

The Green Trace: An Integrated System for Mineral Content Analysis and Pesticide Residue Management in Fruits and Vegetables

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Abstract

Fruits and vegetables may carry pesticide residues that are invisible to the naked eye, while consumers currently have no fast, affordable way to verify either the safety or the nutritional value of their produce before consumption. Existing laboratory methods, such as chromatography-based residue testing, are accurate but expensive, time-consuming, and inaccessible for everyday use. This paper presents an integrated web-based system, “The Green Trace,” that analyses mineral content and detects pesticide residues in fruits and vegetables using real-time image scanning rather than predefined datasets. The system allows a user to register, log in, and capture or upload an image of a fruit or vegetable through a browser interface; the captured image is processed to identify the produce, estimate key mineral values such as iron, calcium, potassium, magnesium and phosphorus, and flag the likely presence and severity of common pesticide classes, including organophosphates, pyrethroids and neonicotinoids. Results, along with a safety recommendation, are displayed to the user and stored in a MySQL-backed history log for future reference. By combining nutrient evaluation and pesticide screening within a single lightweight, dynamic-processing pipeline, the proposed system reduces dependency on manual laboratory testing, promotes food-safety awareness, and supports more sustainable, consumer-driven agricultural practices.

Keywords— Food Safety, Pesticide Residue Detection, Mineral Content Analysis, Image Processing, Web-Based Scanning, Sustainable Agriculture, Food Quality Assessment

1. Introduction

Food safety and nutritional awareness have become pressing concerns as consumers increasingly seek assurance that the fruits and vegetables they purchase are both safe to eat and nutritionally worthwhile. Pesticides are widely used in modern agriculture to protect crops from pests and improve yield, but residues that remain on produce after harvest can pose health risks when consumed regularly or in excess, particularly for children and other vulnerable groups.

At the same time, consumers rarely have any straightforward way of knowing the mineral content of the produce they buy, even though this information is directly relevant to dietary planning.

Conventional approaches to verifying food safety rely on laboratory-based chemical testing, such as gas or liquid chromatography, which is accurate but requires specialised equipment, trained personnel, and considerable turnaround time. These constraints make laboratory testing impractical as a routine, consumer-facing solution. Meanwhile, advances in image processing and dynamic data analysis have opened the possibility of estimating both the identity and the underlying quality attributes of an object directly from a photograph, without depending on large, static, pre-collected datasets.

This paper proposes The Green Trace, a software-based system that allows a user to scan a fruit or vegetable using a camera or an uploaded image and receive, in real time, an estimate of its mineral composition alongside a pesticide-residue risk assessment. Rather than relying on a fixed, predefined dataset of produce samples, the system performs dynamic, on-the-fly analysis of each scanned image, which allows it to remain lightweight while still returning a quick, actionable result. A web-based interface handles user authentication, image capture, result display, and history management, so that a user can revisit previous scans at any time.

The main contributions of this work are: (i) the design of a unified system that evaluates nutrient content and pesticide risk simultaneously rather than as separate tools; (ii) a real-time, dynamic-processing approach that removes the need for exhaustive predefined datasets; and (iii) a simple, browser-accessible interface, backed by a persistent database, that makes food-safety screening usable by non-expert consumers.

The remainder of this paper is organised as follows. Section II reviews related literature on produce quality assessment and pesticide-residue studies. Section III states the problem addressed by this work, and Section IV outlines the objectives. Section V discusses the existing system and

Section VI its limitations. Section VII describes the proposed system, followed by the system architecture in Section VIII and the methodology and algorithm in Section IX. Section X presents the results, output and analysis. Sections XI and XII discuss the inference drawn and the learning outcomes of the project, and Section XIII concludes the paper with directions for future work.

2. Literature Survey

A review of existing research was carried out to understand current approaches to produce-quality assessment, organic farming, and pesticide-residue analysis, and to identify gaps that the proposed system could address. H. Kim and E. Omia surveyed the use of hyperspectral and near-infrared spectral sensors combined with deep-learning models such as CNNs and LSTMs for non-destructive quality assessment, reporting high accuracy without the need to physically cut the produce, though such systems depend on specialised spectral hardware. D. D. Wilson and R. L. Ray reviewed six decades of research comparing organic and conventional farming in the United States, finding that organic produce generally carries a lower pesticide load but is more costly and labour-intensive to produce.

