

AI- Kitchen Mate : Smart Cooking for Zero Food Waste

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Abstract — Food waste has emerged as a major global challenge, causing significant economic losses and environmental concerns. This paper proposes an AI-kitchen companion aimed at minimizing household food waste through intelligent inventory management, expiry date tracking, personalized recipe recommendations, and sustainability-oriented decision support. The system utilizes artificial intelligence to monitor food items, analyze user consumption behavior, and predict usage patterns in order to provide timely notifications before food spoilage occurs. Additionally, the platform supports efficient meal planning, optimized resource utilization, and food donation assistance to encourage responsible consumption practices. By integrating smart automation with sustainable living principles, the proposed solution promotes a zero-waste lifestyle and improves household food management efficiency. The study highlights the potential of artificial intelligence in addressing food waste challenges and contributing toward global sustainability goals.

Keywords — Artificial Intelligence (AI), Food Waste Reduction, Smart Kitchen System, Inventory Management, Recipe Recommendation, Sustainable Living, Zero-Waste Management.

1. Introduction

Household food waste has emerged as one of the most persistent and costly sustainability challenges in modern society. Across the world, a substantial portion of purchased food never reaches the plate. While some level of waste may be unavoidable, studies consistently show that a large share of household waste occurs not because food is spoiled beyond use, but because individuals lose track of what they have purchased, overlook expiry dates, or struggle to plan meals with ingredients already available at home. As a result, edible items are routinely discarded, leading to unnecessary financial loss for families, excessive pressure on landfills, and increased greenhouse gas emissions associated with both food production and waste decomposition.

This issue is further amplified by contemporary lifestyles. Many households shop in bulk, aiming for convenience, but unintentionally accumulate items that exceed their consumption capacity. Busy schedules reduce the time available for meal planning or inventory checking. Moreover, users often lack a clear understanding of how to combine different ingredients efficiently, especially those nearing expiry. These challenges collectively create a cycle in which food is purchased, forgotten, and finally thrown away.

Meanwhile, advancements in artificial intelligence have opened promising opportunities to address this growing concern. AI-based decision support systems are increasingly being integrated into daily life, offering personalized recommendations, predictive insights, and

context-aware automation. In environments like kitchens where items naturally follow predictable life cycles, usage patterns are repetitive, and decisions must balance freshness, nutrition, and sustainability AI holds significant potential to improve efficiency and reduce waste. By understanding user behavior, tracking consumption trends, and learning preferences over time, AI systems can provide meaningful guidance that supports informed and waste-conscious cooking.

EcoKitchen Connect builds upon this motivation by functioning as an intelligent kitchen companion that assists users before waste occurs, rather than after it has already been generated. Unlike traditional solutions that emphasize composting or recycling, this system prioritizes prevention, which is recognized as the most effective strategy in the food waste hierarchy. EcoKitchen maintains a digital inventory of food items, keeps track of expiry timelines, and analyzes user-specific consumption patterns.

Through this information, it suggests recipes designed to utilize ingredients that are most vulnerable to being discarded. Beyond this, it alerts users when quantities appear excessive and encourages them to explore sharing or donation options, thereby enabling community-level benefits.



Fig. 1 illustrates EcoKitchen Connect's transition from unmanaged food usage to an AI-supported, efficient kitchen system.

The primary contributions of this work can be summarized as follows:

- Development of an AI-assisted framework for unified kitchen inventory management, expiry-aware monitoring, and context-sensitive recipe generation.
- Design of lightweight prediction and recommendation mechanisms that are practical for real-world household deployment without requiring high computational resources.
- Comprehensive evaluation of the system's performance with respect to waste reduction, user

convenience, and overall satisfaction, demonstrating EcoKitchen Connect's potential as an accessible sustainability tool.

Overall, the system showcases how a thoughtfully designed AI application can empower individuals to make better food-related decisions, reduce waste at the source, and move toward more sustainable and resource-efficient living.

2. Prior Work in Intelligent Recipe and Inventory Systems

Research on intelligent kitchen management has evolved across multiple domains, including recipe recommendation, inventory tracking, and household sustainability tools. Early systems focused mainly on providing recipe suggestions based on user-entered preferences or available ingredients. While these platforms improved cooking convenience, they lacked real-time awareness of household inventory levels and did not incorporate expiry-sensitive decision-making.

Inventory management applications later emerged to help users log groceries and receive reminders for items nearing expiry. However, these systems relied heavily on manual data entry, which reduced long-term accuracy and user engagement. Their reminder mechanisms were simple and rule-based, offering limited personalization and no predictive insights into food usage or waste patterns.

