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Analysis of AI-Driven Food Authentication, Age Estimation, and Quality Assessment of Processed Foods

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Abstract - *The increasing consumption of processed foods has created a need for reliable and automated methods to detect product counterfeiting, age-related deterioration, labeling inconsistencies, and quality degradation. Conventional authentication and quality assessment techniques rely mainly on laboratory analysis and manual inspection, which are expensive, time-intensive, and unsuitable for rapid large-scale screening. This research proposes an AI-Driven Food Authentication, Age Estimation, and Quality Assessment Framework that integrates Computer Vision, Machine Learning, and Deep Learning for automated analysis of processed food products. The methodology involves collecting and preprocessing images of authentic and counterfeit packaging, different product-age conditions, and varying quality levels, followed by feature extraction. Deep learning models are employed for authenticity detection, while regression or classification models are used for age estimation and quality-level prediction, evaluated using accuracy, precision, recall, F1-score, and mean absolute error (MAE). The framework also incorporates QR/barcode verification, expiry-date analysis, packaging anomaly detection, and an integrated quality score. The study further examines challenges related to dataset imbalance, image-quality variations, packaging diversity, and model generalization. The expected outcome is an automated, non-destructive system capable of providing consistent authentication, age estimation, and quality predictions, supporting food traceability, quality monitoring, and consumer-level decision support.*

Key Words: Artificial Intelligence, Deep Learning, Computer Vision, Food Authentication, Age Estimation, Quality Assessment, Counterfeit Detection, Food Traceability

1. INTRODUCTION

The increasing consumption and distribution of processed foods have raised concerns regarding counterfeit products, adulteration, incorrect labeling, product aging, and quality deterioration. Consumers generally depend on packaging information, manufacturing details, expiry dates, and visual appearance to determine product authenticity and quality. However, counterfeit packaging can closely resemble genuine products, while changes in storage conditions and product age may not always be identifiable through simple visual inspection. Conventional verification methods often require manual inspection or laboratory-based testing, making them time-consuming, costly, and difficult to apply for rapid product-level assessment.

Recent advances in Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), and Computer Vision provide new possibilities for automated food analysis [1], [2], [4]. Image-based AI models can identify patterns in product packaging, labels, colors, textures, and visible defects. These characteristics can be used to distinguish authentic products from potentially counterfeit ones. Similarly, machine learning and deep learning models can assist in estimating age-related conditions and classifying food products according to predefined quality levels.

However, existing AI-based food-analysis studies often focus on individual tasks, such as counterfeit detection, freshness prediction, or quality classification [1], [2], rather than integrating multiple assessment functions into a unified framework. This creates a research gap for a system capable of performing food authentication, age estimation, and quality assessment within a single intelligent framework. Such integration can provide a more comprehensive evaluation of processed food products.

Therefore, this research proposes an AI-Driven Food Authentication, Age Estimation, and Quality Assessment Framework for Processed Foods. The proposed system combines computer vision with machine learning and deep learning techniques to analyze product images and relevant product information. It aims to identify potentially counterfeit products, estimate age-related conditions, and generate a quality assessment based on selected visual and product-level parameters. Additional mechanisms such as QR/barcode verification, expiry-date analysis, packaging anomaly detection, and quality scoring can further support the assessment process.

The proposed framework is intended to provide a non-destructive, automated, and scalable approach to preliminary processed-food evaluation. By reducing dependence on manual inspection and enabling rapid analysis, the system can support food traceability, counterfeit detection, quality monitoring, and informed consumer decision-making. The research ultimately aims

to demonstrate how AI-based technologies can contribute to a more efficient and reliable approach to processed-food authentication and quality assessment.

2. PROBLEM STATEMENT

The processed food sector faces several challenges in ensuring product authenticity, accurate age estimation, and consistent quality assessment. Counterfeit products can imitate genuine packaging, making visual identification difficult for consumers. At the same time, product age and quality may be affected by storage conditions, handling, and shelf-life, while conventional inspection methods may not provide rapid and accessible assessment.

