**DEVELOPMENT OF A REAL-TIME FORMALIN DETECTION KIT USING MQ135 SENSOR AND ESP32 FOR FOOD SAFETY MONITORING IN INDIA**

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**ABSTRACT**

Common preservative formalin can be hazardous if it is present in food or the environment in excess of what is considered safe. Traditional testing techniques are accurate, but they are impractical for on-the-spot inspections and frequently need sophisticated equipment and skilled professionals. The emergence of Internet of Things (IoT) technology has sparked interest in developing smart, portable, and reasonably priced formalin detection systems. This research delves into subjects such as sensor designs, wireless data sharing, real-time analysis, and cloud-based monitoring to examine how IoT is being used for formalin detection. It also addresses issues like increasing the sensitivity of sensors, protecting data, controlling power consumption, and guaranteeing dependable networks. The assessment highlights promising future directions, such as integrating AI, reducing sensor sizes, and developing scalable, environmentally friendly IoT systems for wider application. The aim is to give academics and innovators a comprehensive understanding of the most recent developments and prospects in the use of IoT for formalin detection.

**Keywords:**Formalin, IoT, Cloud-Based, Detection

**INTRODUCTION**

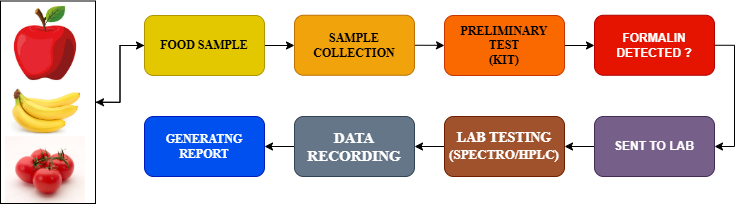
A worldwide history of adulterating food has existed since the 18th and 19th centuries. In Europe and North America, food adulteration has existed for centuries. Food adulteration, also called "Food Fraud", is a description of intentional food degradation. A breach in both the safety and quality of the food items occurs deliberately through sales distortion. Different techniques, including tampering and false or misleading statements, as well as component removal or ingredient reduction, can degrade the quality of the food [1]. Food adulteration is a deliberate contamination of food. Mainly, food adulteration is a profit-making scheme that has a serious worldwide effect. Consumers raising fish and seafood face a high risk of fraud due to the increased demand and restrained sources with a sophisticated supply system. Large numbers of fraud methods made the eatables highly vulnerable to practices such as species substitution, adulteration, uncleared product extension, etc. [2]. Short-term effects of formalin when consumed are pain in the stomach, nausea, vomiting and diarrhoea.In contrast, long-term consumption could trigger cancer. The usage of formalin, a food preservative, could not be seen in the unaided eye. Test kits and laboratory tests are mainly used to detect the presence of formalin in food or any eatables. However, those test kits have several drawbacks: they are use-and-throw kits, and those kits will not provide additional information about the presence levels of the formalin in the eatables. On the other hand, lab tests are expensive [3]. Generally, formalin is a clear and water-based solution made using formaldehyde, and it is commonly used to preserve biological samples and prevent dead bodies from decaying. All types of food adulteration with formalin will not cause serious health problems, but it is still dangerous; just 30ml of formalin, exactly 37% formaldehyde, is enough for an adult to die [4]..

Figure 1. Traditional methods

**LITERATURE REVIEW**

Food adulteration has emerged as a major national concern. It not only violates the fundamental right to safe food but also poses a serious threat to public health, contributing to a wide range of acute and chronic illnesses. Future generations are at risk of impaired physical and mental development due to the harmful effects of adulterated food. This paper highlights the health impacts of consuming contaminated food. It emphasizes the responsibilities of relevant authorities in addressing and eliminating the issue. The primary goal of this work is not to criticize or blame any party but to raise awareness about the current state of food adulteration and to encourage positive change through effective actions by responsible regulatory bodies.[1]