N. Bibi and N. A. Tahrir analysed over two hundred vegetable samples from conventional farms in Malaysia using gas chromatography, and found that certain vegetables, such as cabbage, consistently showed higher pesticide residues, particularly during the wet season, with children identified as a higher-risk consumer group. F. Malhat and F. Eissa conducted a large-scale residue study on Egyptian vegetables, testing thousands of samples against Maximum Residue Limit standards and computing a hazard index; while most produce was compliant, some items such as tomatoes exceeded safe limits and occasionally contained multiple or banned pesticide residues. Tariq Masood and Zafar Ali Shah studied the relationship between organic soil-fertility management and insect-pest dynamics in vegetable systems, showing that healthier soil naturally reduces pest pressure and supports more sustainable cultivation.

1. Recent Advances in the Integration of Deep Learning and Spectral Analysis for Non-Destructive Quality Assessment of Fruits and Vegetables

Author: H. Kim & E. Omia

Methodology:

- Used Near-Infrared (NIR) and hyperspectral sensors.
- Applied CNN and LSTM deep learning models.
- Trained the models using labelled datasets.
- Used data augmentation to improve model performance.
- Predicted quality parameters such as sweetness and moisture content.

Remarks:

- Highly accurate and non-destructive method.
- No need to cut or damage fruits and vegetables.

- More effective than conventional chemical testing.
- Suitable for smart agriculture and automated quality inspection.

2. Organic Production of Fruits and Vegetables in the US

Author: D. D. Wilson & R. L. Ray

Methodology:

- Conducted a systematic literature review.
- Reviewed research published between 1960 and 2021.
- Collected data from multiple research databases.
- Compared organic and conventional farming practices.

Remarks:

- Organic produce contains lower pesticide residues.
- More environmentally sustainable.
- Requires higher production costs and labour.
- Global demand for organic food is increasing.

3. Pesticide Residue Analysis and Health Risk Assessment in Vegetables from Conventional Farms in Cameron Highlands, Malaysia

Author: N. Bibi & N. A. Tahrir

Methodology:

- Collected more than 200 vegetable samples.
- Analysed pesticide residues using gas chromatography.
- Compared residue levels during wet and dry seasons.
- Conducted health risk assessment based on residue levels.

Remarks:

- Cabbage showed high pesticide residue levels.
- Residues were higher during the wet season.
- Children were identified as the most vulnerable group.
- Regular monitoring of pesticide residues is necessary.

4. Pesticide Residues in Egyptian Vegetables: Compliance, Co-occurrence of Multiple Residues, and Health Risk Assessment

Author: F. Malhat & F. Eissa

Methodology:

- Tested thousands of vegetable samples.
- Analysed different classes of pesticides.
- Compared results with Maximum Residue Limit (MRL) standards.
- Assessed health risks using the Hazard Index.

Remarks:

- Most vegetables were within safe residue limits.
- Some tomatoes exceeded MRL standards.

- Detected banned pesticides and multiple pesticide residues.
- Highlights the need for stronger regulations and farmer awareness.

5. Soil Fertility Management and Insect Pest Dynamics in Organic Vegetable Systems of Peshawar: An Integrated Approach

Author: Tariq Masood & Zafar Ali Shah

Methodology:

- Studied the effects of organic fertilisers on soil fertility.
- Compared different soil management practices.
- Measured soil nutrient levels and insect pest populations.
- Evaluated pest incidence under different farming conditions.

Remarks:

- Improved soil fertility increases plant health.
- Naturally reduces pest infestation.
- Supports beneficial insects.
- Promotes sustainable and eco-friendly farming practices.

Collectively, the literature indicates two recurring gaps. First, produce-quality assessment research tends to rely on specialised sensing hardware or large curated datasets, both of which limit accessibility for everyday consumers. Second, pesticide-residue studies, while valuable for policy and monitoring, are laboratory-bound and do not translate into a tool a consumer can use before eating a particular piece of fruit or vegetable. The proposed system is motivated by these gaps: it aims to bring a lightweight, image-based, dual-purpose (mineral and pesticide) assessment directly into the hands of the consumer.

3. Problem Statement

Fruits and vegetables available in the market may carry pesticide residues that are not visible or perceptible to consumers at the point of purchase or consumption. At present, there is no simple, quick method by which an ordinary consumer can check the safety of a given item of produce, nor its nutritional composition, without sending a sample to a laboratory. Existing testing methods, while reliable, are costly, time-consuming, and dependent on trained personnel and specialised equipment, which makes them unsuitable for routine, everyday use. There is, therefore, a need for a software-based scanning solution capable of estimating pesticide-residue levels and mineral content in a fast, accessible, and user-friendly manner.