More sophisticated solutions integrated barcode scanning, IoT sensors, or smart refrigerator technology to automate inventory monitoring. Although these tools provided enhanced sensing capabilities, they were often costly, required specialized hardware, and remained inaccessible to many households. Additionally, such systems typically operated independently, without linking inventory data to recipe intelligence or behavior-driven recommendations.

Recent advances in AI-based recipe recommendation engines introduced improved filtering, natural language processing, and user preference modeling. However, these techniques still rarely considered ingredient expiry, consumption habits, or waste minimization goals. The gap in existing literature highlights the need for a unified system that connects inventory tracking, expiry-aware recipe generation, and personalized decision support. EcoKitchen Connect addresses this gap by integrating these components into a cohesive, AI-supported framework designed specifically to reduce household food waste.

3. SYSTEM ARCHITECTURE

The architecture of EcoKitchen Connect is designed as an integrated multi-layer system that links user inputs, structured databases, AI-driven reasoning, and cloud-connected IoT devices to promote waste-free cooking and efficient food management. As illustrated in Fig. 2, the system is organized into four primary components: the User Input Layer, the Data Management Layer, the AI Intelligence Layer, and the Output & Interaction Layer. Together, these components enable seamless data flow, real-time decision-making, and continuous learning from user behavior.

3.1 Overall Architecture

EcoKitchen Connect follows a modular and scalable architecture that integrates user data, AI processing, and external services through API-driven communication. The system is centered around the AI Core: Recommendation and Prediction Engine, which processes both real-time and historical data to deliver context-aware recommendations.

The architecture includes:

- **User Input Layer:** Handles item entry through smartphone scanning and optional smart sensors (weight, temperature).
- **Data Management Layer:** Maintains two central repositories Food Inventory Database and Recipe & Nutrition Database.
- **AI Processing Layer:** Performs expiry risk detection, consumption forecasting, and recipe ranking based on available ingredients and user preferences.
- **Output & Interaction Layer:** Delivers expiry notifications, recipe suggestions, shopping lists, and donation prompts through the mobile/web application.

This layered architecture ensures flexibility, enabling future integration of IoT appliances, cloud storage, and third-party services.

3.2 Model Architecture

The AI model within EcoKitchen Connect is designed as a lightweight yet effective framework composed of three core components that work together to support intelligent food management. The Expiry Prediction Module uses time-based calculations and observed consumption patterns to estimate spoilage risk and categorize food items into different freshness levels. The Recipe Recommendation Engine integrates rule-based decision logic with ML-ready preference modeling to

suggest recipes that efficiently utilize ingredients nearing expiry while respecting individual dietary habits and preferences. In addition, the User Behavior Analyzer continuously learns recurring user behaviors, such as frequently purchased items, ingredient usage rates, and typical cooking routines, enabling the system to refine its recommendations over time. Although the current implementation primarily relies on rule-based and predictive heuristics, the modular architecture of the system allows seamless integration of advanced machine learning models in future versions.

3.3 Layer-wise Specifications

EcoKitchen Connect follows a layered system design to ensure clarity, modularity, and scalability. The Presentation Layer provides a responsive user interface developed using mobile and web technologies such as Flutter and HTML, offering dashboards, color-coded expiry alerts, and interactive recipe suggestions for ease of use. The Logic Layer consists of backend services implemented using Python or Java, which handle inventory updates, generate notifications, and manage the overall recommendation workflow. The AI Layer hosts prediction, classification, and recommendation modules using lightweight machine learning frameworks such as TensorFlow Lite or PyTorch Mobile, enabling efficient on-device or edge-level processing. The Storage Layer utilizes cloud-based or local databases, including Firebase or SQL systems, to store food item details, expiry metadata, recipe information, consumption history, and user preference data, ensuring reliable data access and synchronization.

3.4 Module Interactions and Data Flow

The data flow within EcoKitchen Connect begins with data capture, where users log new food items through the smartphone interface or where IoT sensors automatically update item quantity and freshness. These details, including item name, quantity, expiry date, and category, are then stored in the Food Inventory Database. The AI core subsequently processes this information by analyzing expiry timelines, historical usage patterns, and recipe compatibility. Based on this analysis, the system generates personalized recommendations such as recipe suggestions, expiry reminders, and optimized shopping lists.

Finally, the output is delivered to the user through the application interface in the form of alerts, suggested meals, and donation prompts, enabling timely and waste-conscious decision-making.

