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AI-Based Dish Recommender System for Reducing Fruit Waste through Spoilage Detection and Ripeness Assessment

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ABSTRACT

The objective of this study is to develop an application that can assess ripeness and detect spoilage of the fruits and suggest a dish based on ingredients, freshness and condition of the fruits. Ripeness will assess through image processing gas sensor will assess the spoilage. An easy-to-use mobile interface enable the scanning together with the device to determine the fruits condition and efficient food choices. This study used the Agile methodology to develop the system. Agile is essential, and it has an iterative approach that focuses on flexibility, combination, and continuous improvement for the system. The process was split into several sprints, each working on important specific features, followed by testing and evaluation. Regular meetings were done to check the progression, solve problems, and plan next steps for the system for development. This method allowed the researchers to adapt to the changes and to ensure the system was developed effectively and efficiently. The system uses an app to minimize fruit waste by providing real-time spoilage and ripeness assessments, smart dish recommendations, and timely alerts. By processing few user inputs, gas sensor data, and image classification, the system accurately detects spoilage and ripeness data for multiple types of fruit. Based on the assessments, it recommends dishes that maximize the fruit usage before it spoils. The user-friendly system helps promote an improved household management and encourages a more mindful consumption. In conclusion the research developed a system using machine learning, image processing and sensor to assess the ripeness and spoilage of the fruits and recommend applicable dishes. Using agile methodology, the system was iteratively tested and improved to ensure the efficiency of the system. The sensor and mobile provide real-times assessment. The proposed system will assist to waste reduction and mindful consumption of the fruits.

Keywords: Machine Learning, Image Processing, Sensor Technology, Spoilage Detection, Dish Recommendation

INTRODUCTION

Food waste is a significant issue in the nation, affecting households and the environment. Food waste occurs annually in tons because food was not properly stored, the consumer did not anticipate it would spoil, or it can be difficult to determine the edibility of food. The classic method is to visually inspect, smell, and check for expiration dates. However, these methods can be very unreliable since expiration dates never accurately reflect the foods actual condition. Products could last beyond their initiation date, while other, improperly stored, products will spoil sooner. Additionally, many products, like fruits, do not have explicit dates on their labels, making it more difficult to assess their quality. The doubt that arises related to food's consumption often results in mis assessment, and when affected, they end up in the trash in the end.

To combat these challenges, Foodify is an app designed to help users determine whether the food is still safe to eat. Using a variety of factors, including appearance and spoilage patterns, the application is able to judge the freshness of food items. Once the application deems the food to be safe to eat, it will suggest a dish based on the items you have on hand. The app helps users maximize their food, avoids waste, and allows users to create delicious food. This option facilitates better consumption of food while saving users money and resources, and helping the environment in reducing food waste The app integrates technology into daily food management to

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inspire the user to not simply throw their food away quickly to reduce waste and promote sustainability. The app detects spoilage and recommends meal ideas to the user so that they can reduce food waste and make a nutritious meal.

Related Studies

As addressed by Lin Broberg Jonsson (2024) in the study "Designing Food Recommender Systems to Promote Sustainable Behavior and Food Waste Reduction", food waste escalates at a speedy rate, which threatens food security, and environmental sustainability.

The study of Mingming Zhao, Zhiheng You, Huayuan Chen, Xiao Wang, Yibin Ying, and Yixian Wang "Integrated Fruit Ripeness Assessment System Based on Artificial Olfactory Sensor and Deep Learning" (2024), this study created a transportable system to detect if the fruits are ripe using the importance of special sensors and Artificial Intelligence (AI) deep learning. This study will work by distinguishing gases released from fruits like apples, bananas, peaches, grapes, and other fruits as they are going to ripen. They will use 25 types of coloring substances that will react to the gases, generating a unique scent of fingerprint for every stage of fruit ripeness. The study was 97.39% accurate when it was tested on one set of data. It is very convenient, affordable, easy to use, and does not affect or damage the fruit when they are going to use the tool to check the ripeness of fruits.

From a related study, as stated by Weiwei Zhang, "A Fruit Ripeness Detection Method using Adapted Deep Learning-based Approach" (2023), Fruit ripeness plays a very essential role in the field of agriculture, helping to enable satisfaction harvesting and post-harvesting. Many different methods have a hard time achieving a high accuracy for detecting fruit ripeness. This study focuses on improving the detection of fruit ripeness using a deep-learning approach. Deep learning offers better accuracy, but somehow it is still facing challenges in achieving high accuracy. To solve this, the study used the YOLOv8 algorithm, training the custom datasets to improve the detection of fruit ripeness. As a result, YOLOv8 outperforms other existing approaches.

