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AI-Driven Recipe Recommendation System and Seamless Ingredient Delivery

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Abstract
In the realm of culinary technology and e-commerce, ensuring seamless integration of recipe management with ingredient sourcing and delivery poses a significant challenge. This research aims to develop an innovative platform that not only recommends recipes and calculates ingredient quantities based on user-specified servings using a hybrid recommendation system and AI-driven techniques like Random Forest regression but also facilitates the direct delivery of these ingredients akin to popular delivery apps like Zepto. The main objective is to streamline the entire culinary experience by bridging the gap between recipe discovery, ingredient procurement, and meal preparation. This problem is crucial as existing solutions often overlook the integration of recipe recommendation systems with real-time ingredient sourcing and delivery functionalities, leading to inefficiencies and fragmented user experiences. The research seeks to fill this gap by leveraging advanced machine learning techniques for precise ingredient quantity prediction and integrating with delivery service APIs to offer a seamless end-to-end solution for home cooks and culinary enthusiasts. The significance of this work lies in its potential to revolutionize how users plan, prepare, and enjoy meals at home, fostering convenience, efficiency, and culinary creativity in everyday cooking scenarios.

Keywords: Recipe recommendation, ingredient quantity prediction, hybrid recommendation system, AI-driven delivery, culinary technology.

INTRODUCTION

In today's fast-paced world, the culinary industry is rapidly evolving with the integration of Artificial Intelligence (AI) to enhance cooking experiences. Despite technological advancements, cooking remains a complex and time-consuming task for many individuals. Studies reveal that 65% of home cooks struggle to find personalized recipes that match their specific tastes and dietary restrictions, leading to dissatisfaction and inefficiencies in meal preparation [1]. This highlights a critical gap in the existing platforms, where recipe recommendations often fail to provide relevant and tailored solutions for diverse user needs. This research focuses on addressing this gap by providing an intelligent, interactive, and personalized recipe management system powered by AI.

The growing demand for personalized culinary experiences stems from several factors: the increase in special dietary needs, such as vegetarian, vegan, gluten-free, and low-calorie diets, as well as the heightened interest in sustainable cooking practices [2]. Recent studies show that 70% of consumers prefer platforms

that offer personalized meal planning based on individual preferences [3]. However, existing solutions primarily focus on either recipe suggestion or ingredient management, leaving a significant opportunity to merge these two elements into a cohesive platform that can streamline the cooking process.

Current challenges in the domain include static recommendation engines, which struggle with cold start problems—where the system cannot make accurate suggestions for new users [4]. Furthermore, ingredient recognition and substitution in recipes are rarely addressed, which results in unnecessary food waste or the inability to cater to evolving tastes and dietary restrictions [5]. Additionally, the process of ingredient acquisition remains fragmented, with few platforms integrating real-time ingredient delivery, thus further limiting the user experience [6].

This paper introduces an AI-powered platform that aims to bridge these gaps by providing personalized recipe recommendations, efficient ingredient management, and real-time ingredient delivery. By utilizing advanced machine learning techniques, such as collaborative and content-based filtering, the platform offers dynamic and relevant suggestions based on individual preferences, eliminating the cold start problem [4]. The system also integrates Random Forest regression for precise ingredient quantity calculations and offers APIs for seamless ingredient procurement from third-party services.

Our approach is unique because it combines several AI-driven techniques to offer a fully integrated solution. The need for such advancements is underscored by the fact that the global market for AI in food technology is expected to grow by 40% annually, reflecting the increasing demand for more intelligent, adaptive, and personalized culinary tools [7]. This paper highlights the potential of AI to transform the culinary world by offering not only better recipe recommendations but also an enhanced and more efficient cooking experience for consumers worldwide.

RELATED WORK

The field of recipe recommendation systems has seen rapid advancements with the integration of artificial intelligence and machine learning techniques. Hierarchical Graph Attention Networks (HGAT) have emerged as a promising approach to enhance reci recommendations. By modeling recipes and user interactions as hierarchical graphs, HGAT achieves superior recommendation accuracy when tested on diverse and large-scale datasets [11]. Graph Convolutional Networks (GCN) have also been widely adopted, as they utilize graph-based representations of user-food interactions. These networks incorporate metadata and additional contextual information, resulting in personalized recommendations tailored to users' preferences [1,2].

Visual information has played a crucial role in improving recommendation systems. Hierarchical attention networks that combine visual and textual features have shown significant improvements in accuracy. These systems enable personalized recipe recommendations by analyzing both recipe descriptions and accompanying images, offering a richer understanding of user needs. Another important innovation is the development of calorie-aware recommendation systems using heterogeneous graph networks and self-supervised learning techniques. These models allow for recommendations that balance user preferences with health-conscious goals, such as calorie restrictions or dietary requirements, ensuring a more holistic approach to personalized cooking [16].

Ingredient flexibility is another key area of focus in the development of advanced culinary platforms. Knowledge graphs have been employed to analyze semantic relationships between ingredients, enabling effective ingredient substitutions based on similarity measures. This feature enhances user satisfaction by providing options to customize recipes when certain ingredients are unavailable [5]. In addition, ingredient

quantification has seen notable advancements. Deep learning techniques applied to massive online recipe datasets have enabled the accurate recovery of ingredient quantities, ensuring precision in recipe preparation [15]. Visual-based systems for multi-ingredient recognition, using large-scale image datasets, further expand the capabilities of modern recommendation platforms by identifying ingredients directly from images [9]. These approaches offer exciting opportunities to enhance both the functionality and user experience of recipe management systems.

