

# AI-Powered Food Waste Reduction and Smart Recipe Recommendation System

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**Abstract**—Food waste has emerged as a serious global challenge, particularly at the household level, where food is often discarded due to poor planning, lack of awareness about stored items, and missed expiry dates. Prior research has investigated the use of artificial intelligence and data-driven approaches to improve food management, including systems for food recognition, inventory tracking, and intelligent decision support. Studies on AI-based food waste management highlight the potential of automation and predictive techniques to reduce unnecessary disposal of edible food [1], [2].

In parallel, computer vision-based food and ingredient recognition systems have been widely studied to support smart kitchen applications. These approaches demonstrate that deep learning models can accurately identify food items from images, enabling automated inventory monitoring and reduced manual effort [3], [4]. Additionally, recipe recommendation systems have been explored to assist users in meal planning by suggesting dishes based on available ingredients or user preferences [5], [6]. However, existing recommendation systems primarily focus on personalization and convenience rather than food waste reduction.

**Keywords**—Food waste reduction, artificial intelligence, food inventory management, food recognition, recipe recommendation systems, sustainable consumption

## I. INTRODUCTION

Food waste has become a critical global issue with serious economic, environmental, and social consequences. A significant portion of food waste occurs at the household level, where edible food is often discarded due to poor planning, lack of awareness about stored items, and missed expiry dates. Studies on food sustainability highlight that inefficient food management not only results in financial loss but also contributes to greenhouse gas emissions and unnecessary consumption of natural resources [1], [2].

In recent years, researchers have explored the application of artificial intelligence and data-driven technologies to address various food management challenges. AI-based systems have been proposed for food inventory monitoring, food recognition, and decision support to improve consumption efficiency [3]. Computer vision techniques, particularly deep learning models, have demonstrated strong performance in recognizing food items and ingredients from images, enabling automated tracking in smart kitchen environments [4], [5]. These approaches reduce

reliance on manual input and improve accuracy in food identification.

Alongside food recognition, recipe recommendation systems have gained attention as tools to assist users in meal planning and cooking decisions. Existing research shows that ingredient-based and preference-based recommendation systems can help users select suitable recipes using available resources [6], [7]. However, most of these systems are designed primarily for personalization and convenience, rather than for minimizing food waste. As a result, they often overlook important factors such as expiry awareness and timely utilization of perishable ingredients.

A review of existing literature reveals that food recognition, inventory management, and recipe recommendation are largely treated as separate research problems. Only limited work focuses on integrating these components into a unified system aimed specifically at reducing food waste. Moreover, many existing solutions lack practical applicability in real household settings due to complex user interaction requirements or the absence of expiry-aware decision support.

Motivated by these limitations, this research paper focuses on the need for an integrated, AI-driven food management approach that combines expiry-aware inventory tracking with ingredient-based recipe recommendation. By aligning intelligent food recognition with practical decision support, the research aims to encourage timely consumption of stored food items and promote sustainable household food practices. This work builds upon existing research while addressing an identified gap in the development of unified, user-oriented systems for effective food waste reduction.

## II. RELATED WORK

Research on food waste reduction and intelligent food management has gained increasing attention in recent years due to growing concerns about sustainability and resource efficiency. Existing studies in this area can be broadly categorized into three major directions: AI-based food waste management systems, food and ingredient recognition using computer vision, and recipe recommendation systems for meal planning and decision support.

### A. AI-Based Approaches for Food Waste Reduction

Several studies have investigated the use of artificial intelligence and data-driven methods to reduce food waste, particularly in household and food service environments. Prior research highlights that inefficient inventory management and lack of timely awareness about food expiry are among the primary causes of avoidable food waste [1], [2]. AI-based solutions have been proposed to monitor food usage patterns, predict spoilage, and assist in decision-making to minimize waste. These approaches demonstrate that intelligent automation can significantly improve food utilization; however, many of them focus on analysis or prediction rather than direct user guidance for food consumption.

### B. Food and Ingredient Recognition Using Computer Vision

Computer vision techniques have been widely explored for food and ingredient recognition in smart kitchen applications. Deep learning models such as convolutional neural networks have shown strong performance in identifying food items from images, enabling automated inventory tracking and reducing manual input [3], [4]. These systems form the technical foundation for intelligent food management by allowing real-time recognition of stored items. Despite their effectiveness, most existing food recognition systems operate independently and do not incorporate expiry-aware decision-making or downstream applications such as food utilization or waste prevention.