The contrast between this study to the proposed system is that this study only focuses on detecting the ripeness of the fruits, while the proposed system focuses on both spoilage and ripeness. Also, this system uses the YOLOv8-based ripeness detection, while the proposed system will use sensor analysis to detect spoilage and ripeness. The study is designed for the Agricultural sector to help farmers, and the proposed system is mainly designed for Individuals, consumers, and businesses. The study is more advanced scientifically in detecting fruit ripeness, but the proposed system is more useful in real-world applications because it offers both ripeness and spoilage.

The difference between this study and the proposed system is that this study used Internet of Things (IoT) sensors to detect food spoilage and to monitor environmental conditions like temperature, humidity, gas emissions, etc. The proposed system uses Artificial Intelligence (AI) and Machine Learning (ML) and includes Arduino to detect food spoilage and ripeness.

METHODOLOGY

For this research, the Agile methodology was used. Agile is a flexible and iterative approach to software development that emphasizes collaboration, customer feedback, and continuous improvement. It allows the researchers to adapt to changes quickly and deliver working software in shorter cycles, known as sprints. The diagram below shows the process that the researcher will follow to develop and implement the system

Research Design

Research design is the overall plan used to integrate the research; it serves as the collection and analysis of data. A well-structured research design ensures that the research question is effectively addressed and that results are valid and objective.

The researchers use a developmental research design, which focuses on designing, developing, and evaluating new products to address real-world problems. This design involves iterative testing, refinement, and validation

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to improve the effectiveness of the system beforehand. The research employs an experimental approach to test the accuracy, reliability, and efficiency of the system.

Developmental Research Approach

- The system is designed and developed to use AI-driven and IoT-based systems.
- The feedback will be collected to improve the performance of the system

Experimental Research

- The system tests are performed in different light conditions to measure the accuracy of the system.
- The researchers try different kinds of sensors to determine the spoilage of the fruits
- Machine Learning models are trained based on given datasets

System Development Model

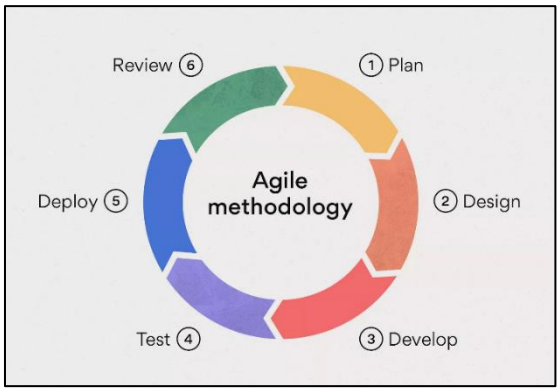

Figure 1 Agile Development Model

As illustrated in *Figure 1*, the Agile Development model will discuss the step-by-step process plan. For instance, design, develop, test, and deploy software and hardware. It presents the framework that will support the researchers through the development stages of this study to ensure the final output of this study meets the expectations of the users and works completely.

- Planning

  In this phase, it refers to defining the goals, tasks and the priorities for the process of agile methodology such as sprint or iteration. This phase is continuous and adaptive, for the researchers to adjust based on the feedback.

- Design

  The team develops a basic system in Figma focused on determining ripeness of fruit, recommending dish, and offline notifications from the user.

- Development

  The system is built out of the final form, using the recommendations from end-user.

- Testing

  The system is tested for functional errors, consistency, or bugs. This system should be verified in this phase to deem the system appropriate for world use.

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- Deployment

The implemented system is now on a specific state of readiness for world use and has a set-up to receive accounts and operate in seamless operation for all stakeholders.

- Sprint Review

The researcher evaluated the performance of the system, provided any feedback, and has normalized for overall system performance.

Data Gathering Technique

- Interview: Conducted through house-to-house interviews and user feedback
- Observation: Studying existing recommender systems and their inefficiencies.
- Survey: Distributed questionnaires to a selected group of respondents to collect data regarding user preferences, behavior, and satisfaction with the existing systems.
- Research: Involved reviewing related studies to gain background knowledge and support findings.

