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Review Article

A Review of Methods for Detecting Calcium Carbide Induced Ripening in Fruits

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A B S T R A C T

The use of calcium carbide (CaC_2) as a ripening agent for fruits is banned in most countries across the world, including India (under the prevention of Food Adulteration Act (PFA: 44 AA), 1955 and Food Safety and Standards Regulation Act, 2011). Yet, in our country; it is a common practice to use industrial-grade Calcium Carbide for ripening of climacteric fruits like mango, banana, papaya etc. which leaves behind traces of arsenic and phosphorus, along with heavy metals like Fe, Co, Hg, Pb etc. CaC_2 reacts with moisture to produce acetylene gas, which accelerates the ripening process, but the byproducts of this process pose a severe threat to human health. Hence, there is a need of accessible and economically feasible methods for detecting CaC_2 induced ripening in fruits, for all stakeholders in the fruit supply chain, especially the end consumer. This review investigates the utility, limitations, and underlying principles of key methods. While laboratory-based techniques like gas chromatography-mass spectrometry are highly accurate, they are time-consuming and destructive. Sensor-based and colorimetric methods target residues of CaC_2, arsenic, and the VOC (volatile organic compound) profile of fruit. Spectroscopy based methods have been explored, including the more accurate hyperspectral imaging and the low-cost, portable sensors in the visible-near infrared wavelength band, which show potential for hand-held applications.

Keywords: Calcium Carbide, Fruit Ripening, Non-invasive detection, Spectroscopy, Biosensor, Colorimetry

Introduction

Fruits play a vital role in human nutrition. They are rich sources of dietary fibre, antioxidants, vitamins, and minerals. Eating fruits regularly promotes physical and mental well-being and helps in preventing chronic health issues such as heart disease, obesity, and diabetes. Ripening is a complex process that involves significant biochemical and physiological changes. The full nutritional and sensory value of a fruit, including aroma, colour, texture, etc., emerges once it is ripened. For climacteric fruits like mango, banana, papaya, sapota (chikoo), etc., ripening continues even after harvest. The natural ripening of climacteric fruits is a process driven by a plant hormone called “ethylene” (C_2H_4). Ethylene starts a series of enzyme reactions that lead to the transition of fruit from an unripe state to one ready for consumption. Key changes include the breakdown of chlorophyll pigments, which reveals underlying carotenoids such as xanthophylls and carotenes. Consequently, we observe noticeable shifts in fruit colour and reflectance properties (relevant for spectroscopy). At the same time, complex carbohydrates, mainly starch, are broken down into simpler sugars like sucrose, glucose, and fructose. This increases the fruit's sweetness and overall flavour. Enzymes like.

Pectinases and cellulases alter the cell wall structures, causing the fruit to soften and lose firmness. This natural process is generally uniform, resulting in consistent colour, texture and chemical profile.

In fruit supply chains, the natural ripening process often conflicts with logistical needs. To extend shelf life, reduce damage, and enable long-distance transport, climacteric fruits are usually picked when they are still unripe, firm, and green. This creates a need for post-harvest ripening to make fruits ready to eat as they are sold. Natural ripening occurs slowly and is often uneven for different fruits, while market demands call for speed and uniformity of ripening for fruits in a batch. As a result, artificial ripening methods are commonly used.

In India, industrial-grade calcium carbide (CaC_2) is widely used for artificial ripening. Calcium carbide reacts with moisture to produce acetylene (C_2H_2) gas, which mimics ethylene and triggers the ripening process prematurely. However, this method does not completely ripen the fruit. While the breakdown of chlorophyll occurs, conversion of starch to sugar is often incomplete, leaving the fruit starchy, acidic, and lacking in the desired flavour and aroma.

Apart from that, the process of ripening fruits with calcium carbide leaves behind residues of arsenic, phosphorus and other harmful heavy metals, including Fe, Co, Hg, Pb etc., that accumulate in the fruit. This leads to health risks for people handling and consuming the fruit. Acute effects range from headaches to digestive issues, while chronic exposure can lead to neurological disorders and even cancer. (Hong et al.; Richard et al.)[1,2]

Indian law bans the use of calcium carbide for ripening under the Prevention of Food Adulteration Act, 1955, and the Food Safety and Standards Regulations Act, 2011. Further, to meet the need for controlled post-harvest ripening, the Food Safety and Standards Authority of India (FSSAI) allows the use of ethylene gas at low concentrations (up to 100 ppm), typically applied through ethephon (2-chloroethylphosphonic acid), for fruit ripening. Ethephon enables internal ethylene generation, triggering the natural ripening processes and ensuring uniform maturity without toxic residues, as in the case of CaC_2.