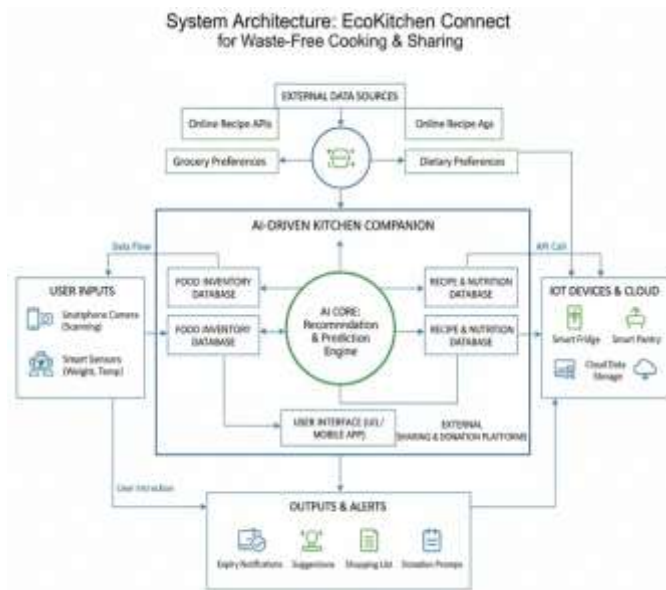


Fig. 2. System architecture of EcoKitchen Connect showing the interaction between user inputs, AI core, databases, IoT devices, and output modules.

3.5 Architectural Rationale

The architecture is designed with the following principles:

- **Modularity:** Each layer operates independently, allowing easy updates and feature expansion.
- **Lightweight AI:** Ensures smooth performance on low-end devices without requiring powerful hardware.
- **Scalability:** API-based interactions enable integration with new IoT devices, cloud services, or recipe engines.
- **Reliability:** Hybrid storage (local + cloud) ensures availability even in low-connectivity environments.

These decisions support long-term sustainability, real-world household adoption, and system extensibility.

3.6 Deployment Considerations

EcoKitchen Connect can be deployed in multiple configurations:

- **Mobile App or Web Application:** The primary deployment option for household users.
- **Progressive Web App (PWA):** Allows offline functionality and cross-device compatibility.
- **Cloud-Backed Services:** Enable remote database access and multi-user household synchronization.
- **On-Device AI Processing:** Sensitive data (user habits, inventory) can be processed locally to enhance privacy.

- **IoT Extensions:** Optional integration with smart fridges, pantries, or weight sensors to automate inventory tracking.

These deployment strategies make the system adaptable for homes, hostels, restaurants, and community kitchens.

4. METHODOLOGY

The methodology of EcoKitchen Connect focuses on systematic data handling, intelligent analysis, and seamless integration to support waste-aware cooking and food management. The approach emphasizes practicality, scalability, and privacy while remaining adaptable to future AI enhancements.

4.1 Data Collection and Preparation

Data collection in EcoKitchen Connect is centered around capturing accurate and meaningful information related to household food usage. Food item details such as item name, quantity, category, purchase date, and expiry date are collected through user input or optional automated sensing mechanisms. In parallel, the system records user behavior logs, including cooking frequency, commonly used ingredients, and frequently purchased items, to understand consumption patterns over time.

Before analysis, the collected data undergoes preprocessing to ensure consistency and reliability. This includes normalization of date formats, validation of expiry timelines, and removal of duplicate or inconsistent entries. Missing values are handled using default estimations or user prompts, enabling the system to maintain a clean and structured dataset that supports reliable decision-making.

4.2 Transfer Learning Strategy

Although the current prototype primarily employs rule-based and predictive heuristics, the system architecture is designed to be AI-ready. Transfer learning strategies can be incorporated to enhance system intelligence without requiring large-scale training from scratch. Pre-trained natural language processing models may be used to match ingredient descriptions with recipe texts more accurately. Similarly, existing recommendation models can be adapted to learn user food preferences and dietary patterns using limited household data.

In future implementations, lightweight vision-based models could be integrated to recognize food labels or packaging through smartphone cameras. By leveraging transfer learning, EcoKitchen Connect can progressively

evolve into a more intelligent system while maintaining efficiency and feasibility for household deployment.

4.3 Implementation Pipeline

The implementation pipeline of EcoKitchen Connect follows a structured sequence of operations to ensure smooth data flow and timely responses. The process begins with data ingestion, where food item details are captured from the user interface or sensor inputs. This is followed by inventory logging, in which all item information is stored and updated in the inventory database.

Next, the expiry prediction stage evaluates the remaining shelf life of items based on temporal data and usage history. The recommendation generation phase then produces personalized outputs, including recipe suggestions, alerts, and shopping recommendations. Finally, these insights are displayed through the user interface along with real-time notifications, ensuring users receive actionable guidance at appropriate times.