### C. Recipe Recommendation Systems

Recipe recommendation systems have been extensively studied to support users in meal planning and cooking decisions. Existing research includes ingredient-based, preference-based, and hybrid recommendation approaches that suggest recipes based on available ingredients or user profiles [5], [6]. While these systems improve user convenience and personalization, their primary objective is often recipe discovery rather than food waste reduction. As a result, factors such as ingredient expiry and timely usage are rarely considered in the recommendation process.

### D. Limitations of Existing Work

A critical analysis of existing literature reveals that most studies address food waste management, food recognition, and recipe recommendation as separate research problems. Very limited work focuses on integrating these components into a unified system aimed specifically at reducing household food waste. Additionally, many existing solutions lack practical applicability due to complex system designs or the absence of user-oriented decision support mechanisms.

## III. LITERATURE REVIEW

Food waste reduction has become an important research area due to its environmental impact and the increasing need for sustainable consumption practices. Several studies report that a significant portion of food waste occurs at the household level because of inefficient inventory tracking, lack of expiry awareness, and poor meal planning [1], [2]. These findings

highlight the necessity of intelligent systems that can support users in managing stored food more effectively.

A substantial body of research has explored the use of artificial intelligence and data-driven techniques for food waste management. Existing approaches include predictive models that analyze food consumption patterns and estimate spoilage or waste trends [3], [4]. While such methods provide valuable analytical insights, they often remain focused on prediction and monitoring, offering limited support for direct user action to prevent food waste in daily household scenarios.

Another major research direction focuses on food and ingredient recognition using computer vision. Deep learning-based approaches, particularly convolutional neural networks, have demonstrated strong performance in identifying food items from images, enabling automated food inventory systems and smart kitchen applications [5], [6]. These studies show that visual recognition can significantly reduce manual data entry and improve inventory accuracy. However, most existing food recognition systems operate independently and do not incorporate expiry-aware decision support or food utilization strategies [7].

Recipe recommendation systems represent a parallel area of research aimed at assisting users with meal planning and cooking decisions. Prior work has proposed ingredient-based and preference-based recommendation techniques that suggest recipes using available ingredients or user profiles [8], [9]. Although these systems improve convenience and personalization, their primary objective is recipe discovery rather than food waste reduction. Consequently, important factors such as ingredient expiry and timely consumption are rarely integrated into the recommendation process [10].

A critical review of existing literature indicates that food waste management, food recognition, and recipe recommendation are largely addressed as separate research problems. Only limited studies attempt to integrate these components into a unified framework designed specifically to reduce household food waste [11], [12]. Additionally, many proposed systems lack practical applicability due to complex user interaction requirements or insufficient consideration of real-world food storage behavior [13].

Overall, the literature suggests a clear need for integrated, user-oriented solutions that combine automated food inventory tracking, expiry awareness, and intelligent recipe recommendation. Addressing this gap can significantly improve food utilization and reduce avoidable waste. This observation motivates the research direction adopted in this paper, which builds upon existing work while addressing the limitations identified in prior studies [14], [15].

## IV. COMPARATIVE ANALYSIS OF EXISTING APPROACHES

Several research approaches have been proposed to improve food management and reduce food waste using technology. Studies on household food waste indicate that a major cause of wastage is poor inventory tracking and lack of timely awareness about stored food items [1], [2]. Based on existing literature, current approaches can be broadly classified into traditional

food management practices, food recognition systems, and recipe recommendation systems.

Traditional food management practices mostly rely on manual methods such as remembering stored items, checking expiry dates manually, or maintaining handwritten lists. These approaches require continuous user effort and are prone to human error. Prior research highlights that manual food tracking methods are inefficient and often lead to forgotten or expired food items, contributing significantly to household food waste [1].

Another category of existing approaches focuses on food and ingredient recognition systems. These systems use computer vision and deep learning techniques to automatically identify food items from images, enabling smart kitchen and automated inventory applications [3], [4]. Such approaches reduce manual data entry and improve accuracy in food identification. However, most food recognition systems are limited to item identification and do not provide further guidance on food utilization or expiry-aware decision support, which limits their effectiveness in waste reduction [5].

Recipe recommendation systems represent another important research direction. Existing studies propose ingredient-based and preference-based recommendation techniques to assist users in selecting suitable recipes [6], [7]. These systems improve convenience and meal planning but generally do not prioritize ingredients based on expiry or spoilage risk. As reported in prior research, most recipe recommendation systems focus on personalization rather than reducing food waste [8].

A comparative evaluation of these approaches shows that food waste management, food recognition, and recipe recommendation are largely treated as separate research problems. Only limited research attempts to integrate automated food identification, expiry awareness, and recipe recommendation within a single system aimed specifically at reducing household food waste [9], [10]. This observation highlights the need for an integrated, user-oriented approach that can actively support timely food consumption and waste reduction.