The major problems addressed in this research are:

- **Food Authentication Problem:** There is a need for an automated method to distinguish authentic processed food products from potentially counterfeit products using packaging, labeling, and visual characteristics.
- **Age Estimation Problem:** Determining the actual age or age-related condition of a processed food product can be difficult when relying only on manufacturing and expiry information. An AI-based approach is required to estimate age-related characteristics from available product data and visual features.
- **Quality Assessment Problem:** Existing quality inspection methods can require manual expertise or laboratory analysis. A computational method is needed to classify and assess food quality using measurable visual and product-level characteristics.
- **Integration Problem:** Authentication, age estimation, and quality assessment are often treated as separate analytical tasks. There is a need for an integrated AI framework capable of performing these assessments within a unified system.
- **Reliability and Generalization:** Variations in product categories, packaging designs, image quality, lighting conditions, and available datasets can affect AI model performance [5]. Therefore, the proposed system must be evaluated using appropriate performance metrics to determine its reliability and applicability.

This research addresses these problems by developing an AI-driven framework that integrates computer vision, machine learning, and deep learning techniques to provide automated and non-destructive assessment of processed food products.

3. LITERATURE REVIEW

Melikoglu [1] stated in his research, "Artificial Intelligence and Deep Learning in Food Shelf Life Management: A Global Review," that AI and deep learning can support food-quality prediction, freshness assessment, and shelf-life management. The paper was published in Food and Humanity, vol. 6, Art. no. 101089, 2026.

Osemwowa [2] stated in her research, "The Application of Artificial Intelligence in Food Fraud and Adulteration Analysis: A Review," that AI and machine learning can support food authentication and the detection, prediction, and prevention of food fraud and adulteration. The paper was published in Food Additives & Contaminants: Part A, vol. 43, no. 6, pp. 795–805, 2026.

Padmasri [3] stated in his research, "Hyperspectral Imaging-Driven Detection of Neutraliser Adulteration in Milk Using Spatial-Spectral Features," that hyperspectral imaging and spatial-spectral analysis can be used to detect adulteration in milk. The paper was published in Food Additives & Contaminants: Part A in 2026.

Fragkos [4] stated in his research, "The Role of Artificial Intelligence in Combating Food Fraud: A Systematic Literature Review," that AI, machine learning, and deep learning can support the detection of food adulteration, mislabeling, and other forms of food fraud using imaging and spectral data.

Felizzato [5] stated in his research, "Methodological Challenges in Machine Learning and Deep Learning Applied to Food Analysis: A Critical Review," that AI can support food quality control and authenticity assessment, while dataset quality, validation, and model generalization remain important challenges.

4. RESEARCH GAP

The reviewed literature [1]–[5] highlights that existing research on fake product detection is often fragmented across different domains and product categories. Artificial Intelligence and Machine Learning studies mainly focus on image classification, counterfeit detection, and visual defect identification, whereas blockchain-based research emphasizes product authentication, traceability, and secure verification. Studies on food authentication primarily examine adulteration detection, packaging verification, and quality assessment, while research on electronics, cosmetics, pharmaceuticals, fashion, and household products focuses on counterfeit identification and product authenticity. Despite these advancements, most solutions operate independently and lack a unified framework that combines visual analysis, packaging verification, QR/barcode authentication, and product-information validation across multiple product categories. Furthermore, challenges related to dataset diversity, model generalization, packaging variations, and reliable counterfeit identification remain insufficiently addressed [5]. Hence, the present research aims to develop and examine an integrated AI- and ML-driven fake product detection framework that combines computer vision,

image classification, packaging analysis, and product-information verification to identify potentially counterfeit food and non-food products and improve product authentication, reliability, and consumer trust.

5. RESEARCH OBJECTIVES

The main objective of this research is to explore how Artificial Intelligence (AI) can improve the authenticity verification, age estimation, and quality assessment of processed food products. The study focuses on understanding the challenges of fake food and product identification and proposing an AI-driven solution for detecting potentially counterfeit products and assessing food quality.