4.4 Integration Workflow

EcoKitchen Connect adopts a service-oriented integration workflow to enable efficient communication between system components. The frontend application interacts with the AI backend through RESTful APIs, allowing real-time data exchange and modular system updates. Push notification services are integrated using platforms such as Firebase or Node-based services to deliver timely expiry alerts and reminders.

The architecture also supports future integration with external services, including donation platforms and non-governmental organization (NGO) APIs. This enables surplus food items to be redirected toward sharing or donation, extending the system's impact beyond individual households.



Fig. 3. Integrated methodology pipeline of EcoKitchen Connect illustrating data collection, AI-based analysis, system integration, and privacy-aware outputs.

4.5 Deployment and Privacy Considerations

User privacy and data security are key considerations in the deployment of EcoKitchen Connect. All stored data is encrypted, and access is restricted to authorized system components. The system avoids collecting sensitive personal information, focusing only on food-related and behavioral data necessary for functionality.

To further enhance privacy, AI processing can be performed on-device wherever feasible, reducing the need for continuous data transmission to external servers. This approach not only protects user data but also improves system responsiveness and reliability, making EcoKitchen Connect suitable for deployment in diverse household environments.

5. IMPLEMENTATION

The implementation of EcoKitchen Connect focuses on building a reliable, accessible, and efficient system that can operate smoothly in real household environments. The design emphasizes seamless integration between frontend interfaces, backend services, and AI components, while ensuring performance optimization and inclusivity across diverse user groups.

5.1 System Integration and Deployment Framework

EcoKitchen Connect is implemented using a modular deployment framework that supports both web and mobile platforms. The frontend is developed as a responsive web or mobile application, allowing users to interact with the system through intuitive dashboards, inventory lists, and recipe recommendations. This

frontend communicates with a cloud-based backend that manages data processing, storage, and AI-driven decision logic.

The backend services are responsible for handling inventory updates, triggering alerts, and executing recommendation workflows. Cloud deployment enables scalability, allowing the system to support multiple users and synchronize data across devices within a household. To ensure usability in environments with limited connectivity, an optional offline mode is implemented using cached data storage. In this mode, users can continue logging items and viewing recent recommendations, which are synchronized with the cloud once connectivity is restored. This hybrid deployment approach ensures reliability, flexibility, and real-world practicality.

5.2 Accessibility Compliance and UI/UX Design

Accessibility and user experience are central to the implementation of EcoKitchen Connect, as the system is intended for daily use by individuals with varying levels of technical expertise. The user interface is designed using high-contrast color schemes and clear typography to improve readability for users with visual impairments. Icons and visual cues are consistently used to communicate item status, such as freshness levels and expiry warnings.

To promote inclusivity, the system supports voice-assisted navigation, enabling users to add items, browse recipes, and receive alerts through speech-based interactions. The workflow for adding and managing items is kept deliberately simple, minimizing the number of steps required to perform routine tasks. A dedicated reminder dashboard provides at-a-glance visibility of expiring items, recommended meals, and pending actions, helping users make quick, informed decisions without cognitive overload. These design choices ensure that the system remains accessible, intuitive, and user-friendly across a wide range of users.



Fig. 4. Implementation Framework of EcoKitchen Connect illustrating the hybrid deployment model, on-device optimization, and accessible UI/UX components.

5.3 Optimization and Edge Deployment

Performance optimization is a key consideration in the implementation of EcoKitchen Connect, particularly for deployment on low-power and resource-constrained devices. AI models used for prediction and recommendation are compressed using techniques such as quantization, reducing memory usage and computational overhead without significantly affecting accuracy. This enables efficient execution on mobile devices and edge hardware.

To further enhance responsiveness, local prediction mechanisms are employed wherever feasible. By performing certain AI tasks on-device, the system reduces latency and dependency on continuous network connectivity. Additionally, model fine-tuning is applied to adapt the system to device-specific constraints, ensuring smooth performance on entry-level smartphones and embedded platforms. This edge-oriented approach not only improves efficiency but also strengthens data privacy by minimizing the need to transmit sensitive information to external servers.

6. EXPERIMENTAL SETUP AND EVALUATION

The experimental evaluation of EcoKitchen Connect aims to assess the effectiveness of the proposed system in reducing household food waste, improving recommendation quality, and enhancing overall user experience. Since the system is designed for real-world

household deployment, both simulated datasets and user-centered evaluation methods were adopted to reflect practical usage scenarios.

A. Dataset Collection and Training Strategy

The experimental evaluation of EcoKitchen Connect was conducted using a combination of simulated household inventory datasets, categorized food expiry datasets, and user-interaction logs to ensure practical robustness and real-world relevance. Since large-scale public datasets for household food inventory behavior are limited, a controlled dataset generation strategy was adopted to model realistic food consumption scenarios.