This study introduces an IoT-based system designed to detect formalin contamination in fruits and vegetables, integrating machine learning techniques for improved accuracy. It emphasizes the significant health hazards associated with formalin-tainted food, particularly in Bangladesh, and reviews existing detection methods. Utilizing a volatile compound HCHO gas sensor linked to an Arduino platform, the system measures formalin concentration through voltage readings. It applies machine learning algorithms for classification and prediction. The results indicate that this digitalized solution offers an effective and user-friendly method for consumers to identify unsafe formalin levels in food.[2]

In Bangladesh, where fish is a dietary staple, safeguarding it from formalin contamination remains a significant challenge due to its perishable nature. This research presents a smart application that utilizes digital image processing for fast and non-destructive detection of formalin in fish. By analyzing images of fish eyes, the system can differentiate between formalin-treated and untreated fish. The proposed framework, based on EfficientNet-B3 and VGG-16 models, achieved accuracy rates of 98.05% and 98% during training and validation, respectively. This technique offers a rapid and reliable inspection method without damaging samples. It is particularly valuable for large-scale operations where manual checks are impractical. Unlike human inspection, digital image processing ensures objective assessments, eliminating biases and subjective errors. Despite challenges such as variations in fish appearance and external factors like inconsistent lighting conditions, this technology shows strong potential to enhance automated formalin detection in the fish supply chain, promoting food safety and protecting public health.[3]

This study presents a machine learning-based detection system designed to identify the presence of the toxic chemical formalin in food, with a focus on fruits. It outlines the health hazards linked to formalin contamination and emphasizes the urgent need for reliable detection techniques. The proposed solution involves a digital device, possibly integrated with a smartphone, that employs pre-trained models to distinguish between naturally occurring and artificially introduced formalin, providing an accessible tool for consumers without technical expertise.[4]

While various fruit recognition methods have been developed based on colour and shape attributes, challenges remain as different fruits can share similar colour and shape characteristics. As a result, relying solely on colour and shape analysis is often not sufficiently robust or reliable for accurate fruit identification. To address this, a new fruit recognition system is proposed, combining colour, shape, and size feature analysis to enhance classification accuracy. Using nearest neighbour classification based on extracted feature values, the system identifies and classifies fruit images. It then displays the fruit's name along with a brief description to the user. The proposed system achieves up to 90% accuracy in fruit recognition. It offers valuable applications in fields such as education, image retrieval, and agricultural science.[5]

This study evaluated the performance of a formaldehyde detector developed by the proponents. The main objective was to assess the device's consistency in detecting the presence of formaldehyde. Specifically, the device was tested using three different concentrations of formalin. A small-scale experimental setup was employed, where the gas sensor was placed inside an eight-litre sealed container. The sensor was exposed to formalin for five minutes, followed by five minutes without exposure. Formalin concentrations of 1%, 5%, and 10% were used, with three trials conducted for each concentration. Results showed that the device produced consistent response graphs across all tests, demonstrating its sensitivity to formaldehyde at varying concentrations. Additionally, the formaldehyde detector operated effectively within its specified limits.[6]

Several fruit recognition methods have been developed based on colour and shape attributes. However, due to the similarity or overlap in colour and shape among different fruits, these approaches often lack robustness and accuracy in distinguishing between fruit images. To address this limitation, a new fruit recognition system has been proposed, integrating three types of feature analysis, colour-based, shape-based, and size-based methods, to improve recognition accuracy. The proposed system classifies and identifies fruit images by applying the nearest neighbours classification algorithm based on the extracted feature values. It then displays the fruit name along with a brief description for the user. The system achieves up to 90% accuracy in fruit identification. It serves as a valuable tool across various fields, including education, image retrieval, and agricultural science.[7]

In India, agriculture is a key livelihood, so ensuring the quality of fruits and vegetables is crucial. A quality assessment system can help identify spoiled produce, prevent further spoilage, and assist farmers in pricing and classification. This paper discusses the use of wireless sensor networks (WSNs) for agricultural monitoring. It extends the concept of assessing food quality. It compares destructive methods (like cutting) with non-destructive methods (like computer vision and hyperspectral imaging). To improve accuracy, the proposed system uses a multi-sensor network to evaluate product quality and upload results to an agricultural cloud for research.[8]