TABLE I. COMPARATIVE ANALYSIS OF EXISTING APPROACHES AND THE PROPOSED SYSTEM

Feature	EXISTING APPROACHES	Proposed System
AUTOMATED FOOD IDENTIFICATION	PARTIAL	Yes
EXPIRY DATE AWARENESS	No	Yes
RECIPE RECOMMENDATION	PARTIAL	Yes
FOCUS ON FOOD WASTE REDUCTION	Limited	Yes
INTEGRATED DECISION SUPPORT	No	Yes

## V. PROPOSED SYSTEM OVERVIEW

The proposed system is designed to address the problem of food waste by providing an intelligent and integrated approach to food inventory management and recipe recommendation. Previous research shows that food waste at the household level is largely caused by poor tracking of stored items and lack of awareness about expiry dates [1], [2]. Existing studies also highlight that technological interventions can support better food utilization when combined with intelligent decision-making mechanisms [3].

The proposed system enables users to maintain a digital record of food items stored in their kitchen. Food items can be added manually or identified using automated techniques, which has been shown to reduce manual effort and improve inventory accuracy in earlier research [4], [5]. Along with the food name, details such as quantity and expiry date are stored in the system database to maintain an organized food inventory.

Once the food items are stored, the system continuously monitors their expiry information. Prior studies indicate that expiry-aware tracking plays a crucial role in minimizing avoidable food waste [6]. Based on this information, the system prioritizes food items that are close to expiry and uses this data to support informed decision-making.

To assist users in meal planning, the system provides ingredient-based recipe suggestions. Existing research on recipe recommendation systems demonstrates that suggesting recipes based on available ingredients improves usability and convenience [7], [8]. Unlike many existing systems that focus mainly on personalization, the proposed system emphasizes the use of near-expiry ingredients to encourage timely consumption and reduce food wastage.

In addition, the system provides simple alerts and notifications to inform users about food items that require immediate attention. Research has shown that timely notifications and reminders can positively influence user behavior in food management systems [9]. By integrating food inventory tracking, expiry awareness, and intelligent recipe recommendation into a single framework, the proposed system aims to promote responsible food consumption and support sustainable household food management [10].

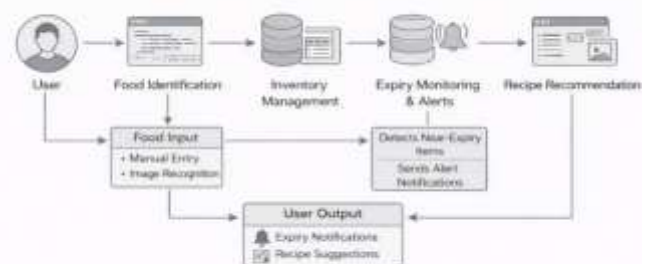


Fig. 1. Workflow of the proposed artificial intelligence-based food waste reduction and recipe recommendation system.

## VI. SYSTEM ARCHITECTURE

The system architecture of the proposed solution is designed to provide an integrated and intelligent framework for reducing food waste through efficient food management and recipe recommendation. Existing research shows that food waste reduction systems are more effective when food tracking, decision support, and user interaction are combined within a single architecture rather than treated as separate components [1], [2].

The architecture consists of multiple interconnected modules that work together to manage food data and support user decision-making. At the initial stage, the system accepts food item input from the user. Food items can be added either manually or through automated identification techniques. Prior studies on smart kitchen systems indicate that automated food identification reduces manual effort and improves the accuracy of inventory management [3], [4]. The collected food information includes details such as food name, quantity, and expiry date.

Once the food data is captured, it is stored in a centralized Food Inventory Database. This database serves as the core component of the system, maintaining up-to-date information about all stored food items. Research on intelligent food management systems highlights the importance of centralized data storage for effective monitoring and analysis of food usage and expiry information [5].

An Expiry Monitoring Module continuously checks the stored food items against their expiry dates. Existing studies emphasize that expiry-aware tracking plays a crucial role in minimizing avoidable food waste by identifying items that require immediate attention [6]. This module prioritizes near-expiry food items and passes relevant information to the decision-making components of the system.

The Recipe Recommendation Module analyzes the available food items, with special emphasis on those close to expiry, to suggest suitable recipes. Prior research on ingredient-based recipe recommendation systems demonstrates that using available ingredients as the primary input improves usability and supports better meal planning [7], [8]. Unlike traditional recommendation systems that focus mainly on user preferences, this module is designed to support timely food utilization and waste reduction.