Conceptual Framework

This section assists in visualizing the sequence of events carried out by the system itself, including communication with the app. The AI-based Dish Recommender System for Reducing Fruit Waste Through Spoilage Detection and Ripeness Assessment employs a methodical process utilizing hardware sensors and data processing with an app to reach its aim of reducing edible food waste.

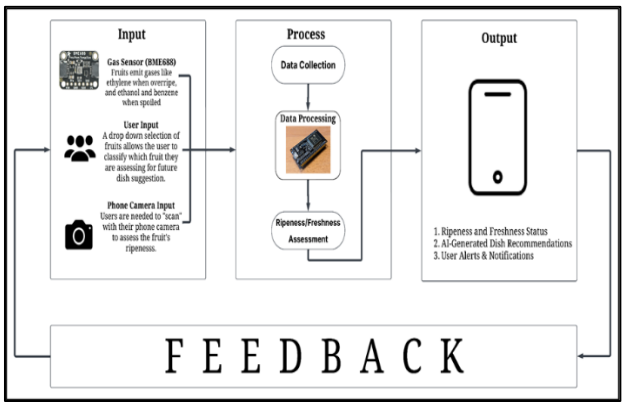

Figure 2: Input-Process-Output and Feedback Model

Figure 2 illustrates that the system data inputs consist of a gas sensor (MQ135) and some user inputs. The gas sensor sends related data to the user about spoiling fruits enabling real-time monitoring inside the mobile application. Additionally, the user input allows the user to identify out of a set of fruits they selected on the "fruit selection" screen, which fruit the user is about the assess and to take pictures of fruits using their phones built-in camera to help inform dish recommendation. The processing of the system is conducted through data collection, data processing, and ripeness assessment. The ESP32 microcontroller pre-processes and collects data from the sensor readings. The data processing system converts, analyze and process the data in the collection system and assesses the freshness and ripeness levels of the fruit using the AI-based model. The system is designed to provide the user with real-time updates about the ripeness and freshness of their food so that they can evaluate the conditions. The AI-powered recommender suggests dish ideas based on the freshness levels detected prior to food perishability. Additionally, the mobile application sends notifications and timely alerts when the food is on their verge to spoil, to help create mindfulness in the user's decision-making process in regards to food waste.

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Application Development

System Development refers to a process that involves steps to build a system such as a website, mobile application, or program so people can use it to address and solve problems or simplify work.

Prototype

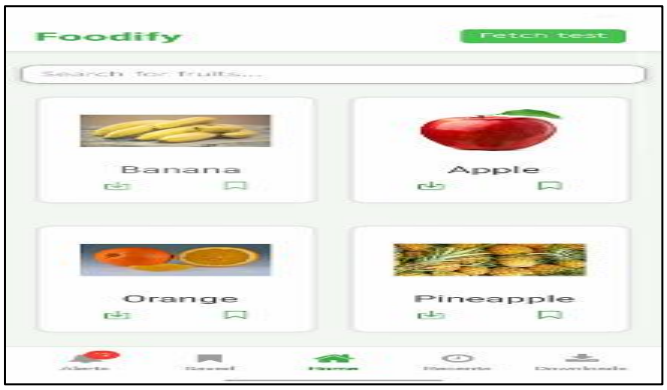

Figure 3: home page

The Home Page acts as the main interface for users to begin analyzing fruit. On this section, users can decide what type of fruit they would like to scan or detect before deriving its ripeness, freshness, or general degree of spoilage- with the use of the machine.

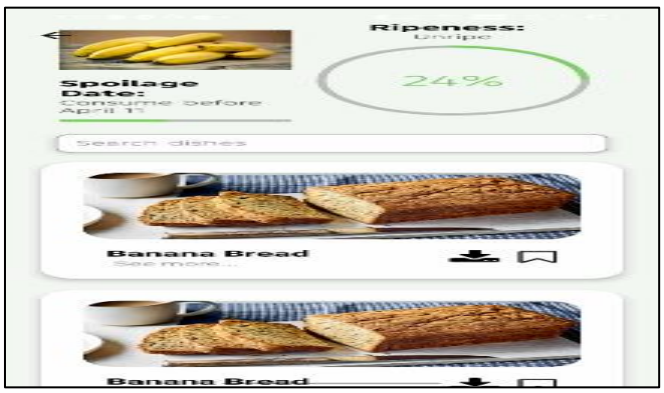

Figure 4. Recipe Expanded Section

The Recipe Expanded section takes cooking with fruit to a whole new level by providing recipe suggestions based on the fruits that were detected or scanned. Whether you are scanning a fresh apple, a slightly overripe banana, or a group of berries, the feature reviews the overall fruit condition and offers the recipes that would be the best use of the entire fruit. If a fruit is estimated to have an expiry date, the system will not recommend a recipe.