The specific objectives are:

- To analyze the role of Artificial Intelligence and deep learning in detecting counterfeit and fake processed food products.
- To study the application of image processing and computer vision for food authentication and assessment of product quality and packaging condition.
- To examine AI-based methods for estimating the age, freshness, and validity of processed food products using dates and visual information.
- To develop a conceptual framework integrating AI-based authentication, age estimation, quality assessment, and QR-code verification into a single system.

6. HYPOTHESIS

6.1 Authentication Accuracy

H_0: AI-based image analysis does not significantly improve the identification of authentic and potentially counterfeit processed food products.

H_1: AI-based image analysis significantly improves the identification of authentic and potentially counterfeit processed food products.

6.2 Age and Quality Assessment

H_0: AI-based image analysis does not significantly improve the assessment of product age, freshness, and visible quality of processed food products.

H_1: AI-based image analysis significantly improves the assessment of product age, freshness, and visible quality of processed food products.

6.3 Integrated AI Framework

H_0: An integrated AI framework combining authentication, age estimation, and quality assessment does not significantly improve the overall performance of processed food product evaluation.

H_1: An integrated AI framework combining authentication, age estimation, and quality assessment significantly improves the overall performance of processed food product evaluation.

6.4 Hypothesis Testing

Test: Chi-square test of independence to examine the association between AI familiarity and perceived usefulness of AI-based food authentication (Table -1).

Table -1: Contingency Table of AI Familiarity and Perceived Usefulness

AI Familiarity	Useful	Not Useful	Total
Familiar	[ ]	[ ]	[ ]
Not Familiar	[ ]	[ ]	[ ]
Total	[ ]	[ ]	50

H_0: AI familiarity and perceived usefulness are not significantly associated.

H_1: AI familiarity and perceived usefulness are significantly associated.

Significance level: $\alpha = 0.05$.

$$\chi^2 = \Sigma [(O - E)^2 / E] \quad (1)$$

Expected frequency and degrees of freedom are given by

$$E = (\text{Row Total} \times \text{Column Total}) / \text{Grand Total} \quad (2)$$

$$df = (r - 1)(c - 1) \quad (3)$$

Procedure:

- Use the 50 individual survey responses to create a contingency table.
- Calculate expected frequencies and the Chi-square statistic.
- Obtain the p-value and compare it with 0.05.

Decision: If $p < 0.05$, reject H_0; otherwise, fail to reject H_0. Use Fisher's exact test if expected cell counts are too small.

Status: The updated charts provide descriptive summaries only. The hypothesis decision remains pending

until the respondent-level data are tested; no statistical result is inferred from the charts alone.

6.5 Before and After Application Comparison

Objective: To examine whether the introduction of the FoodLens AI application influences respondents' acceptance of AI-based food authentication.

Null Hypothesis (H_0): There is no significant difference in respondents' acceptance of AI-based food authentication before and after the introduction of the FoodLens AI application.

Alternative Hypothesis (H_1): There is a significant difference in respondents' acceptance of AI-based food authentication before and after the introduction of the FoodLens AI application.

Significance Level: $\alpha = 0.05$.

The comparison of respondents' responses before and after introducing FoodLens AI is summarized in Table -2.

Table -2: Comparison of Respondents' Responses Before and After Introducing FoodLens AI

Response Category	Before App (55)	After App (50)	Result
Positive Response	43 (78.2%)	46 (92%)	Increased by 13.8%
Other Responses	12 (21.8%)	4 (8%)	Decreased by 13.8%
Total	55 (100%)	50 (100%)	—

Test: Chi-square test of independence (χ^2), using (1)–(3).

Procedure:

- Use the before-app and after-app survey responses to prepare a contingency table.
- Calculate the expected frequencies for each category.
- Calculate the Chi-square statistic using the observed and expected frequencies.
- Obtain the p-value and compare it with the significance level of 0.05.
- If p is less than 0.05, reject H_0; otherwise, fail to reject H_0. Use Fisher's exact test if expected cell counts are too small.