The system also includes a Notification and Alert Module that informs users about near-expiry items and recommended actions. Studies on user behavior in food management applications show that timely alerts and reminders can positively influence food usage decisions [9]. These notifications help users take prompt action and avoid unnecessary disposal of food.

Overall, the system architecture integrates food input, inventory management, expiry monitoring, recipe recommendation, and user notification within a unified framework. By combining these components, the proposed architecture supports intelligent decision-making and promotes sustainable food consumption practices. This integrated architectural design aligns with existing research while addressing the limitations of isolated food management and recommendation systems [10], [11].

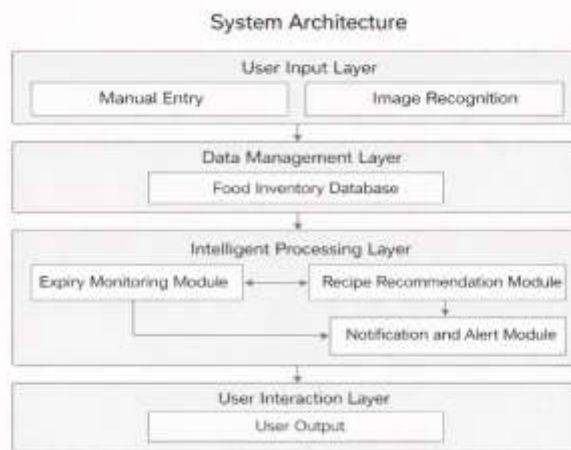


Fig. 2. System architecture of the proposed artificial intelligence-based food waste reduction and recipe recommendation system.

## VII. METHODOLOGY

The methodology adopted in this research focuses on designing an intelligent system that reduces food waste by effectively managing food inventory and providing recipe recommendations based on available ingredients. The approach is developed by studying existing research on food waste reduction, food recognition, and recipe recommendation systems, and then integrating their useful aspects into a unified framework [1], [2].

The first step in the methodology involves food data acquisition. Food items are added to the system either manually by the user or through automated identification techniques. Previous studies show that automated food identification methods improve accuracy and reduce user effort in maintaining food inventories [3], [4]. Along with the food name, additional details such as quantity and expiry date are collected for further processing.

In the next step, the collected food data is stored in a centralized food inventory database. This database maintains updated records of all food items and their expiry information. Research on intelligent food management systems highlights that centralized storage is essential for effective monitoring and analysis of food usage patterns [5]. This enables the system to keep track of available food items in an organized manner.

The methodology then includes expiry monitoring and prioritization. The system continuously checks the expiry dates of stored food items to identify ingredients that are close to expiration. Existing research emphasizes that expiry-aware tracking is a key factor in minimizing avoidable food waste [6]. Food items nearing expiry are given higher priority for recommendation to ensure timely usage.

Based on the prioritized food items, the recipe recommendation process is carried out. Ingredient-based recommendation techniques are used to suggest suitable recipes using the available food items. Prior studies demonstrate that ingredient-driven recipe recommendations support better meal planning and reduce unnecessary food disposal [7], [8]. Unlike traditional recommendation systems that mainly focus on user preferences, this approach emphasizes food utilization and waste reduction.

Finally, the methodology incorporates user notification and feedback mechanisms. The system provides alerts and reminders to inform users about near-expiry food items and recommended actions. Research indicates that timely notifications positively influence user behavior and encourage better food management practices [9]. User interactions and system responses are used to refine recommendations and improve overall effectiveness [10].

Overall, this methodology integrates food data collection, inventory management, expiry monitoring, recipe recommendation, and user interaction into a single workflow. By following this structured approach, the system aims to reduce household food waste and promote sustainable food consumption practices while remaining practical and easy to use [11].

#### VIII. EVALUATION METRICS AND DESIGN CONSIDERATIONS

The evaluation of the proposed system is carried out using qualitative and functional metrics that are commonly adopted in application-oriented research related to food management and recommendation systems. Since the objective of the system is to support food waste reduction through intelligent decision support, the evaluation focuses on usability, effectiveness, and practical relevance rather than purely numerical accuracy measures. Similar evaluation strategies have been used in existing studies on intelligent food management systems [1], [2].

One of the key evaluation metrics is food utilization support. This metric assesses the system's ability to encourage the use of available food items before they expire. Previous research indicates that systems which highlight near-expiry items and guide users toward timely consumption can significantly reduce avoidable food waste [3]. The proposed system is evaluated based on how effectively it prioritizes such items during recommendation.