A simple, precise, and cost-effective method has been introduced for measuring formaldehyde in aqueous samples. This technique is based on quantifying classical chromotropic acid–acid-formaldehyde violet spots developed on TLC plates. Various parameters, including the concentrations of chronotropic and sulfuric acid, heating duration, and the sequence of reagent application, were optimized to establish the best working procedure. Spot quantification was achieved by scanning the TLC plates and analyzing the images using a Visual Basic 6.0-based graphical application. The study involved creating a calibration curve, testing both artificial and real samples, and comparing the new method with the standard spectrophotometric method (NIOSH Method-3500, 1994). Findings concluded that this method is highly capable of detecting trace levels of formaldehyde with excellent precision and accuracy, especially in turbid and small-volume samples where traditional methods often fall short.[9]

Fish is a crucial protein source in Bangladesh, where imported fish often contain harmful formalin. A study across six districts found that 22.68% of 939 fish samples were contaminated, especially in large cities like Dhaka. Local small fish were formalin-free, and even large local fish had less contamination. Surprisingly, formalin-free local fish had better shelf life and quality. Despite knowing the health risks, some traders still used formalin to preserve fish. The study also found poor hygiene and handling practices in markets.[10]

The formaldehyde (FA) content in various fish products was determined using a solid-phase microextraction (SPME) method coupled with gas chromatography-mass spectrometry (GC-MS), involving fibre derivatization with pentafluorobenzyl-hydroxyl-amine hydrochloride. The limits of detection (LOD) and quantification (LOQ) were calculated to be 17 μg kg−1 and 28 μg kg−1, respectively. The study analyzed 12 fish species, including sea fish, freshwater fish, and crustaceans, revealing varying FA levels. Different forms of fish—fresh, deep-frozen, canned, boiled, and roasted—were tested, with cooking consistently reducing FA content. Fish from the Gadidae family showed the highest FA concentrations, ranging from 6.4 ± 1.2 mg kg−1 to 293 ± 26 mg kg−1, with four out of 14 samples exceeding the 60 mg kg−1 threshold set by the Italian Ministry of Health. Storage on ice was also studied, showing moderate FA production even at temperatures near 0 °C. FA levels in all other samples were found to be below 22 mg kg−1.[11]

Fish is a vital source of protein and an essential food staple worldwide. In Bangladesh, the fisheries sector significantly contributes to foreign currency earnings and meets the domestic demand for animal proteins. To supplement local production, Bangladesh imports fish and fish products from neighbouring countries. However, several studies have shown that a majority of imported fish are contaminated with formalin, a hazardous and carcinogenic chemical. Data was collected from fish retailers and consumers through surveys conducted in 18 different fish markets across six districts of Bangladesh to assess the marketing of formalin-treated fish. The results revealed that most commercially imported fish were heavily contaminated with formalin. While large local fish species, such as rui (Labeo rohita), catla (Catla catla), and mrigal (Cirrhinus cirrhosus), showed partial formalin contamination, small local fish were found to be free from it. The study analyzed 939 fish samples from various markets in the six districts, finding that 213 fish (22.68%) were directly contaminated with formalin. Contamination rates were significantly higher in large cities like Dhaka (36.78%) compared to smaller towns like Jamalpur (13.33%). Notably, all village markets were free from formalin contamination. Fish traders use formalin to extend the shelf life of fish. However, the study also found that local, formalin-free fish had a much longer shelf life and superior organoleptic characteristics compared to formalin-treated and imported fish. The price of imported fish was lower than that of local fish, and the organoleptic qualities of the imported and formalin-contaminated fish were noticeably inferior to those of local fish, leading to lower consumer satisfaction. Additionally, the study highlighted poor hygienic practices and unsatisfactory sanitary conditions in the markets and among fish traders. It was also revealed that all traders who used formalin in their fish were aware of its harmful effects.[12]