Status: The descriptive comparison shows an increase in positive responses from 78.2% before the application to 92% after its introduction. However, the survey questions and sample sizes differ. Therefore, a valid hypothesis decision remains pending until comparable respondent-level data are tested. No statistical significance is inferred from the current charts.

7. RESEARCH METHODOLOGY

This study uses a qualitative and conceptual approach supported by a literature review and survey analysis to examine challenges in processed food authentication, age estimation, and quality assessment, and propose an integrated AI-based solution.

7.1 Sample Size

Data for this study is derived from 55 survey responses, providing exploratory insights into consumer awareness, concerns regarding fake food products, food quality, and acceptance of AI-based authentication systems.

7.2 Sampling Technique

The study follows a survey-based purposive sampling approach, where structured questionnaires are distributed digitally to collect relevant responses related to food authenticity, product quality, expiry-date awareness, and technology acceptance. Participants are selected based on their willingness to respond and provide relevant insights. The collected responses are analyzed to identify common patterns, concerns, and opportunities that support the development of the proposed research framework.

7.3 Sampling Area

The research primarily focuses on Maharashtra, India, to explore consumer awareness and concerns regarding fake processed food products, product authenticity, freshness, and quality assessment. This geographical scope provides localized insights into consumer perceptions and the potential adoption of AI-based food authentication systems.

7.4 Type of Research

This study is qualitative and conceptual research based on survey analysis and literature review. It focuses on proposing an AI-driven framework for processed food authentication, age estimation, and quality assessment using image processing, deep learning, and product information verification.

8. DATA ANALYSIS AND INTERPRETATION



Fig -1: Frequency of purchasing packaged food products (n = 55).

Purchase Frequency: The survey shows that 54.5% of respondents purchase packaged food several times a week, indicating frequent use of packaged food products among respondents (Fig -1).

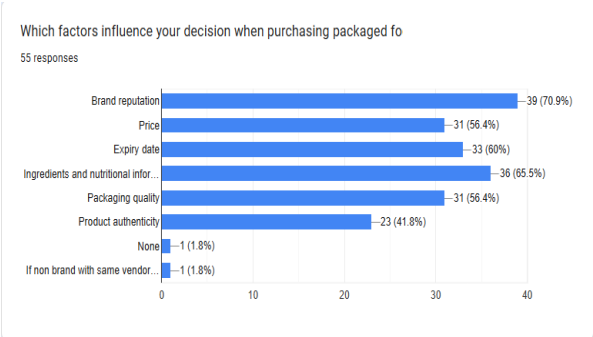

Fig -2: Factors influencing the purchase of packaged food (n = 55).

Brand reputation (70.9%) was the most selected purchase factor, followed by ingredients and nutritional information (65.5%), expiry date (60.0%), and price and packaging quality (56.4% each). Product authenticity was selected by 41.8% of respondents (Fig -2).

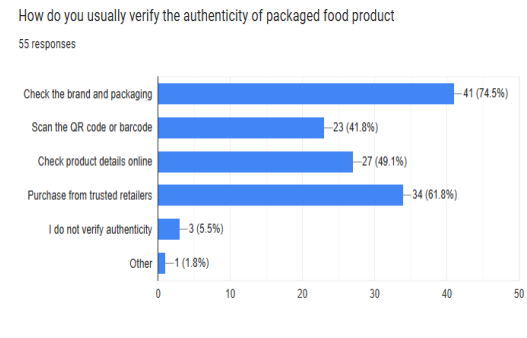

Fig -3: Methods used to verify the authenticity of packaged food products (n = 55).

Authenticity Verification: 74.5% check the brand and packaging, 61.8% purchase from trusted retailers, 49.1% check product details online, and 41.8% scan QR codes or barcodes (Fig -3).

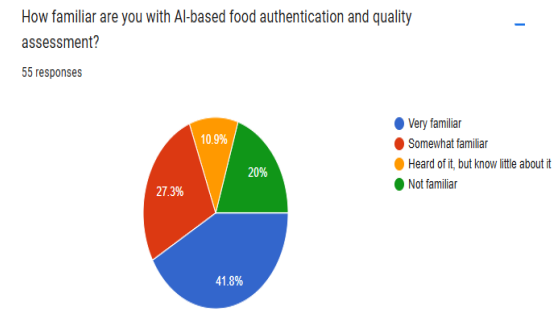

Fig -4: Familiarity with AI-based food authentication and quality assessment (n = 55).

