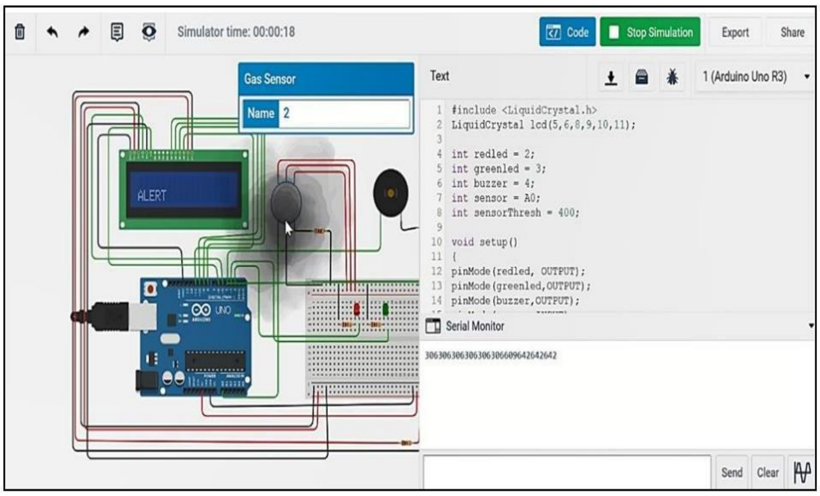

Figure 3b: Sensor output values upon the discovery of smoke

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Figure 3b illustrates the measured MQ2 gas sensor results using the pepper sample. When the circuit is simulated with smoke that the gas sensor detects, the output is displayed as 609 to 642V, which, when the circuit is emulated with smoke, is approximately two times the prior value. Following the observation of voltage differences for several samples, a machine-learning algorithm will be used to identify the percentage of adulterants in the pepper seed sample, with the results being exhibited on the website. [6][12][13][20][21]

D. Analysis of rice granules using Image Processing and Neural Network

The images of the various-sized rice grains were captured. The gathering of the image is the preliminary step of the image processing process. Standard approaches are used to enhance an image's quality via pre-processing processes. The filtering types employed in noise- reduction strategies that generate image smoothing (Figure 4c) include averaging and Gaussian filters. The use of median filters is made for smoothing in this work. Because median filtering retains the image's edges during noise reduction, it is normally employed in digital imaging. One of the key phases in image analysis approaches is segmenting an image, which follows next. This operation's accuracy is heavily reliant on the data that is later extracted. Edge segmentation, Region segmentation, and Thresholding are three approaches that have been proposed to achieve segmentation. In this article, segmentation has been carried out using adaptive thresholding, and edges are found using Canny and Sobel edge detection. Thresholding (Figure 4d) is a tool for the characterization of the parts of a photograph that relies on the light's absorption in their surfaces. The objective of the threshold is to distinguish between the areas and the elements in an image that will be subjected to analysis. The difference in intensity between the foreground pixels and the background pixels is the basis for this division.

The basis for edge detection is the detection of edges by various edge operators. Two distinct edge detection methods, the Sobel edge detector and the Canny edge detector, were employed to compare performance. In Sobel edge detection (Figure 4a), the gradient is determined for each pixel point in the picture. Using a straightforward convolution kernel, a series of gradient magnitudes are produced. On the other hand, the Canny edge detector (Figure 4b) is an ideal detector that produces an ideal filtered picture. This ideal detection method detects the edges of the grayscale picture. Because the Canny edge approach provides strong detection and localization with little response, the edges in the picture are marked just once and spurious edges are not formed because of image noise. This detector is quite powerful and capable of detecting faint edges. The Canny edge detector locates the local maxima and minima of the gradient of the intensity function to differentiate the edges.