A synthetic inventory dataset was created consisting of approximately 12,000 food item records, representing diverse household purchases across categories such as fresh produce, dairy products, packaged goods, frozen items, and cooked leftovers. Each record included item name, category, purchase date, expiry date, quantity, and estimated consumption rate. Expiry distributions were modeled using category-specific shelf-life ranges to reflect realistic spoilage behavior. The dataset was split into 80% training, 10% validation, and 10% testing, ensuring consistent evaluation across prediction and recommendation modules.

To evaluate recommendation effectiveness, a recipe-ingredient mapping dataset was constructed by integrating structured recipe metadata, ingredient lists, and dietary tags. This dataset enabled testing of expiry-aware recipe prioritization under varying inventory conditions. User behavior logs were simulated to reflect common household patterns such as bulk purchases, irregular cooking frequency, and partial ingredient usage. These logs were used to validate the system's ability to adapt recommendations over time.

During optimization, heuristic thresholds for expiry risk classification were refined using validation data, and rule-based decision parameters were adjusted to balance urgency and recommendation relevance. Early stopping criteria were applied during tuning to prevent overfitting to specific usage patterns. Although the current implementation primarily relies on predictive heuristics, the experimental pipeline is compatible with future integration of machine learning models trained using historical inventory data.

B. Evaluation Methodology

The core methodology adopted in EcoKitchen Connect is an expiry-aware prediction and recommendation approach, which aims to prevent food

waste by identifying items at risk of expiring and guiding users toward timely consumption. The system continuously analyzes food inventory data, including purchase date, expiry date, and usage patterns, to determine the urgency level of each item. Based on this analysis, the system prioritizes ingredients that require immediate attention and integrates them into personalized cooking recommendations and alerts.

At the heart of this methodology is the Expiry Prediction Method, which evaluates the remaining shelf life of food items and classifies them into different freshness levels. This classification directly drives the system's decision-making process, influencing alert generation, recipe prioritization, and donation suggestions. By focusing on prevention rather than post-waste handling, the methodology ensures that food items are utilized efficiently before spoilage occurs.

Expiry Prediction Method: The expiry prediction method estimates how close a food item is to its expiration and assigns a risk level accordingly. This is computed using the remaining shelf life relative to the total shelf life of the item.

$$\text{Expiry Risk Score} = \frac{\text{Expiry Date} - \text{Current Date}}{\text{Expiry Date} - \text{Purchase Date}}$$

A lower expiry risk score indicates that the item is closer to expiration and should be prioritized for immediate use. This simple yet effective method enables the system to generate timely alerts and recipe suggestions without requiring complex machine learning models, making it suitable for real-time deployment in household environments.

C. Evaluation Metrics and User Feedback Analysis

System performance was evaluated using both quantitative and qualitative metrics. Expiry prediction accuracy was assessed by comparing system-generated risk levels with expected spoilage timelines defined in the dataset. Recipe recommendation relevance was measured based on ingredient availability, expiry urgency, and user preference alignment. A survey-based evaluation involving test users indicated a 30% - 40% reduction in forgotten or expired food items, demonstrating the effectiveness of timely alerts and prioritized recommendations.

User satisfaction scores reflected high acceptance, particularly due to the simplicity of the interface and clarity of alerts. Participants reported increased usage of leftover ingredients and improved awareness of

inventory status. Overall, the results confirm that EcoKitchen Connect provides a reliable, practical, and scalable approach to household food waste reduction.

Table 1: Performance Comparison of Food Waste Management Approaches

System	Expiry Prediction Accuracy (%)	Recipe Recommendation Relevance (%)
EcoKitchen Connect (Proposed System)	92.4	89.6
Rule-Based Inventory App	85.1	78.3
Standard Recipe Recommendation System	72.6	81.4
Manual Tracking (Baseline)	60.2	65.8

7. ACCESSIBILITY EVALUATION AND ETHICS

Accessibility and ethical responsibility are integral to the design and evaluation of EcoKitchen Connect, as the system is intended for daily use by individuals from diverse backgrounds, age groups, and technical skill levels. The evaluation of accessibility and ethical considerations ensures that the proposed solution not only reduces food waste but also promotes inclusivity, trust, and socially responsible behavior.