AI Familiarity: 41.8% were very familiar with AI-based food authentication, 27.3% somewhat familiar, 10.9% had heard of it but knew little, and 20.0% were not familiar (Fig -4).

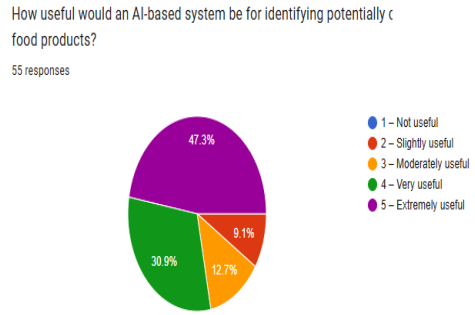

Fig -5: Perceived usefulness of an AI-based system for identifying counterfeit food products (n = 55).

Perceived Usefulness: 78.2% rated an AI-based counterfeit food detection system as very or extremely useful, indicating positive perceived value (Fig -5).

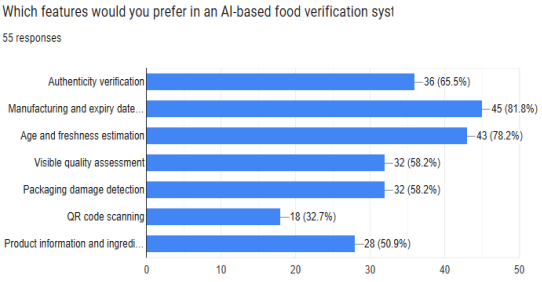

Fig -6: Preferred features of an AI-based food verification system (n = 55).

Preferred Features: Manufacturing/expiry-date information was selected by 81.8%, age/freshness estimation by 78.2%, and authenticity verification by 65.5%. Visible quality assessment and packaging-damage detection were each selected by 58.2% (Fig -6).

9. APP ANALYSIS

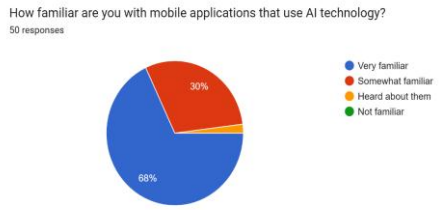

Fig -7: Familiarity with mobile applications that use AI technology (n = 50).

The survey indicates that 68% of respondents are very familiar with AI-based mobile applications, while 30% are somewhat familiar. Only 2% have heard about such applications, indicating a high level of awareness and familiarity with AI technology among respondents (Fig -7).

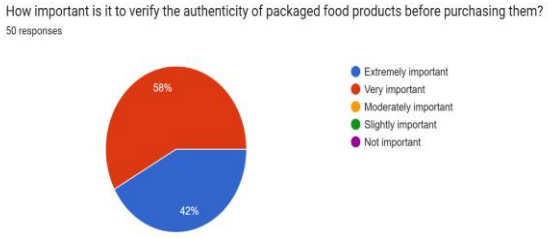

Fig -8: Importance of verifying the authenticity of packaged food before purchase (n = 50).

The findings reveal that 58% of respondents consider food authenticity verification very important, while 42% consider it extremely important. This indicates strong consumer awareness regarding product genuineness and the need for reliable food authentication solutions (Fig -8).

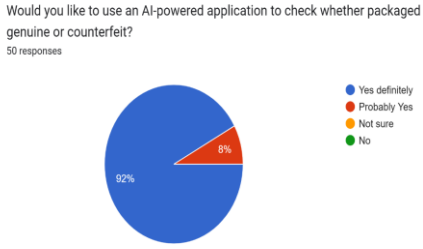

Fig -9: Willingness to use an AI-powered application to detect genuine and counterfeit food (n = 50).