Despite the legal restrictions, calcium carbide is still used for ripening fruits because of its low cost, effectiveness, and availability. It is not viable to tell fruits ripened with calcium carbide from naturally ripened ones just by looking. Hence, various techniques are used for this purpose. These range from laboratory-based chemical methods which are more accurate but time consuming, to image processing, and even using hyperspectral cameras.

Methods Used for Fruit Ripening

The postharvest ripening of fruits can be achieved through various methods that manipulate exposure to ethylene (C_2H_4) or its analogues to induce biochemical changes. Natural ripeningrelies on the production of ethylene by the fruit itself at controlled temperature and humidity, while chemical methods, such as using ethephon sachets or calcium carbide in powder form, provide external sources of ethylene or its analogues to accelerate ripening. These methods vary in their mechanisms, time frames, safety, and suitability for commercial or experimental purposes.

Ethylene Based Ripening

Freshly harvested fruits for natural ripening are kept in wooden crates lined with dry straw and grass, covering them to create a semi-closed environment. The respiration of fruits produces heat and moisture, creating a microclimate that increases the accumulation of naturally produced ethylene, which in turn leads to ripening. The fruits are monitored daily until they show uniform yellow colouration and softening.

Figure 1.Naturally Ripened mangoes placed with dry straws

A review article by Maduwanthi et al.[5] shows naturally occurring ethylene released from other ripening fruits also accelerates ripening, with increased respiration levels and endogenous ethylene levels. Apples, pears, tomatoes, etc. have been studied as natural ripening agents and found to be effective.

Sogo-Temi et al.[6] examined natural ripening agents such as African bush mango (Irvingia gabonensis) fruit and Jatropha curcas leaves. They were placed with unripe bananas inside black polythene bags at room temperature. It was found that fruits ripened with these agents had much lower heavy

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metal residue as compared to chemical agents.

For postharvest treatment using artificially produced ethylene, commercially available ethephon sachets are placed directly within fruit cartons or containers. This method often manages ripening during transit. The sachets release ethylene gas into the container, which triggers the fruit's natural ripening process. This hormonal signal activates biochemical changes, including chlorophyll breakdown, starch-to-sugar conversion, and the development of carotenoid pigments.

Another safe method of postharvest ripening, also permitted by FSSAI (Guidance Note No. 04/2018),[3] is controlled exposure of fruits to ethylene gas in regulated ripening chambers that maintain optimal temperature (15°–25°C) and relative humidity (90–95%), with ethylene concentration not exceeding 100 ppm. Proper ventilation in these chambers is essential to avoid carbon dioxide buildup (maintained below 5000 ppm), as ethylene is very flammable at higher concentrations. The sources of ethylene gas in ripening chambers are -

1. Ethylene gas cylinders
2. Compressed ethylene gas (aerosol cans)
3. Catalytic converters for dehydrating ethanol

$$C_2H_5OH \rightarrow C_2H_4 + H_2O\,(g) \qquad (1)$$

4. Ethephon (39% SL) with alkali (usually NaOH pellets)

$$C_2H_6ClO_3P + OH^- \rightarrow C_2H_4 + Cl^- + H_2PO_4^- \qquad (2)$$

A study by Maduwanthi et al.[4] on the effect of ethephon on mango ripening and post-harvest quality drew a conclusion that post-harvest, the application of liquid ethephon at 750- 1000 ppm is optimal for Langra mangoes. The given con- centration effectively induces uniform ripening and develops desirable quality attributes-color and sugar content-within 4-6 days of storage.