4. Objective

The objectives of this work are to develop a software-based system for scanning fruits and vegetables through a web interface; to detect and estimate pesticide-residue levels using image analysis; to analyse and display the mineral content of the scanned produce; to provide results that are quick, easy to interpret, and accessible to non-expert users; and to promote greater awareness of safe food consumption and sustainable agricultural practices.

5. Existing System

Current approaches to verifying the safety and quality of fruits and vegetables are largely built around laboratory-based chemical analysis, such as gas or liquid chromatography, which offers high accuracy in detecting specific pesticide compounds but requires expensive instrumentation and expert interpretation. Organic-farming practices reduce reliance on synthetic pesticides but come at a higher production cost and cannot, by themselves, verify the safety of a specific batch of produce at the point of sale. Soil-management research has shown that healthier soil naturally suppresses pest populations, which is valuable at the farming stage but does not help a consumer standing in front of a shelf of produce. Separately, deep-learning and spectral-imaging techniques have improved non-destructive quality assessment, but these systems tend to depend on specialised sensors and large training datasets, and are rarely integrated into a single, consumer-facing tool that evaluates both nutrient content and pesticide risk together.

6. Limitations of Existing System

The existing approaches described above suffer from several practical limitations. Laboratory testing is expensive and slow, making it impractical for routine or large-scale consumer use. Specialised sensing equipment, such as hyperspectral or NIR scanners, adds significant hardware cost and is not something an ordinary consumer can access. Most systems address either nutrient estimation or pesticide detection in isolation, rather than evaluating both simultaneously. Deep-learning approaches that depend on large predefined datasets can struggle to generalise to produce varieties or imaging conditions not represented in training data. Finally, none of the reviewed systems provide a simple, browser-accessible interface with persistent history tracking that would let an everyday user check produce quickly and refer back to past results.

7. Proposed System

The proposed system, The Green Trace, addresses these limitations by combining mineral-content estimation and pesticide-residue detection into a single, lightweight, web-based platform that relies on real-time image scanning and dynamic data processing rather than large predefined datasets. A user registers or logs in through the web interface, after which they are directed to a dashboard offering access to their profile, scan history, and produce-analysis tool.

To perform an analysis, the user captures or uploads an image of a fruit or vegetable through the built-in scanner. The captured image is processed to identify the type of produce and to estimate its mineral composition, covering nutrients such as potassium, calcium, iron, magnesium and phosphorus. In parallel, the system evaluates the likely presence and severity of common pesticide classes, including organophosphates, pyrethroids and neonicotinoids, and combines this with a freshness assessment based on the item's colour and texture. The results, along with an overall safety recommendation such as advising the user to wash the produce thoroughly before consumption, are displayed in a simple, easy-to-read format and are also stored in the system's database so that the user can review their scan history at any time.

Because the analysis is performed dynamically on each scanned image rather than through lookups against a large static dataset, the system remains lightweight and can return results quickly, making it suitable for everyday, farmer- and consumer-facing use while still supporting future scalability and smart-agriculture integration.

8. System Architecture

The system architecture is organised around a central website that branches into a Home Page and an Authentication module. The Authentication module supports both Login and Signup, using either Google sign-in or an email-and-password flow; on successful verification, the user is directed to the User Dashboard. From the dashboard, three principal modules are accessible: Profile, which allows a user to view and update their account details; History, which fetches previously stored scan records; and Analysis, which displays the results of a produce scan. All three modules read from and write to a central database that stores user accounts, login credentials, scan images, and analysis results. User-supplied input, such as name, email, password and scanned images, flows into the database, while the system returns analysis results together with mineral and produce information as output. This architecture keeps the front-end interface, the analysis logic, and the persistent data store cleanly separated, which simplifies both maintenance and future extension of the system.



Fig. 1. System Architecture of the Proposed System

9. Methodology

The methodology adopted for this project follows a structured, module-by-module development process, moving from user-facing interface design through to backend data management and, finally, the core image-analysis pipeline.

9.1 Module 1: User Interface and Database Setup

The first module focused on building the user interface and the underlying login system using HTML, CSS and JavaScript, with an emphasis on responsive, accessible design. The login page, styled under the name “The Green Trace,” offers users the choice of signing in with Google or entering their registered email address before continuing. Alongside the interface, a MySQL database was created with a Users table, storing name, email and password details, and a Scan History table, storing records of past scan results. When a new user registers, their details are saved to the Users table; during subsequent logins, the system checks the entered credentials against the stored record and grants access only when they match.