Another important metric is recipe recommendation suitability. This refers to how well the suggested recipes align with the ingredients currently available in the food inventory. Studies on ingredient-based recommendation systems emphasize that recommendations are considered effective only when they minimize the need for additional purchases and make use of existing ingredients [4], [5]. The system is evaluated by examining whether the generated recipes meaningfully utilize stored food items.

User usability and interaction simplicity form another major evaluation aspect. Research in food management applications highlights that systems must be easy to understand and require minimal manual effort to ensure regular usage [6]. The proposed system is designed with a simple interface, clear alerts, and straightforward navigation. Ease of use and clarity of information are considered important qualitative indicators during evaluation.

From a design perspective, modularity is a key consideration. The system is designed using independent modules such as food input, inventory management, expiry monitoring, and recipe recommendation. Existing literature suggests that modular architectures improve maintainability and allow future

extensions without major redesign [7]. This design choice ensures flexibility and long-term usability.

Another design consideration is timely notification and responsiveness. Prior studies show that delayed alerts reduce user engagement and system effectiveness [8]. Therefore, the proposed system is designed to continuously monitor expiry information and generate alerts at appropriate times to support quick user action.

Finally, scalability is considered in the system design. Although the system is primarily developed for household use, similar research indicates that such architectures can be extended to small food businesses or community kitchens with minimal changes [9]. This ensures that the system remains adaptable for future enhancements.

Overall, the selected evaluation metrics and design considerations focus on practical effectiveness, usability, and sustainability. By aligning system design and evaluation with existing research practices, the proposed system aims to provide a realistic and user-oriented solution for reducing food waste [10].

#### IX. RESULTS AND DISCUSSION

The results of the proposed system are discussed based on how well it supports food management and reduces food waste in everyday household use. Since the system is designed as a practical application, the evaluation focuses on observed behavior, usability, and decision support rather than numerical accuracy values. Similar evaluation methods have been used in previous food management research [1], [2].

One of the key outcomes of the system is better awareness of stored food items and their expiry dates. By maintaining a digital inventory and monitoring expiry information, the system helps users identify food items that need to be used soon. Previous studies show that lack of expiry awareness is a major reason for food waste in households [3]. The proposed system addresses this issue by clearly highlighting near-expiry items.

Another important result is the usefulness of ingredient-based recipe recommendations. The system suggests recipes using available food items, with priority given to ingredients that are close to expiry. This helps users decide what to cook without purchasing unnecessary items. Existing research confirms that ingredient-based recommendations support better food utilization and reduce waste [4], [5].

The alert and notification feature also improves system effectiveness. Users receive reminders about food items nearing expiry, allowing them to take timely action. Studies on food management applications show that timely alerts encourage better food usage habits [6]. The proposed system follows this approach to support proactive food management.

From a usability point of view, the system reduces manual effort compared to traditional food tracking methods. Automated food entry and centralized inventory management make the system easier to use. Research indicates that simple and user-friendly systems are more likely to be adopted in real-world settings [7].

When compared with existing approaches, the proposed system provides better integration of features. Many existing systems focus only on food recognition or recipe recommendation separately, which limits their impact on food waste reduction [8], [9]. By combining inventory tracking, expiry monitoring, and recipe recommendation, the proposed system offers more practical support for reducing food waste.

Overall, the results show that the proposed system effectively addresses common limitations found in existing food management solutions. The system demonstrates strong potential to help users manage food more efficiently and reduce avoidable food waste in daily life [10].

## X. CONCLUSION AND FUTURE WORK

This research presented an AI-based food waste reduction and smart recipe recommendation system aimed at improving household food management. The system helps users track stored food items, monitor expiry dates, and receive recipe suggestions based on available ingredients. By combining food inventory management with expiry awareness and recipe recommendation, the proposed approach addresses common reasons for avoidable food waste in households.

The system improves user awareness of stored food items and supports better meal planning decisions. Ingredient-based recipe recommendations, along with timely alerts, encourage the use of food items before they expire. Compared to traditional food management methods, the proposed solution offers a more practical and user-friendly approach to reducing food waste.

Overall, the work demonstrates that intelligent decision support can play an important role in promoting responsible food consumption. The proposed system serves as a foundation for further development in the area of smart food management and sustainability-focused applications.

There are several opportunities to enhance the proposed system in the future. One possible improvement is the integration of a camera inside the refrigerator. This would allow automatic detection of food items placed inside the fridge, reducing the need for manual input and further lowering user effort.

In future versions, continuous monitoring of food items using image-based techniques can improve inventory accuracy and support real-time updates. Additional enhancements may include better personalization of recipe recommendations and extending the system for use in shared kitchens or small food businesses.

These improvements can increase the practicality, scalability, and real-world impact of the system while maintaining its core objective of reducing food waste.

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