Acetylene Ripening Using Calcium Carbide

For acetylene ripening, Calcium Carbide (CaC_2) is wrapped in newspapers or tissue papers, and these packets are placed directly among the unripe fruits inside boxes. The box is kept at room temperature, that is, about 25°C, for 24 - 48 hours. During this time, calcium carbide reacts gradually with the moisture present in the air, producing acetylene gas (C_2H_2), which accelerates the ripening process by mimicking the effect of natural ethylene. Although effective, this method leaves behind traces of arsenic and phosphorus along with other heavy metals, which makes it unsafe for consumption, and hence the method is illegal in countries like India, the United States, and the European Union.

A comparative study by Sabuz et al.[7] on ethephon- and acetylene-induced ripening highlights the effects of chemical ripening agents on fruit quality. While external agents like ethephon or acetylene can accelerate ripening and achieve uniform colour and sweetness, this process often compromises biochemical and sensory quality, including sugars, vitamins, pigments, texture, and overall nutritional value, compared to naturally ripened fruits. The study concludes that while ethephon and acetylene (at 1000 ppm) are equally effective, quadrupling banana ripening speed, this acceleration comes at a significant cost to the fruit's biochemical quality. The sugar content, vitamin C, and pigments (both chlorophylls and carotenoids) are altered. Artificial ripening also affected flesh firmness, pulp moisture, Total Soluble Solids (TSS), and pH. Essentially, the artificially induced ripening process prevents the bananas from developing the same chemical profile, particularly in vitamins and pigments, that is found in naturally ripened bananas.

Another study by Hussain et al.[8] concludes that while artificial ripening with agents like calcium carbide is fast, it significantly degrades the mango's quality. This practice lowers nutritional value by reducing essential minerals and organic acids and also deteriorates the sensory quality (taste, aroma). This makes the artificially ripened fruit biochemically inferior to one ripened naturally.

Problems with using Calcium Carbide as A Ripening Agent

Calcium Carbide (CaC_2) is industrially produced by burning lime (CaO) and coke(C) at a temperature of around 2000 °C in an electrical furnace, and trace elements such as arsenic (As) and Phosphorus (P), are usually present as impurities in both, coke and lime.

$$CaO + 3C \rightarrow CaC_2 + CO \qquad (3)$$

During the heating process in the electric furnace, ar- senic traces combine with calcium to form calcium arsenide (Ca_3As_2), while phosphorus impurities form calcium phosphide. (Ca_3P_2). These impurities become even more dan- gerous when calcium carbide comes in contact with moisture, as toxic gases Arsine (AsH_3) and Phosphine (PH_3) are released; both of which are carcinogenic to human beings. (Ekanem et al. 2021).[9]

When calcium Carbide (CaC_2) comes in contact with mois- ture present in the air, it releases acetylene(C_2H_2),

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which accelerates fruit ripening by mimicing the effects of ethylene.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2 \quad (4)$$

But acetylene produced from CaC_2 comprises of phosphine and arsenic up to 95 and 3 ppm, respectively (et al. Siddiqui and Dhua, 2010; Maduwanthi and Marapana, 2019).[10,11] This acetylene ripens the fruits but arsenic and phosphorus residues will accumulate in the fruits along with other harmful heavy metals like lead (Pb), cadmium (Cd), Iron (Fe), mercury (Hg) etc.

Consuming arsenic is linked to serious health problems,[1] including higher chances of various cancers (skin, lung, liver, bladder), skin lesions, heart disease, nerve disorders, kidney damage, and immune system issues. Acute arsenic poisoning can lead to stomach pain, weakness, trouble swal- lowing, numbness, low blood pressure, and can be deadly. Too much phosphorus can upset mineral balance, resulting in bone loss, kidney problems, and artery calcification.[2] Moreover, the acetylene gas produced during the ripening process acts as a nervous system depressant. Breathing it in can cause headaches, dizziness, mood changes, memory loss, and seizures. Workers handling calcium carbide are at risk too, facing possible respiratory issues, skin and eye irritation, or burns from direct contact.

But even after the legal implication, and severe health risks involved; a survey conducted by Directorate of Marketing and Inspection (Ministry of Agriculture, Government of India) in 2016 showed that 99% of the fruits were ripened artificially by using CaC_2 of industrial origin.