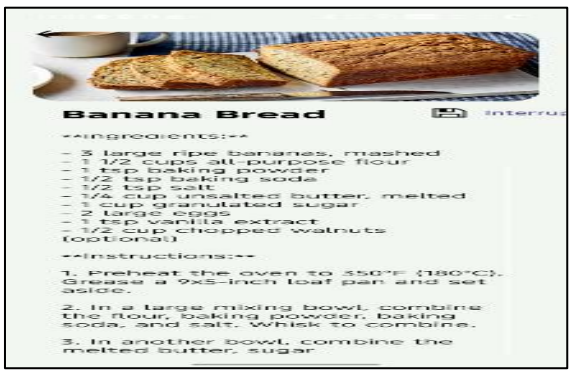

Figure 5. Fruit Recipe Section

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The Fruit Recipe Page functions as the final destination for users interested in exploring an expansive recipe library based on the fruit selected. If you are interested in making a fruity smoothie, dessert, or a healthy meal with fresh produce, the recipe space on the Fruit Recipe Page offers an extensive collection of fruit-based recipes to fit your taste and needs.

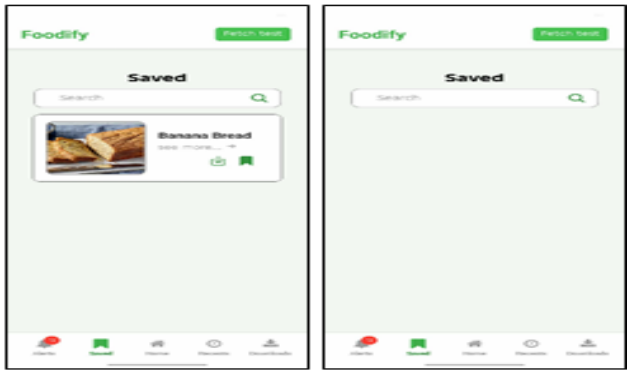

Figure 6. Saved Dishes Section

The primary function of the saved recipes pages is to provide users with seamless access to their favorite recipes for later viewing without directing to the dish selection pages.

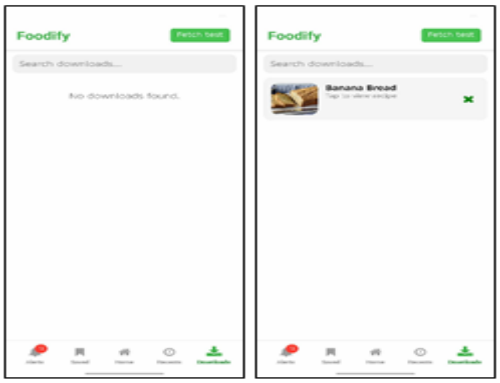

Figure 7. Downloaded Dishes Section

The saved recipes page services primarily to ensure the user has hassle-free access to their favorite recipes at a later time without going back to the food selection pages. The primary function of the Download is for the user to have hassle-free access to their favorite recipes even with no internet connection available. The user can download recipes beforehand to view them offline whenever needed; whether the internet is disconnected, maintenance, or it is simply out of reach.

Figure 8. Recently Open Section

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The Recently Opened Fruits section offers access and the ability to quickly revisit the fruits that were recently opened. This feature allows for a hassle-free access by remembering which fruits were recently opened, and gives the ability to easily find and view them again.

Figure 9. Notifications Section

In this part of our app, users will be alerted to receive timely notifications if the fruit they selected is nearing the estimated spoilage date. We designed this feature to help reduce food waste, make the best use of their fresh produce, and encourage them to eat their fruit while still at good quality and safe to eat.

RESULT AND DISCUSSION

This section presents the results acquired from evaluating the AI-Based Dish Recommender System for Reducing Fruit Waste utilizing a five-point Likert scale questionnaire, which follows the ISO/IEC 25010 standards. The survey involved a total of N=40 respondents, including students, educators, and end-users with varying levels of experience in using computer systems. The primary goal of this evaluation was to determine the system's operational quality, efficiency, and effectiveness in meeting its objective of reducing fruit waste through accurate spoilage detection and targeted dish recommendations.