The organoleptic, biochemical, and bacteriological properties of five tropical marine fish species—silver jewfish, Bombay duck, big-eye tuna, Chinese pomfret, and ribbon fish—stored on ice were examined. Organoleptically, all the fish remained acceptable for consumption for 10 to 13 days before becoming inedible. Proximate analysis revealed a slight increase in moisture content, a gradual decrease in protein and lipid content, and minimal or no significant change in ash content. As storage time increased, values for pH, TVB-N, peroxide levels, and Aerobic Plate Count also rose but remained within acceptable limits for up to 10 days. Myofibrillar ATPase activity and protein solubility changes indicated that Ca2+ ATPase activity decreased gradually in the presence of both 0.1 M and 0.5 M KCl. In contrast, no significant changes were observed in Mg2+ ATPase activity, whether Ca2+ was present or not. The solubility of myofibrillar proteins in all fish samples decreased substantially during ice storage. The reduction in Ca2+ ATPase activity and solubility suggests that denaturation of the myofibrillar proteins occurred during ice storage.[13]

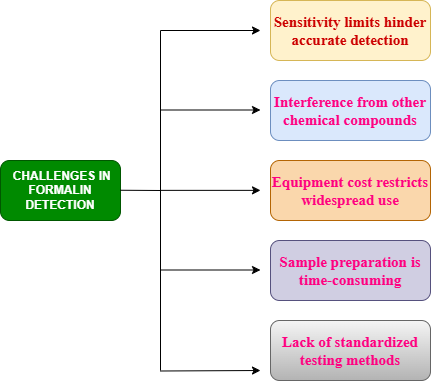
Point-of-care testing (POCT) for bacterial infections offers key advantages in disease diagnosis by shortening the time needed to get results and making it possible to perform tests at the patient's bedside or in remote medical facilities. Immunochromatographic lateral flow biosensors present an affordable and highly sensitive platform for POCT. This paper discusses the creation and validation of a multiplex immuno-disc sensor specifically designed to detect Pseudomonas aeruginosa and Staphylococcus aureus. Antibodies conjugated to gold nanoparticles are used as the signalling mechanism. This sensor is capable of detecting bacterial concentrations in the range of 500–5000 CFU/ml. A primary benefit of the immuno-disc sensor is its ability to detect whole bacterial cells directly without needing any sample preparation. Furthermore, we outline the development of a small, portable device that converts the colour intensity of the gold nanoparticles at the test site into a quantitative voltage reading, which directly corresponds to the bacterial concentration. By combining the immuno-disc sensor with this portable colour reader, a quick, sensitive, cost-efficient, and accurate diagnostic tool is created, capable of detecting a variety of infectious agents in patient samples.[14]

Measuring ultra-low levels (such as parts-per-billion) of small-molecule markers in body fluids like serum, urine, and saliva poses significant challenges due to the need for highly sensitive and selective assay strategies. In this study, we introduce a novel amperometric nano-bioelectrode that combines 1-pyrenebutyric acid units, stacked with carboxylated multiwalled carbon nanotubes, on gold screen-printed electrodes to attach NAD+-dependent formaldehyde dehydrogenase (FDH) covalently. This bioelectrode demonstrated a formaldehyde detection limit as low as 6 ppb in 10 times diluted urine, with a broad dynamic detection range from 10 ppb to 10 ppm. Characterization through Fourier transform infrared, Raman, and electrochemical impedance spectroscopy confirmed the successful creation of the FDH bioelectrode. Using flow injection analysis, the bioelectrode showed superior performance in terms of lower detection limits and a greater affinity for formaldehyde (apparent KM of 9.6 ± 1.2 ppm) compared to traditional stirred solution methods (apparent KM of 19.9 ± 4.6 ppm). Selectivity tests showed that the bioelectrode was highly selective for formaldehyde, with only moderate cross-reactivity to acetaldehyde (~25%) and negligible reactivity with other compounds like propanaldehyde, acetone, methanol, and ethanol. Formaldehyde, known as an indoor pollutant, has been associated with neurotoxic effects and systemic toxicity when exposed to chronic, high doses. Elevated levels of formaldehyde in urine have also been linked to diseases like bladder cancer, dementia, and early-stage cognitive impairments. The results highlight the potential of pyridyl carbon nanostructure-based FDH bioelectrodes for simple, enzyme-selective electrochemical detection of small molecules like formaldehyde. The approach can also be adapted for other small-molecule biomarkers by designing enzyme systems or receptors specific to those markers.[15]