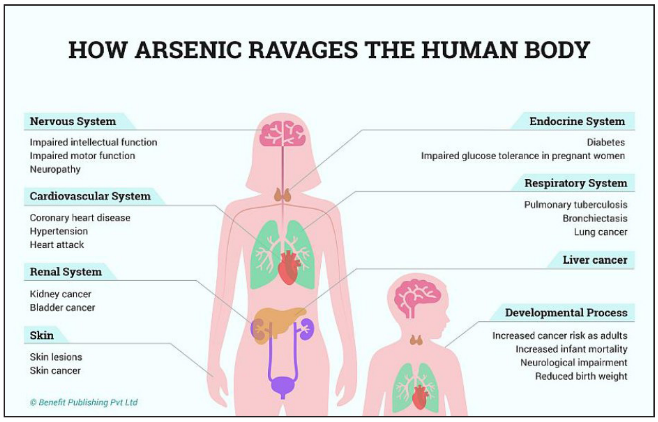

Figure 3.The severe impact of consuming arsenic (As) on human body. Source: Darshan Desai, Pure and Eco India

Methods for Detecting fruits Ripened with Calcium Carbide

A plethora of techniques have been studied and applied in an attempt to distinguish between fruits that are naturally ripened and those ripened artificially by CaC_2. These procedures involve direct chemical testing for residues, sensory evaluation, several spectroscopic methods, imaging, electronic sensing systems, and chromatographic techniques. The goal is to seek methods that are accurate, preferably real-time and non-invasive making them suitable for application in various stages of the fruit supply chain.

Impurity Detection Using Colorimetry

An important strategy is identifying traces of arsenic (*As*), an impurity commonly found in industrial-grade CaC_2. Arsenic here serves as an indication of the usage of calcium carbide in the ripening process. Lakade et al.[12] developed a real-time colorimetric test using lauryl-sulfate-capped gold nanoparticles (AuNPs). In this method, arsenic residues on the fruit surface displaces the lauryl sulfate cap, causing the AuNPs to clump together. This clumping creates a clear colour change from red to purple, which allows for easy testing of fruit extracts in the field.

Volatile Marker Analysis using Gas Chromatography - Mass Spectrometry

This method focuses on finding unique volatile organic com- pounds (VOCs) produced during ripening with CaC_2. Vemula et al.[13] studied the volatile profile of sapota (sapodilla) or chikoo fruits using headspace solid-phase microextraction gas chromatography–mass spectrometry (HS-SPME–GC-MS). While many compounds, including alcohols, aldehydes, and esters, were found in all ripening methods, the study identified 3,5-dimethyl-1,2,4-trithiolane isomers only in fruits ripened with CaC_2. The formation of these trithiolane residues re- sulted from impurities, such as divinyl sulfide in the CaC_2 reacting with fruit enzymes. This establishes them as specific chemical markers for this ripening method.

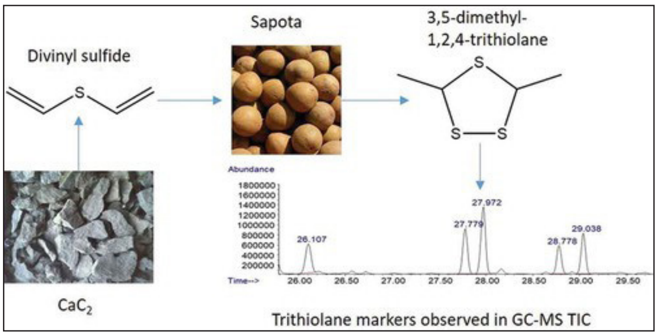

Figure 4.Trithiolane markers observed in sapota fruits using GC-MS. Source: Vemula et al.[13]

Electrochemical Biosensor Based Detection

To directly measure CaC_2 residues, researchers have de- veloped electrochemical biosensors. Ramachandra et al.[14] created a biosensor using a platinum (Pt) working electrode modified with a ceria (CeO_2) nano-interface and attached acetylcholinesterase (AChE) enzyme. The detection method relies on the competitive inhibition of the AChE bioelectrode by CaC_2 residues, mainly its reaction products calcium perox- ide and acetylene. This electrochemical method showed high sensitivity, achieving a low limit of detection (LOD) of 0.6 nM and high recovery rates. It offers a portable and effective way to measure CaC_2 contamination in fruits.