9.2 Module 2: Image Scanning, Analysis and Result Management

The second module implements the core scanning and analysis functionality. An image of the fruit or vegetable is captured through the device camera or uploaded by the user, after which the system performs basic image processing to improve clarity and reduce noise. The processed image is then analysed to identify the type of produce, estimate its mineral content, and detect the likely presence and severity of pesticide residues, all performed automatically without manual intervention. Once the analysis is complete, the results, including the produce name, freshness assessment, mineral breakdown and pesticide levels, are displayed to the user in a clear, structured format and are simultaneously

written to the Scan History table, allowing the user to revisit any previous result through the History page.

9.3 Algorithm

Step 1: Start the system and prompt the user to log in or sign up.

Step 2: Verify user credentials against the database.

Step 3: On successful verification, direct the user to the dashboard.

Step 4: Accept an image of the fruit or vegetable via camera capture or upload.

Step 5: Pre-process the image to improve clarity and reduce noise.

Step 6: Identify the type of produce from the processed image.

Step 7: Estimate the mineral content (potassium, calcium, iron, magnesium, phosphorus).

Step 8: Detect and estimate pesticide-residue levels (organophosphates, pyrethroids, neonicotinoids).

Step 9: Assess overall freshness based on colour and texture cues.

Step 10: Combine the above results into a single, structured output with a safety recommendation.

Step 11: Display the results to the user and store them in the Scan History table.

Step 12: Allow the user to view past results through the History page.

Step 13: Repeat the process for continuous, on-demand scanning.

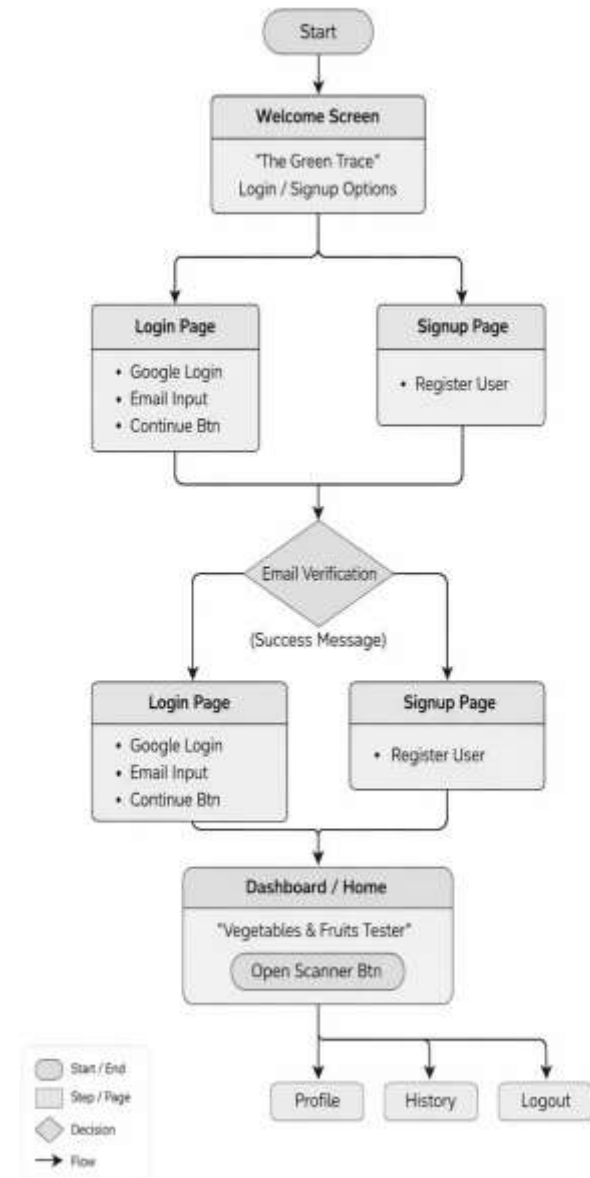


Fig. 2.Flowchart of Proposed System

10. Results and discussion

10.1 Performance Analysis

The performance of the system was evaluated based on its ability to authenticate users, capture and process images, and return combined mineral and pesticide results within a short time frame. The authentication module, supporting both Google sign-in and email-based login with verification, functioned reliably across the tested scenarios, and users were correctly redirected to the dashboard on successful login.