The results of the development and evaluation of the AI-Based Dish Recommender System for Reducing Fruit Waste through Spoilage Detection and Ripeness Assessment are presented in this chapter. The system was designed by integrating artificial intelligence, gas sensor technology, and a mobile application to help users detect food ripeness, monitor spoilage, and receive recipe recommendations that promote sustainable food consumption. The concept was to provide a practical tool for households and small vendors to minimize waste by combining sensor-based detection with AI-driven suggestions.

Profile of Respondents

The system evaluation involved 40 participants organized by demographics to gain multiple views of usefulness and usability. More participants identified as students and end-users, which is consistent with the target audience for the application. Their experience levels with computer systems ranged from Intermediate to Expert, which also means the evaluators were proficient to assess the functionality and usability for each purpose.

Gender

Gender distribution among respondents was balanced, with 55% male and 18 females (45%) respondents. Male and female representation allows the results of the evaluation to be generalizable without being confused by male/female preferences or reporting tendencies.

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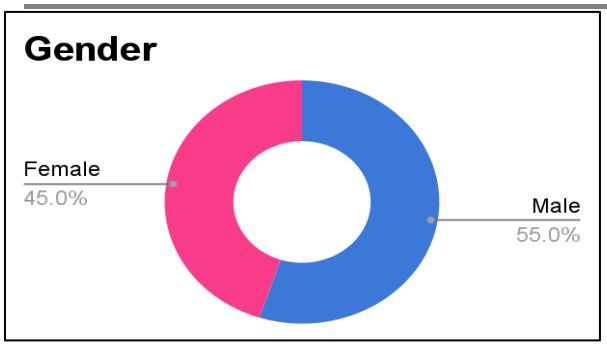

Figure 10. Distribution of Respondents by Gender

Age

The age structure shows the key user groups. In total, the greatest number of respondents provided an answer in the 20-29 age range (N=20), followed by 37.5% (N=15) in Below 20. Only 12.5% (N=5) reported being in the 30-39 age range. This pattern of younger respondents is typical of those who come forward to adopt technology, but also reflects the emphasis on the student and end-user focus of the evaluation.

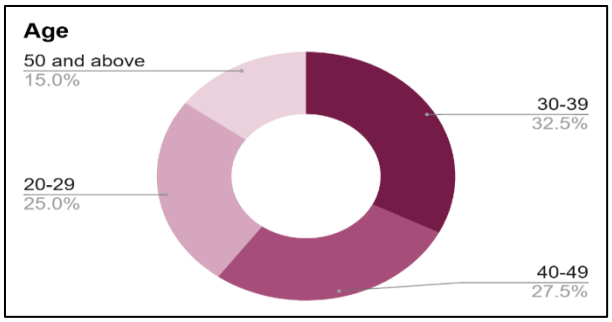

Figure 11. Distribution of Respondents by Age

Occupation

The occupational profiles were deliberately geared toward the end-users of the application. Students were the majority of the sample, taking up 25% of the sample count, while generalEnd-users/Clients accounted for 25 percent. Education/IT staff included 12.5% of the sample. This distribution ensures the quality assessment is primarily based upon what would happen to those who would use the system for their intended daily use.

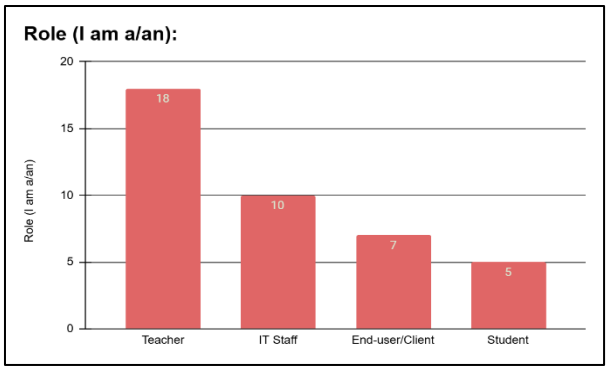

Figure 12. Distribution of Respondents by Occupation

Experience in Using Computer Systems

It appears that the experienced levels were high for an exam of a technical evaluation. Those who had Advanced experience had 37.5% of expertise and N=17 had Expert experience. Only 20% of participants were Intermediate with no Intermediate categories and there was no category in Beginner. These level of computer

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literacy suggests that these evaluators were likely well equipped to accurately assess the technical and overall usability of the testing equipment thoroughly and competently.