Digital Image Processing

On a simpler level, standard digital cameras combined with computer vision algorithms have been explored. This method involves extracting colour histograms and texture features from an RGB image of the fruit. By applying machine learning models like Support Vector Machines (SVM) or k-Nearest Neighbors (k-NN), systems are trained to recognize the subtle, unnatural color uniformity or patching characteristic of fruits ripened artificially with CaC_2. Anitha Raghavendra et al.[15] achieved 85.7% classification accuracy. Image processing using RGB cameras is a non-invasive and low-cost approach, but with a major downside. It relies entirely on surface-level visual cues. It cannot reliably detect the underlying biochemical state of the fruit and can be easily deceived by chemical agents that produce a visually appealing colour without proper internal ripening. S. Maheswaran et al.[16] achieved an accuracy of 91% in detecting artificially ripened mangoes by comparing histogram values. The workflow was executed using smartphone-based image processing software.

Vis-NIR Spectroscopy

A non-destructive method is using visible range and Near-Infrared (NIR) spectroscopy to detect spectral patterns that represent pigmentation (in the visible region) and the biochemical state of the fruit (in the NIR region). Lakade et al.[17] collected spectral data from mangoes in the 600–1100 nm range and used multivariate methods, like principal component analysis (PCA) and partial least squares (PLS), to effectively tell apart naturally ripened fruits from those ripened with CaC_2.. The study confirmed that arsenic content was a key factor in their analysis, proving the NIR method to be a quick, non-invasive option for detecting CaC_2 usage.[18] Finally, I studied how spectroscopy can differentiate between naturally tree-ripened avocados and those artificially ripened with calcium carbide (CaC_2). They used a triad spectroscopy sensor to measure chlorophyll fluorescence (ChIF) in the 410 nm-940 nm wavelength range and found clear differences in the spectral patterns. Unripe avocados had the lowest spectral intensity, while tree-ripened ones had the highest. Avocados treated with different amounts of CaC_2 (50 g, 75 g, 100 g) showed varying spectral intensities. The study calculated the ratio of peak intensities at 460 nm and 860 nm (I460/I860) as a marker for ripening method classification. They found that tree-ripened avocados had the lowest ratio (0.64), unripe avocados had the highest (0.9), and CaC_2-ripened avocados had I460/I860 values between 0.73 and 0.85, depending on the amount used. This suggests that ChIF spectroscopy is a useful non-invasive method for identifying CaC_2-induced ripening.

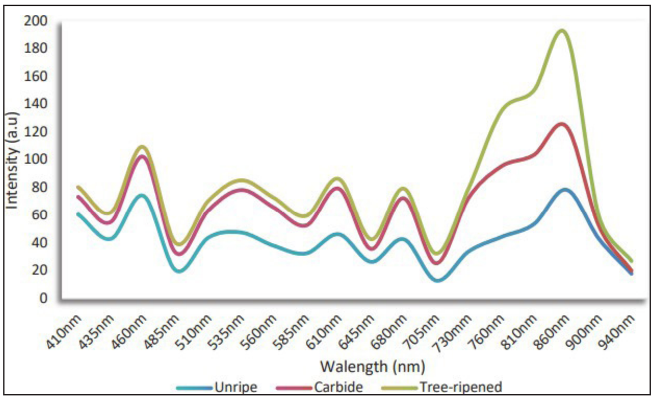

Figure 5.Average Spectral Intensity of Unripe, Carbide ripened, and Tree- ripened avocados. Source: Ifmalinda et al.[18]

Electronic Nose (E-Nose)

This technique utilises a series of gas sensors that respond differently to various VOC (volatile organic compounds), mimicking the human sense of smell. The combined sensor responses create a unique "odour fingerprint". By training the system with pattern recognition algorithms, e-noses can effectively distinguish the aroma profile of artificially ripened fruits from naturally ripened ones. For example, Shan et al.[19] successfully applied an e-nose with a Random Forest algorithm to differentiate between naturally and artificially ripened crab apples.