Roughly 87 samples were collected in this experiment to investigate the categorization of granule grades. It can distinguish all grains accurately if there isn't any grain overlap. The Neural Network cannot appropriately distinguish grains that overlap one other. The accuracy in this instance was judged to be 96%.[4][7][8][10][11]

Figure 4a: Sobel Edge Detection

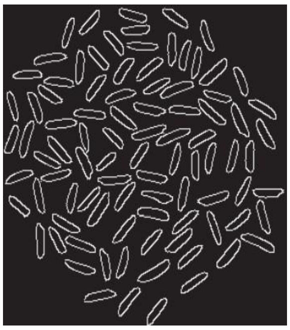

Figure 4b: Canny Edge Detection

Figure 4c: Image Smoothing

Figure 4d: Threshold Image

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III. COMPARISON OF DIFFERENT TECHNIQUES

In this paper, a survey on the available methods for adulteration detection is analyzed. Considering four major techniques for the detection of black pepper adulteration namely hyperspectral imaging, geo-tracing of black pepper by using metal oxide semiconductor gas sensors array, using IoT sensors, and edge detection technique used for the analysis of rice granules.

Table 1: Comparison of different techniques

TECHNIQUE	FEATURES	ACCURACY	ERROR RATE
Geo-tracing of black pepper using MOS gas sensors array	Geo-tracing in a pneumatic system design consisting of a metal oxide semiconductor (MOS) gas sensors array and then conducting PCA analysis	92.5%	≤7.5%
Hyperspectral imaging	Using hyperspectral imaging, the NIR-HSI system 1003B-00572 can detect papaya seeds present in samples of black pepper and berries.	90%	< 8%
IoT Sensors for pepper adulteration detection	An IoT monitoring system is used to detect black pepper adulteration. Gas sensors like MQ3, MQ135, and MQ138 are used for the detection of various organic compounds in pepper samples.	97%	<3%
Analysis of rice granules using edge detection	The images of rice granules were captured and processed. Canny and Sobel edge detection and region detection are used for the segmentation of these images.	96%	4%

IV. CONCLUSION

Food adulteration prevention is difficult due to its unpredictability. Food corporations, the government, and researchers have recently made significant efforts in numerous areas. Apart from developing new analytical techniques, food producers are also increasing their understanding of their supply chain's length (number of layers), complexity, and fragility. Transparency in the food chain and complete raw material traceability are essential for a successful food fraud detection and prevention system.

Since pepper has a major share in the world of spices it is necessary to detect the adulterants like papaya seeds to ensure that these substances do not hinder the quality of black pepper. Although these manual methods use IoT sensors, hyperspectral imaging, and other chemical methods, they do not achieve 100% accuracy it is possible to detect the adulterants from the pepper samples in most cases.

Geo-tracing is a faster and cheaper technique than other manual techniques. The adulteration is detected based on the output voltage of the circuit designed, But the hyperspectral imaging tool is more accurate and can detect impurities in both peppercorns and pepper powder. This technique makes use of the pixel distribution at a specified pixel range.

The IoT-based technique can also be used to prevent the defilement of pepper samples. It is based on the response of gas sensors to the odour of various food samples. This method achieves spontaneity at much higher rates when compared to other techniques. Edge detection on the other hand finds its application in the analysis and processing of rice granules. All these methods can help reduce the number of impurities found in the pepper samples to a great extent.