The survey shows that 92% of respondents would definitely use an AI-powered application for detecting genuine and counterfeit food products, while 8% would probably use it. This demonstrates strong user acceptance and potential demand for the proposed FoodLens AI application (Fig -9).

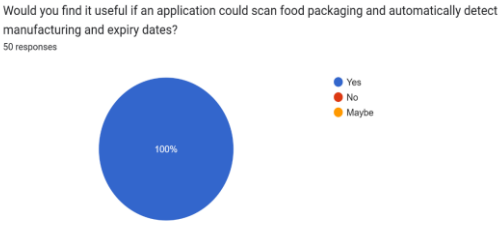

Fig -10: Usefulness of automatic detection of manufacturing and expiry dates (n = 50).

All respondents (100%) expressed that automatic detection of manufacturing and expiry dates would be useful. This highlights the importance of integrating scanning and date recognition features to improve convenience and help consumers make informed purchasing decisions (Fig -10).

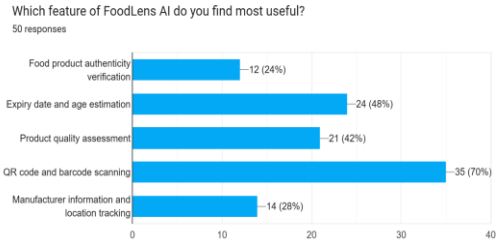

Fig -11: Most useful features of FoodLens AI (n = 50).

The findings indicate that QR code and barcode scanning received the highest preference at 70%, followed by expiry date and age estimation at 48%. Product quality assessment was selected by 42%, manufacturer information and location tracking by 28%, and food product authenticity verification by 24%. This suggests that scanning and product information features are important components of the application (Fig -11).

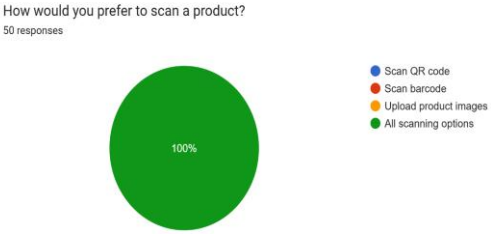

Fig -12: Preferred methods of scanning a product (n = 50).

All respondents (100%) preferred having all scanning options available, including QR code scanning, barcode scanning, and product image uploading. This highlights the importance of providing multiple scanning methods to improve application accessibility and user convenience (Fig -12).

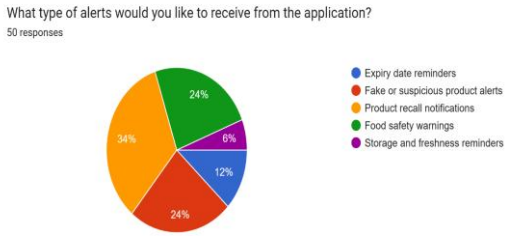

Fig -13: Preferred types of alerts from the application (n = 50).

The results show that 34% of respondents preferred product recall notifications, while 24% selected fake or suspicious product alerts and another 24% preferred food safety warnings. Expiry date reminders received 12%, whereas storage and freshness reminders received 6%. This indicates that users value safety-related notifications and timely product alerts (Fig -13).

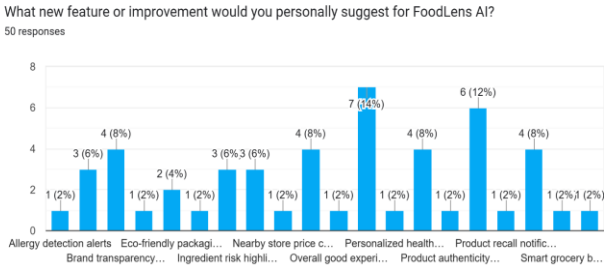

Fig -14: Suggested new features and improvements for FoodLens AI (n = 50).

The findings show that personalized features received the highest suggestions (14%), followed by product recall notifications (12%). Other suggestions included allergy detection, brand transparency, and improved product information, highlighting the need for continuous application improvement (Fig -14).