The scanning module was tested using produce images captured directly through the interface; a sample scan of a tomato returned a freshness classification of "Fresh" along

with an estimated mineral profile (including potassium at approximately 250 mg per 100 g and calcium at approximately 40 mg per 100 g) and a pesticide-risk breakdown across organophosphates, pyrethroids and neonicotinoids, together with a recommendation to wash the produce thoroughly before consumption.

A feature-based comparison between conventional testing approaches and the proposed system is presented in Table 2. The comparison highlights that, unlike laboratory-based or hardware-dependent methods, the proposed system combines both nutrient and pesticide evaluation within a single low-cost, browser-accessible tool, while also retaining a history of past scans for future reference.

Overall, the results indicate that moving from predefined datasets to real-time image scanning and dynamic data processing allows the system to deliver a quicker, dual-purpose evaluation of nutrients and pesticide residues than manual laboratory testing, while remaining accessible to non-expert users through a simple web interface.

10.2 Output Visualisation

The implemented interface begins with a welcome screen for “The Green Trace,” offering Login and Signup options, followed by an email-verification step confirming the user's identity. Once verified, the user reaches a dashboard styled as a “Vegetables & Fruits Tester,” with menu access to Profile, History and Logout, and a prominent “Open Scanner” control leading into the scan-image page. Within the scanner, the user can open the camera and capture an image of the produce; the captured photo, together with the resulting freshness label, mineral breakdown and pesticide-level estimate, is then displayed on the results screen, demonstrating that the system functions end-to-end from authentication through to result display and storage.



Fig. 3. Welcome Page

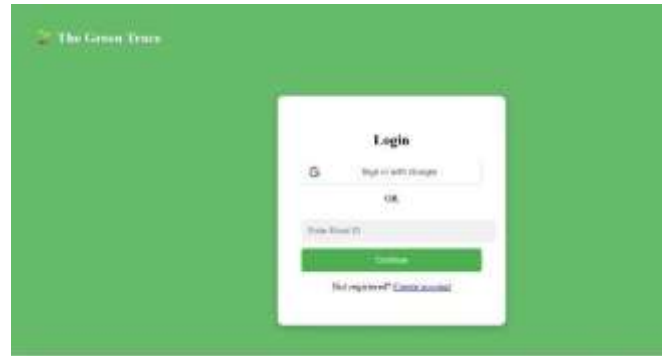


Fig. 4,5 Login and Sign In Page



Fig. 6. Main Interface of the vegetable & Fruits Testing System





Fig. 7,8. Image upload and analysis screen

11. Inference

The results point to a clear accessibility gap in current food-safety practice: consumers presently lack any simple, low-cost method of checking food safety before consumption, since laboratory methods remain too expensive and time-consuming for routine, daily use. The literature reviewed also confirms that integrating AI-driven image analysis with dynamic processing can meaningfully improve the speed of non-destructive quality assessment relative to conventional chemical testing. Given that certain produce items, such as cabbage and tomatoes, have been repeatedly found in prior studies to exceed safe pesticide limits, a software-based, consumer-facing screening tool of the kind proposed here is a valuable addition for protecting higher-risk groups, including children.

12. Learning Outcomes

This project provided practical experience in translating a real-world food-safety problem into a working software system. It strengthened proficiency in system-design documentation, including the construction of block diagrams and data-flow diagrams to map out user journeys and system behaviour. It also built full-stack awareness, through the integration of a front-end web interface with a back-end MySQL database for storing user accounts, scan history and analysis results. Finally, it deepened an appreciation of how accessible technology can support sustainable agricultural practices and public awareness of food safety and nutrition.

13. Conclusion and future scope

This paper presented “The Green Trace”, a web-based system that integrates mineral-content analysis and pesticide-residue detection for fruits and vegetables using real-time image scanning and dynamic data processing rather than reliance on large predefined datasets. The system supports user authentication, image-based produce scanning, combined nutrient and pesticide-risk reporting, and persistent scan history, all delivered through a lightweight, browser-accessible interface. By bringing together two

evaluations, nutrient content and pesticide safety, that are typically handled separately, the system offers a quicker and more accessible alternative to manual laboratory testing for everyday consumers.

Future work can extend the system in several directions. Incorporating more advanced computer-vision and spectral-analysis models could improve the precision of both mineral estimation and pesticide-residue detection across a wider variety of produce. Connecting the system with agricultural or public-health databases could allow it to issue region-specific safety advisories, while integration with a mobile application would make the tool considerably more convenient for everyday, on-the-go use compared with a website alone. Overall, the proposed approach demonstrates a practical, scalable path toward accessible, consumer-facing food-safety and nutrition screening.

14. References

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