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REFERENCES

[1]. Food Marketing and Tech Magazine - https://fmtmagazine.in/adulteration-of-food/
[2]. Adulterated Food Wikipedia Page - https://en.wikipedia.org/wiki/Adulterated_food
[3]. H. E. Lee, Z. J. A. Mercer, S. M. Ng, M. Shafiei and H. S. Chua, "Geo-Tracing of Black Pepper Using Metal Oxide Semiconductor (MOS) Gas Sensors Array," in IEEE Sensors Journal, vol. 20, no. 14, pp. 8039-8045, 15 July 15, 2020, doi: 10.1109/JSEN.2020.2981602
[4]. P. Neelamegam, S. Abirami, K. Vishnu Priya and S. R. Valantina, "Analysis of rice granules using image processing and neural network," 2013 IEEE Conference on Information & Communication Technologies, 2013, pp. 879-884, doi: 10.1109/CICT.2013.6558219
[5]. Imer Orrilloa,1 , J.P. Cruz-Tiradob,1 , Alicia Cardenasa , Maritza Orunaa , Alessandra Carneroa , Douglas F. Barbinb , Raúl Siche, "Hyperspectral imaging as a powerful tool for identification of papaya seeds in black pepper", in ScienceDirect Food Control
[6]. G. Punit Rao , Vijayakumar Ponnusamy, Sowmya Natarajan, "Development of IoT Sensor for Pepper Adulteration Detection using Sensor Arrays", in Turkish Journal of Computer and Mathematics Education Vol.12 No.11 (2021), 5538-5545
[7]. N. Fatima, Q. M. Areeb, M. M. Khan and I. M. Khan, "Tracing Adulteration in Cumin, Cinnamon, and Coffee using Transfer Learning," 2021 International Conference on Data Analytics for Business and Industry (ICDABI), 2021, pp. 562-566, doi: 10.1109/ICDABI53623.2021.9655951
[8]. Y. Wu and Y. Pan, "Cereal grain size measurement based on image processing technology," 2010 International Conference on Intelligent Control and Information Processing, 2010, pp. 209-212, doi: 10.1109/ICICIP.2010.5564253
[9]. D. Ma et al., "The Quality Detection and Recognition for Food Seasoning Based on an Artificial Olfactory System," in IEEE Instrumentation & Measurement Magazine, vol. 25, no. 9, pp. 42-52, December 2022, doi: 10.1109/MIM.2022.9955467
[10]. D. Sharma and S. D. Sawant, "Grain quality detection by using image processing for public distribution," 2017 International Conference on Intelligent Computing and Control Systems (ICICCS), 2017, pp. 1118-1122, doi: 10.1109/ICCONS.2017.8250640
[11]. R. H. Hridoy, A. D. Arni and M. A. Hassan, "Recognition of Mustard Plant Diseases Based on Improved Deep Convolutional Neural Networks," 2022 IEEE Region 10 Symposium (TENSYMP), 2022, pp. 1-6, doi: 10.1109/TENSYMP54529.2022.9864487 Cruz Huacarpuma, R., de Sousa Junior, R., de Holanda, M., de Oliveira Albuquerque, R., García Villalba, L. and Kim, T., 2017. Distributed Data Service for Data Management in Internet of Things Middleware. Sensors, 17(5), p.977.
[12]. Chen, B., Liu, C., & Hayashi, K. (2014). Selective Terpene Vapor Detection Using Molecularly Imprinted Polymer Coated Au Nanoparticle LSPR Sensor. IEEE Sensors Journal, 14(10), 3458-3464. doi: 10.1109/jsen.2014.2346187.
[13]. Z. J. A. Mercer, H. S. Chua, P. Mahon, S. S. Hwang, and S. M. Ng, "Authentication of geographical growth origin of black pepper (piper nigrum l.) based on volatile organic compounds profile: A case study for Malaysia and India black peppers," in 2019 IEEE International Symposium on Olfaction and Electronic Nose (ISOEN), 26-29 May 2019 2019, pp. 1-3, doi: 10.1109/ISOEN.2019.8823265.
[14]. S. Kiani, S. Minaei, and M. Ghasemi-Varnamkhasti, "A portable electronic nose as an expert system for aroma-based classification of saffron," Chemometrics and Intelligent Laboratory Systems, vol. 156, pp. 148-156, 2016/08/15/ 2016, doi: https://doi.org/10.1016/j.chemolab.2016.05.013.
[15]. Malaysian Pepper Board. Sarawak Pepper: A Hallmark of Quality. (2018).
[16]. Bhattacharjee, P., Singhal, R. S., & Gholap, A. S. (2003). Supercritical carbon dioxide extraction for identification of adulteration of black pepper with papaya seeds. Journal of the Science of Food and Agriculture, 83(8), 783–786.
[17]. Barbin, D. F., ElMasry, G., Sun, D.-W., & Allen, P. (2012). Predicting quality and sensory attributes of pork using near-infrared hyperspectral imaging. Analytica Chimica Acta, 719, 30–42.
[18]. Rinnan, Å., Berg, F. v. d., & Engelsen, S. B. (2009). Review of the most common pre- processing techniques for near-infrared spectra. TRAC Trends in Analytical Chemistry, 28(10), 1201–1222.
[19]. Lam, M., Nguyen, T., & Chung, W. (2020). Deep Learning-Based Food Quality Estimation Using Radio Frequency-Powered Sensor Mote. IEEE Access, 8, 88360- 88371.
[20]. Lee, S. (2015). Terpene sensor array with bridge-type resistors by CMOS technology. IOP Conference Series: Materials Science and Engineering, 87, 012065. doi: 10.1088/1757-899x/87/1/012065