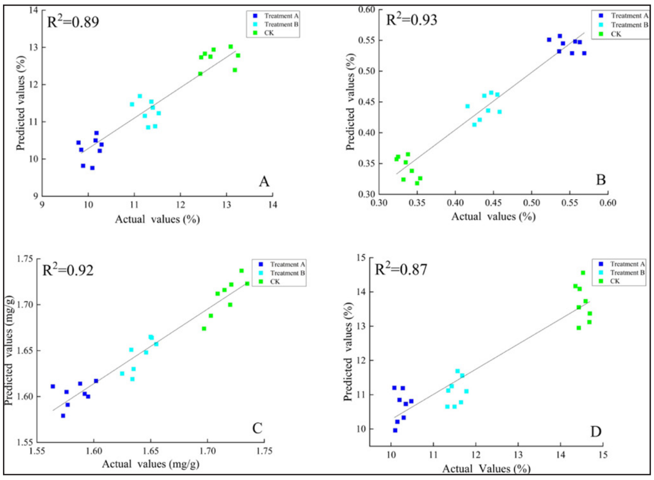

Figure 6.Partial least squares regression (PLSR) results for predicted quality indexes based on the integral value of e-nose response curves. (A) Soluble sugar; (B) titratable acid; (C) soluble protein; (D) soluble solids. Source: Qiao et al.[19]

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Hyperspectral and Multispectral Imaging

These techniques combine digital imaging with spectroscopy to assess the chemical composition of a fruit's surface and subsurface. Multispectral Imaging (MSI) analyses a few specific spectral bands and has been successfully used. For instance, Rodriguez et al.[20] developed a multispectral NIR-LED spectrometer that, when combined with chemometrics, could detect "CaC2 chemical residue" on mangoes with high classification accuracy. Hyperspectral Imaging (HSI) is a more advanced variant that captures hundreds of continuous spectral bands, creating a detailed spectral "fingerprint" for every pixel. Lu, Gao et al.[21] achieved a high accuracy of 98.74%. Its power lies in mapping chemical contaminants like arsenic or other surface residues that are not visible to the naked eye. Although the exorbitantly high cost makes the technique less accessible.

Comparison of The Methods Used

Methods such as gas chromatography-mass spectrometry are highly accurate, but they are inherently invasive; that is, the fruit needs to be destroyed for analysis. Apart from that, the process is time-consuming and requires a dedicated laboratory setup, making it unviable for handheld or real-time applications.

Advanced techniques like hyperspectral and multispectral imaging have proven highly effective in a research context, achieving accuracy up to 98.74%,[21] but they suffer from two major drawbacks – one being the high cost of these specialised cameras and the computational overhead required, which makes them unaffordable for the end consumers, while the other aspect is the operational complexity of hyperspectral imaging systems, leading to the requirement of trained technicians for use. In contrast, NIR spectroscopy-based sensors are cheaper, making them accessible, and the compact size proves to be more suitable for real-time, handheld applications. Although the spectral range is smaller.

Standard image processing using RGB cameras is a non-invasive and low-cost approach, but its complete dependence on surface-level visual cues makes it unreliable for assessing the changes in the internal biochemistry of the fruit.

E-noses and biosensors are highly sensitive, but they are typically designed for a single, specific target, such as traces of arsenic, or detecting the presence of acetylene gas (or any other VOC). This narrow focus means they cannot provide a holistic assessment of the fruit's ripening progression and the underlying biochemical changes. Additionally, regular calibration of these sensors is a challenge to maintain accuracy.

Examining Field Applicability

A crucial aspect for real-world application of these methods is their feasibility for consumer-level and field-deployable use. The most accessible and low-cost technique is digital image processing, since it relies on existing consumer hardware. Cameras found in smartphones are used with computer vision algorithms to analyse surface-level features.[16]

Among chemical methods, colorimetric impurity-based tests provide a portable, real-time and low-cost approach, making them suitable for large-scale field inspection and even consumer-level use. Gold nanoparticle (AuNP)-based assays are a good example[12] that change colour from red to purple in the presence of markers indicative of CaC_2 ripening.

Electrochemical biosensors and e-noses can be used in handheld devices for field applications, where VOC (volatile organic compound) patterns can be used to train machine learning models to identify calcium carbide-induced ripening. Barnali et al.[22] developed a low-cost, portable gas sensing system for identifying artificial ripening in mangoes.