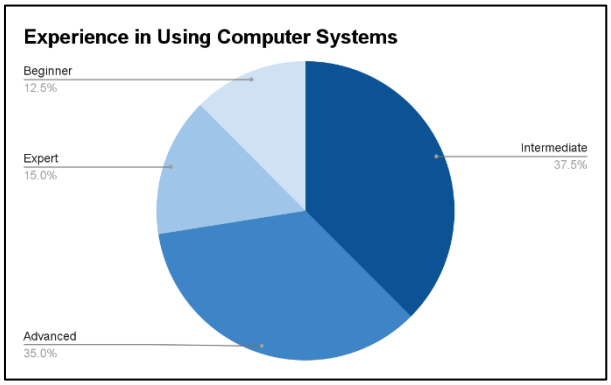

Figure 13. Distribution of Respondents by Computer System Experience

System Evaluation

Seven major sub-characteristics of ISO/IEC 25010 were assessed in a way that best illustrated the overall quality of the system. The following table lists the mean scores, standard deviation, and verbal interpretation for each of the 40 responses based on the 40 responses.

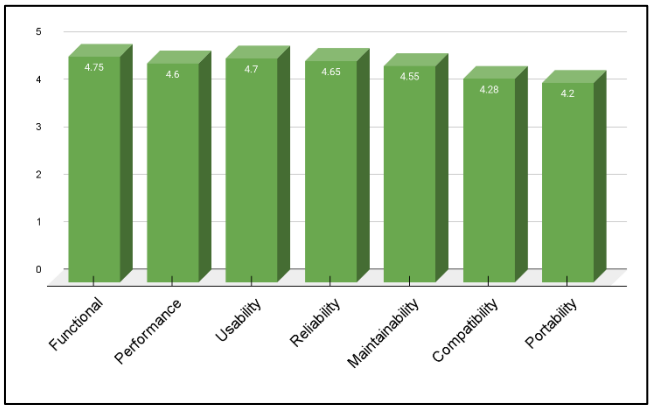

Figure 14. Mean Evaluation Scores by ISO/IEC 25010 Sub-Characteristic

1. Functional Suitability – They rated the system's ability to detect ripeness and spoilage, suggesting recipes that may be useful for reducing food waste as helpful in reducing food waste. Average score: 4.75 / 5.

2. Performance Efficiency – The app worked quickly and only one lag in processing sensor data and showing results. Average score: 4.60/5.

3. Usability – Respondents found the interface easy to use, visually easy and intuitive for everyday uses. Average score: 4.70 / 5.

4. Maintainability – Changes to food, recipes, and features were suggested users noted, and they were able to add new items without altering the system structure. Average score: 4.55/5.

5. Reliability – The app continuously produced accurate classifications and did not crash during tests. The highest rating was 4.65 / 5.

6. Compatibility – The system can be tested on multiple Android devices and versions, presenting very good compatibility across brands. Score: 4.28 / 5.

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7. Portability – It is easier for users to update the app, maintain data, and suggest next versions for iOS integration. Average score: 4.20/5.

The results demonstrated that the recommender system functioned as intended, was reliable, and easy to use, but had some limitations in food coverage (i.e., vegetable and meat items) and accessibility features.

Summary

This study created the AI-Based Dish Recommender System for Reducing Food Waste through Spoilage Detection and Ripeness Assessment, which is a novel food management system that uses sensor technology, artificial intelligence and mobile app, to formulate an innovative food management system. The study stipulated the recommender system met the goals of increasing food waste awareness, thereby assisting users with ingredient management and promoting sustainability practices through recipe provisioning.

CONCLUSION

The evaluation results concluded the recommender system was proficient in determining spoilage and ripeness of fruit, and it was able to recommend relevant recipes. Survey information from users determined users were positively oriented to the recommender system outcome with the highest scores on reliability, functionality and usability. The recommender system is viewed to have significant practical applications to reduce food waste in residential food consumption and promote more sustainable practices in food consumption.

Future work will seek to expand food categories, enhance the AI models, and include accessibility features.

RECOMMENDATIONS

Future researchers are encouraged to:

1. Expand detection capabilities to include vegetables, dairy, and meat products.
2. Implement cloud-based data storage for multi-device syncing and analytics.
3. Add accessibility tools such as voice narration and push notification alerts.
4. Explore VR or AR visualization for a more interactive food monitoring experience.

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