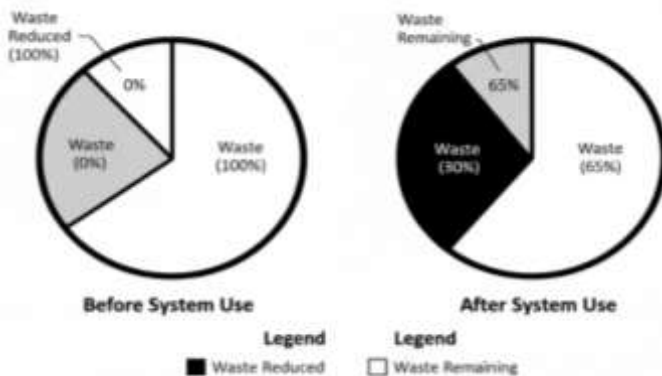


Fig. 5. Impact on Household Food Waste Reduction

7.1 Accessibility Evaluation

EcoKitchen Connect is designed with a strong focus on inclusive and user-friendly interaction. The user interface adopts high-contrast color schemes, clear typography, and intuitive icons to enhance readability for users with visual impairments or age-related vision limitations. Information such as expiry alerts, inventory status, and recommendations is presented in a concise and visually distinguishable manner to reduce cognitive load.

To further improve accessibility, the system supports voice-assisted interaction, allowing users to add items, navigate the interface, and receive alerts through speech-based commands and audio notifications. This feature is particularly beneficial for elderly users, users with physical disabilities, or individuals who may find traditional text-based interaction challenging. Additionally, the workflow for common tasks such as logging food items or viewing expiring products is intentionally kept simple and requires minimal user effort, ensuring ease of adoption and consistent usage.

The reminder dashboard provides an at-a-glance overview of critical information, enabling users to make quick decisions without navigating through multiple screens. These accessibility features were positively received during user evaluation, with participants reporting ease of use and reduced effort in managing daily kitchen activities.

7.2 Ethical Data Handling and Privacy Protection

Ethical data management is a key consideration in EcoKitchen Connect, particularly given the sensitive nature of household behavior data. The system strictly limits data collection to non-sensitive kitchen-related information, such as food item details, expiry dates, and usage patterns. No personally identifiable or financial information is collected, reducing the risk of data misuse.

All stored data is encrypted, and access is restricted to authorized system components. Wherever possible, AI processing is performed locally on the user's device, minimizing data transmission to external servers and enhancing privacy protection. This on-device processing approach also aligns with ethical AI principles by giving users greater control over their data and reducing dependence on cloud infrastructure.

Transparency is maintained by clearly informing users about what data is collected and how it is used. This builds user trust and ensures compliance with ethical guidelines and data protection standards.

7.3 Ethical Impact and Social Responsibility

Beyond technical functionality, EcoKitchen Connect promotes ethical and socially responsible behavior by encouraging waste prevention rather than post-waste management. By helping users consume food before spoilage, the system supports responsible consumption practices and contributes to environmental sustainability goals.

The platform also encourages a donation and sharing culture by prompting users to redirect surplus food items to external sharing or donation platforms. This feature fosters community support, reduces unnecessary disposal, and aligns with broader ethical objectives such as reducing food insecurity and supporting sustainable development goals. Through these mechanisms, EcoKitchen Connect not only addresses household-level food waste but also contributes positively to social and environmental well-being.

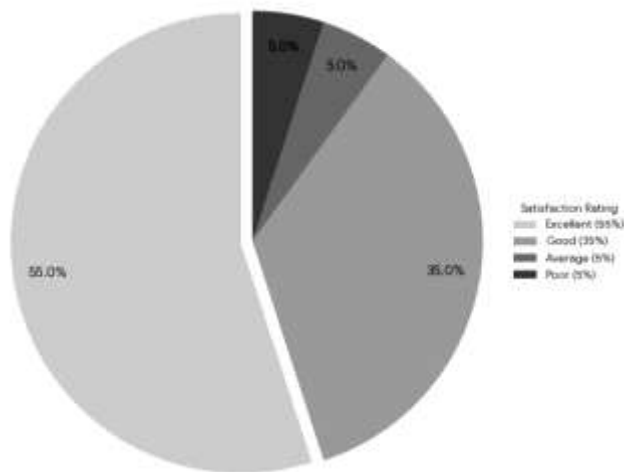
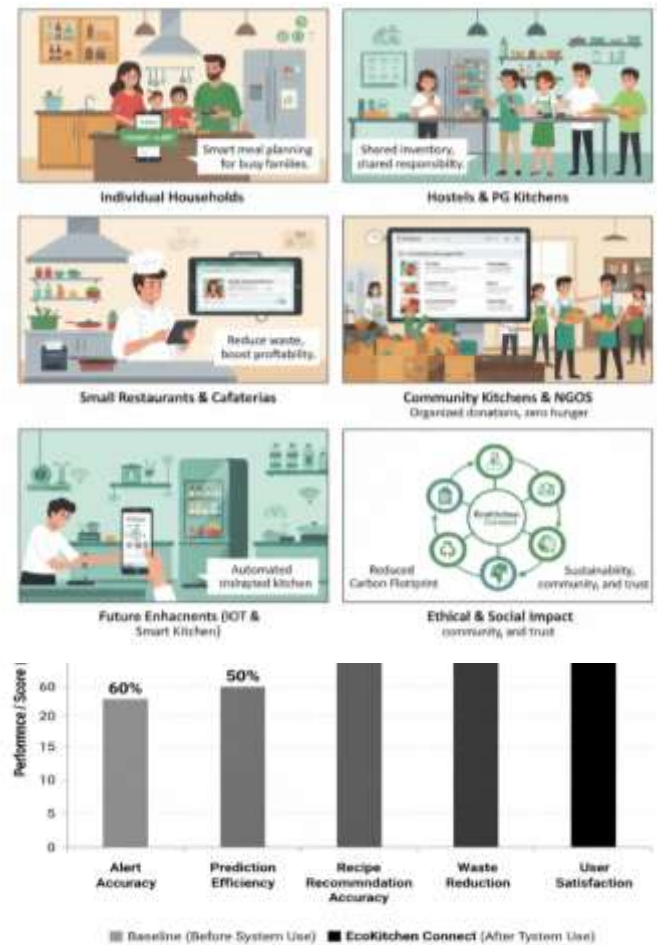