Hyperspectral imaging is the most accurate non-invasive method which captures spectral data for each pixel in an image, providing a large volume of data to analyse and find relevant patterns, but the high cost and computational complexity make it infeasible for consumer-level applications. However, NIR spectroscopy (600 nm-1100 nm)-based devices are compact, resource-efficient and much more affordable, making them an excellent choice for the end-consumer. The applicability of NIR spectroscopy for detecting CaC_2 ripening has been studied[18] and found to be highly relevant. Ankita et al.[17] used NIR spectroscopy for detecting calcium carbide-induced ripening in mangoes and were able to distinguish between CaC_2 and naturally ripened mangoes using multivariate analysis methods.

Future Scope

Given the strengths and weaknesses of the detection meth- ods discussed in the previous section, future research should focus on creating and testing practical, scalable, and accessible technologies. The following areas are especially important:

Development of Low-Cost, Portable Sensor Systems

While HSI and E-Nose technologies show considerable promise, their current cost and complexity hinder widespread use. Future efforts should concentrate on making these sensors compact and cheaper. There is also an opportunity to use low-cost Visible-NIR spectral sensors for creating portable ripeness assessment systems.

Sensor Fusion for Improved Accuracy

Each non-invasive method targets different aspects of CaC_2 ripening, such as surface colour using RGB cameras, volatile profile using E-noses, and chemical residues using colorimetry, chromatography, etc. Future research should also explore using sensor fusion to create systems that combine multiple data streams from these methods. For instance, a device that merges digital image processing (for colour and texture) with an E-nose (for VOC profiling) can improve classification accuracy and decrease false positives compared to techniques focused on a single parameter.

Expansion of Spectral, Chemical, Imaging and VOC Libraries

The effectiveness of all machine learning-based techniques depends on the quality of their training data. There is a need for comprehensive, open-access libraries in this domain, be it spectral, chemical, VOC or imaging data. Future studies should work on creating these datasets, also covering a wider range of fruits (beyond bananas, sapota, etc.), recording the progression of ripening in different stages, and using CaC_2 from different sources to account for variations in impurities.

Transition from Laboratory to Field Application

The ability of hyperspectral imaging systems and near-infrared spectroscopy to carry out non-invasive, real-time assessments of fruit ripening needs to move from laboratory setups to practical real-life applications. Future efforts should aim to design and test spectral systems that can be integrated into post-harvest processing and sorting of fruits, also allowing for inspection of fruit batches at distribution centres.

Conclusion

This review explores the serious public health risk posed by the illegal use of industrial-grade calcium carbide (CaC_2) for ripening of fruits. The method is popular because it is cheap, easy to procure and quick. However, it significantly deteriorates the nutritional and sensory quality of the fruit, lowering levels of vitamin C, organic acids, and sugars. It also introduces harmful impurities in the fruit, such as traces of arsenic, phosphorus and heavy metals like lead, mercury, iron etc.; which are associated with serious health risks, including neurological disorders and cancers of various types.

The ways to detect CaC2 use have gradually transitioned from very sensitive lab-based techniques to faster, non-invasive

technologies. Traditional methods, like HS-SPME-GC-MS and electrochemical biosensors, are very specific and sensitive. They can identify unique volatile markers, such as 3,5- dimethyl-1,2,4-trithiolane, or measure CaC2 residues at the nanomolar level. However, their complexity, expense, and invasive nature limits their use in large-scale monitoring.

As a result, the field is moving toward non-invasive solutions. Techniques based on detecting impurities, like the AuNP colorimetric assay, have shown effectiveness by using arsenic as a reliable marker. NIR spectroscopy-based approaches have proved to be effective, especially the use of intensity ratios across wavelengths that represent ripeness progression and biochemical markers of calcium carbide ripening. In addition, new technologies that use machine learning, such as multispectral and hyperspectral imaging, electronic nose, and digital image processing, show great potential. These methods classify fruits by examining their spectral, volatile, or visual characteristics for real-time detection of CaC_2-induced ripening. This can help improve enforcement of regulations. In summary, present research strongly suggests a clear and much-needed shift from mere lab tests to accessible, affordable, and non-invasive screening technologies for actual field use in order to safeguard public health from the risks associated with CaC_2-based ripening of fruits.

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