10. MAJOR FINDINGS

Based on the analysis of 50 survey responses, the major findings of the study are:

- **AI Awareness:** 68% of respondents were very familiar and 30% were somewhat familiar with AI-based mobile applications.
- **Food Authentication:** 58% considered authenticity verification very important, while 42% considered it extremely important.
- **Application Acceptance:** 92% of respondents were definitely willing to use an AI-powered application for identifying genuine and counterfeit food products.
- **Expiry Detection:** 100% of respondents found automatic manufacturing and expiry-date detection useful.
- **Preferred Features:** QR code and barcode scanning (70%), expiry-date and age estimation (48%), and product quality assessment (42%) were the most preferred features.
- **Scanning and Alerts:** 100% preferred multiple scanning options, while product recall notifications (34%) were the most preferred alerts.
- **System Relevance:** The findings support the development of FoodLens AI, integrating product authentication, expiry detection, quality assessment, multiple scanning options, and product safety notifications.

11. RESULTS AND ANALYSIS

The survey was conducted through Google Forms to understand consumer awareness, purchasing behaviour, food authenticity verification, and expectations regarding the proposed AI-based food authentication and quality assessment system.

- **Packaged Food Purchasing:** 54.5% of respondents purchase packaged food several times a week, indicating regular consumption of packaged food products.

- **Purchase Factors:** Brand reputation (70.9%), ingredients and nutritional information (65.5%), and price (63.6%) were the major factors influencing purchasing decisions.
- **Authenticity Verification:** 74.5% of respondents verify products by checking brand and packaging, while 41.8% use QR codes or barcodes.
- **AI Awareness and Usefulness:** 41.8% were very familiar with AI-based food authentication, while 78.2% considered AI-based counterfeit food detection very or extremely useful.
- **Application Acceptance:** In the application survey of 50 respondents, 92% showed definite interest in using FoodLens AI for identifying genuine and counterfeit food products.
- **Preferred Features:** Manufacturing and expiry-date information (81.8%), age/freshness estimation (72.7%), and authenticity verification (65.5%) were among the most preferred features in the initial survey.
- **Application Requirements:** 100% of application survey respondents preferred multiple scanning options and found automatic expiry-date detection

useful. QR/barcode scanning (70%) was the most preferred application feature.

- **System Relevance:** The findings support the proposed integration of AI-based food authentication, expiry-date detection, age estimation, product quality assessment, and safety notifications in FoodLens AI.

12. CONCLUSION

The research focuses on developing an AI-Based Food Authentication and Quality Assessment System to help consumers verify food products and assess their quality. The proposed system combines artificial intelligence, image processing, and product information verification to identify potentially counterfeit products and estimate food freshness.

The survey responses provide insights into consumer purchasing habits, awareness of expiry dates, and concerns regarding food authenticity and safety. The proposed system aims to improve consumer confidence by providing accessible product information and supporting food quality assessment.

In conclusion, the integration of AI into food authentication and quality assessment has the potential to improve transparency, support informed purchasing decisions, and contribute to safer food consumption. However, the system's effectiveness depends on reliable data, accurate models, and proper validation [5].

13. LIMITATIONS OF RESEARCH

- **Limited Survey and Coverage:** The study has limited responses and geographical coverage, which may restrict the generalizability of the findings.
- **Technical and Dataset Limitations:** AI performance depends on the quality and diversity of datasets [5], and the proposed system requires further testing with real food products.
- **Environmental and Food Variety Factors:** Differences in food types, packaging, lighting, image quality, and storage conditions may affect the accuracy of the system.

14. FUTURE SCOPE OF RESEARCH

- **QR Code and Mobile Application:** Develop QR-based verification and a user-friendly mobile app for product authentication and food quality assessment.
- **AI and Dataset Enhancement:** Expand the dataset with diverse food images and improve AI accuracy for detecting genuine, counterfeit, fresh, and spoiled products.
- **IoT and Real-World Validation:** Integrate IoT sensors for storage monitoring and validate the system through laboratory testing and industry collaboration.

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