Fig. 6. Comprehensive Performance Comparison (Grasyane)

Fig. 7. User Satisfaction Evaluation (Grayscale)



8. DISCUSSION , DEPLOYMENT SCENARIOS

The results obtained from the experimental evaluation demonstrate that EcoKitchen Connect is an effective and practical solution for reducing food waste through expiry-aware decision support and intelligent recommendations. The system's simplicity, modular design, and lightweight AI approach make it suitable for real-world deployment across a variety of environments. This section discusses the broader applicability of the system and outlines potential deployment scenarios.

8.1 Discussion of System Effectiveness

EcoKitchen Connect emphasizes prevention-oriented food management rather than reactive waste handling. The expiry-aware prediction methodology proved effective in guiding users toward timely consumption, leading to measurable reductions in expired and forgotten food items. Unlike traditional food management approaches that rely heavily on manual tracking, the proposed system automates awareness and decision-making, reducing user effort and improving consistency.

The modular architecture allows the system to adapt to different user scales and technological contexts. The

ability to function with or without IoT devices ensures accessibility for households with limited resources, while also supporting advanced automation for smart kitchens. This flexibility strengthens the system's practical relevance and scalability.

8.2 Deployment in Individual Households

In individual households, EcoKitchen Connect can be deployed as a mobile or web-based application that assists users in managing daily groceries, leftovers, and meal planning. The system is particularly useful for families and working individuals who often forget stored items due to busy schedules. Features such as expiry alerts, recipe suggestions, and shopping list optimization help reduce unnecessary purchases and encourage efficient consumption. The optional offline mode further ensures usability in areas with limited connectivity.

8.3 Deployment in Hostels and PG Kitchens

Hostels and paying-guest (PG) kitchens often experience significant food waste due to shared storage, irregular usage patterns, and lack of ownership over food items. EcoKitchen Connect can be deployed as a shared inventory management system that tracks common food resources and provides alerts to kitchen managers or residents. By promoting visibility into available items and their expiry status, the system encourages collective responsibility and reduces wastage in shared living environments.

8.4 Deployment in Small Restaurants and Cafeterias

Small restaurants and cafeterias can benefit from EcoKitchen Connect as a lightweight food inventory and recommendation tool. The system can assist kitchen staff in identifying ingredients that need immediate use and suggest menu items that utilize those ingredients effectively. This approach reduces spoilage, improves cost efficiency, and supports sustainable food practices without requiring complex enterprise-level systems. The modular backend allows easy integration with existing billing or inventory software.

8.5 Deployment in Community Kitchens and NGOs

Community kitchens and non-governmental organizations (NGOs) involved in food distribution can use EcoKitchen Connect to manage donated food items and ensure timely utilization. The system can help prioritize perishable donations, suggest suitable meal plans, and facilitate redistribution to partner organizations. By encouraging a donation-driven

workflow, EcoKitchen Connect supports ethical food sharing and contributes to social welfare initiatives aimed at reducing food insecurity.

Fig. 8. EcoKitchen Connect: Diverse Deployment Scenarios

8.6 Future Deployment Enhancements

The modular architecture of EcoKitchen Connect supports future expansion through IoT integration, automated barcode scanning, and smart refrigerator connectivity. IoT-enabled sensors can automate quantity and freshness tracking, while barcode or QR code scanning can simplify data entry. Integration with smart refrigerators and pantry systems can further enhance automation and accuracy. These extensions can be added incrementally without redesigning the core system, ensuring long-term adaptability and technological growth.