Formaldehyde is a colourless gas that is emitted into indoor environments from sources such as furniture and various other products. In 2006, the International Agency for Research on Cancer (IARC) classified formaldehyde as a carcinogen to humans, even at low concentrations. The World Health Organization (WHO) has set a guideline value of 82 ppb (parts per billion) for formaldehyde exposure. Traditional methods for analysis, such as gas chromatography (GC) or high-performance liquid chromatography (HPLC), require sampling and are off-line techniques. These methods are time-consuming, cumbersome, and involve expensive equipment and consumables. This review discusses advancements over the past decade in the development of portable, highly sensitive, and real-time formaldehyde analyzers.[16]

Figure 2. Range PPM

|  |  |  |
| --- | --- | --- |
| **Method Type** | **Samples Used** | **Range (ppm)** |
| Machine Learning | Fish, fruits, vegetables | 49 |
| Chemical Analysis | Fish, seafood | 15.37 |
| Machine Learning | Fish, fruits | 50 |
| Fuzzy Logic | Tofu, salted fish | 193.21 |
| QCM Sensors | Fish | 500 |
| UV-VIS Spectrophotometry | Aqueous solutions | 3.60 |
| HPLC-UV | Apple juice, urine, rainwater | 1.98 |
| HPLC-UV | Milk | 0.39 |

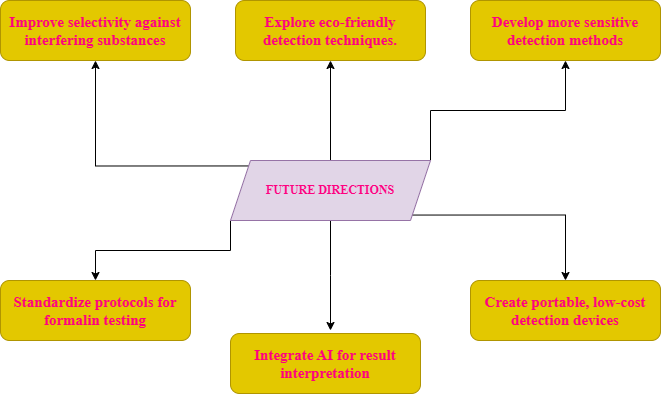
****Table 1. PPM range based on the review paper

**CHALLENGES IN DETECTING THE FORMALIN**

Figure 3. Challenges

This diagram suggests future directions for formalin detection: improving selectivity, exploring eco-friendly methods, developing highly sensitive techniques, creating portable, low-cost devices, standardizing protocols, and integrating AI for better result interpretation.

**FUTURE DIRECTIONS IN FORMALIN DETECTION**.



This diagram suggests future directions for formalin detection: improving selectivity, exploring eco-friendly methods, developing highly sensitive techniques, creating portable, low-cost devices, standardizing protocols, and integrating AI for better result interpretation.

**CONCLUSION**

Formalin's extensive use and detrimental consequences on human health make its identification a crucial study topic. Despite their accuracy, traditional laboratory-based techniques are constrained by their expense, intricacy, and requirement for specialized infrastructure. Real-time, remote, and continuous monitoring of formalin levels across several environments is made possible by the integration of IoT technology, which presents interesting possibilities. Devices that are portable and easy to use are being made possible by developments in sensor technology, wireless communication, cloud computing, and data analytics. However, for large-scale deployment, issues including sensor sensitivity, power consumption, data security, and network stability need to be resolved. Future research should concentrate on creating inexpensive, environmentally friendly, highly sensitive sensors that are connected with AI for more intelligent detection.

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