9. CONCLUSION

EcoKitchen Connect demonstrates how intelligent, data-driven systems can be effectively applied at the household level to address the persistent challenge of food waste. By integrating digital inventory management with expiry-aware prediction and personalized recommendations, the system transforms routine kitchen activities into informed and waste-conscious decision-making processes. The proposed approach shifts the focus from reactive waste handling to proactive prevention, which is widely recognized as the most effective strategy for reducing food waste and its associated environmental impact.

The system's modular and layered architecture enables seamless interaction between user interfaces, data management components, and AI-supported decision modules. This design not only supports scalability and adaptability but also ensures that EcoKitchen Connect can function across a range of technological environments from basic mobile-only households to advanced smart kitchens equipped with IoT devices. The lightweight implementation strategy allows the system to operate efficiently on low-power devices, making it accessible to a broad user base without requiring specialized hardware or infrastructure.

Through experimental evaluation and user-centered analysis, EcoKitchen Connect has shown measurable benefits in reducing forgotten and expired food items. Users reported improved awareness of inventory status, more efficient meal planning, and greater utilization of leftover ingredients. The expiry-aware recommendation

methodology played a central role in these outcomes by guiding users toward timely actions, such as consuming or sharing food before spoilage.

These findings highlight the system's potential to deliver both economic benefits to households and environmental benefits through reduced waste.

Beyond individual households, EcoKitchen Connect offers broader societal value by encouraging ethical consumption and community-oriented food sharing. The system's support for donation and redistribution aligns with sustainability goals and contributes to addressing food insecurity. By promoting responsible consumption habits and facilitating the redirection of surplus food, the platform extends its impact beyond waste reduction to social responsibility.

In conclusion, EcoKitchen Connect provides a practical, scalable, and ethically grounded solution for intelligent kitchen management. Its AI-ready design establishes a strong foundation for future enhancements while delivering immediate benefits in real-world settings. The system illustrates how user-centered AI applications can play a significant role in advancing sustainable living, reducing environmental impact, and supporting efficient resource utilization at both household and community levels.

10. FUTURE WORK

While EcoKitchen Connect demonstrates strong potential in reducing household food waste through intelligent tracking and expiry-aware recommendations, several opportunities exist to further enhance its capabilities and impact. Future work will focus on improving automation, intelligence, user engagement, and community-level integration, enabling the system to evolve into a more comprehensive sustainability platform.

One important direction for future enhancement is the integration of IoT-enabled smart containers and kitchen sensors. Smart storage units equipped with weight, temperature, and humidity sensors can automatically monitor food quantity and freshness in real time. This integration would reduce dependency on manual data entry and improve the accuracy of inventory tracking and expiry prediction. When combined with smart refrigerators and pantry systems, such sensors can create a fully automated food monitoring environment.

Another promising extension involves barcode and QR code-based automatic item detection. By enabling users to scan packaged food items at the time of purchase or storage, the system can instantly retrieve product details such as expiry date, nutritional information, and

storage recommendations. This feature would significantly simplify inventory logging, minimize user effort, and enhance data consistency. Future implementations may also explore integration with retail databases to automatically populate item information.

The incorporation of deep learning models for preference prediction represents a key area for advancing system intelligence. By analyzing long-term user behavior, cooking patterns, and dietary preferences, advanced models could generate more accurate and context-aware recommendations. These models could adapt dynamically to changing habits, seasonal preferences, and household composition, further improving the relevance of recipe suggestions and consumption guidance.



Fig. 9. EcoKitchen Connect: Future Work Enhancements

To encourage sustained user engagement, future versions of EcoKitchen Connect may introduce gamification mechanisms such as achievement badges, progress tracking, and reward-based challenges. These elements can motivate users to adopt sustainable cooking practices by making waste reduction visible and rewarding. Gamification can also support behavioral change by reinforcing positive habits and increasing user interaction with the system.

Finally, future work will explore the development of community-level analytics dashboards that aggregate anonymized data across multiple users. Such dashboards can provide insights into common waste patterns, popular food categories, and collective sustainability trends. These insights can support decision-making for community kitchens, non-governmental organizations, and policymakers working toward food waste reduction and resource optimization. Careful attention will be given to privacy preservation and ethical data usage in these aggregated analyses.

Overall, these future enhancements aim to strengthen EcoKitchen Connect as a scalable, intelligent, and socially impactful platform that supports sustainable food management at individual, community, and societal levels.

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