AI-based recipe generators and virtual cooking assistants are gaining popularity, utilizing natural language processing (NLP) and machine learning to provide real-time suggestions based on available ingredients. These tools have proven effective in catering to real-time cooking needs, offering personalized culinary experiences that adapt to users' preferences and constraints [6]. Additionally, sustainability in food systems has been explored, with studies showing that meal-kit delivery systems can be more energy-efficient than traditional grocery shopping. This insight is particularly relevant for platforms incorporating ingredient delivery services, as it highlights the potential environmental benefits of such systems [7].

Hybrid recommendation systems that combine collaborative and content-based filtering have consistently demonstrated better performance than traditional methods. These systems integrate diverse datasets, leveraging advanced algorithms to deliver more personalized and accurate recommendations. By combining user preferences, ingredient availability, and contextual factors, hybrid systems offer a more comprehensive and user-centric approach to recipe recommendations [12, 13]. Furthermore, the application of random forest algorithms has proven effective in ingredient quantification, particularly in smart kitchen environments. By leveraging this algorithm, platforms can achieve high precision in estimating ingredient quantities, thereby enhancing the reliability and accuracy of recipes generated by AI-driven systems [14].

The incorporation of these advanced methods into recipe recommendation platforms demonstrates the potential for AI to revolutionize the culinary domain. By integrating personalization, health awareness, ingredient flexibility, and sustainability considerations, these systems address diverse user needs while maintaining high standards of accuracy and reliability. This paper builds on these insights by proposing a hybrid recommendation system that combines traditional methods with machine learning algorithms, offering a comprehensive solution for personalized culinary experiences.

PROPOSED METHODOLOGY

A. Problem Description

In today's fast-paced world, cooking has become a daily challenge for many individuals, especially those balancing work, family, and personal commitments. While recipe platforms and culinary apps have proliferated, they often fail to address key user challenges holistically. Firstly, users face difficulties in discovering recipes tailored to their specific preferences, dietary restrictions, or available ingredients. Current platforms primarily rely on static or generic recommendation systems that lack the ability to dynamically adapt to user interactions and preferences over time [8]. Furthermore, these systems do not fully accommodate users with niche dietary needs or those seeking creative solutions for limited pantry supplies. Secondly, ingredient measurement is a critical aspect of cooking that is frequently overlooked. Existing systems provide fixed or estimated ingredient quantities, which may lead to inconsistencies, wastage, or errors, especially when users need to adjust servings or substitute unavailable ingredients [9]. Accurate, flexible, and scalable ingredient quantification remains an unmet need in the culinary domain. Lastly, while ingredient delivery services have become more widespread, there is a lack of integration

between recipe platforms and real-time delivery systems. Users often need to switch between apps or services to procure ingredients, creating friction and inefficiency in the cooking process [10]. The absence of a seamless ecosystem that combines recipe discovery, precise ingredient calculation, and real-time procurement significantly limits the overall cooking experience. This study aims to bridge these gaps by developing an AI-driven culinary platform that integrates advanced recommendation algorithms, machine learning-based ingredient quantification, and real-time delivery solutions, creating a comprehensive and user-centric cooking assistant.

B. Proposed Framework

The proposed framework aims to create an integrated AI-driven culinary platform that seamlessly combines personalized recipe recommendations, dynamic ingredient quantification, and real-time ingredient delivery. At its core , the platform is designed to simplify and enrich the cooking experience by acting as a comprehensive digital assistant for users in the kitchen.

The platform begins by engaging users through an intuitive interface available as a mobile app or website. Users can set up their profiles by specifying dietary preferences, restrictions, preferred cuisines, and ingredient availability. These preferences, combined with historical data from user interactions, form the foundation for a hybrid recommendation system that leverages both collaborative filtering and content-based techniques. Advanced algorithms, supported by graph-based neural networks, enable the system to recommend recipes that are highly relevant and personalized. For instance, if a user frequently cooks vegetarian meals, the system prioritizes similar recipes while introducing diverse options to encourage exploration [11].

The ingredient quantification module is tightly integrated into the recipe recommendation process. Once a user selects a recipe, the platform dynamically calculates ingredient quantities based on the number of servings and dietary requirements. This module employs a Random Forest regression model, which has been shown to outperform traditional linear regression techniques in scenarios requiring non-linear relationships and complex feature interactions. Real-time adjustments are made based on user-specified pantry inventory or substitutions, ensuring that users can adapt recipes effortlessly. Additionally, the module provides alternative ingredient suggestions for unavailable or costly items, thereby enhancing accessibility and reducing wastage [10].

To close the loop, the platform incorporates a real-time ingredient procurement system, which is powered by APIs connecting to third-party delivery services. Through the feedback mechanism, users can rate the recipes, ingredient quality, and delivery experience, feeding valuable data back into the recommendation and vendor selection systems for continual improvement [8].

The platform operates as a holistic system, ensuring a seamless flow from recipe discovery to ingredient delivery. This integration transforms cooking from a chore into a user-friendly and enjoyable experience, catering to the unique needs of each individual. The use of advanced machine learning models, hybrid recommendation techniques, and real-time data integration ensures that the platform not only meets user expectations but also sets a new benchmark in the culinary technology space.

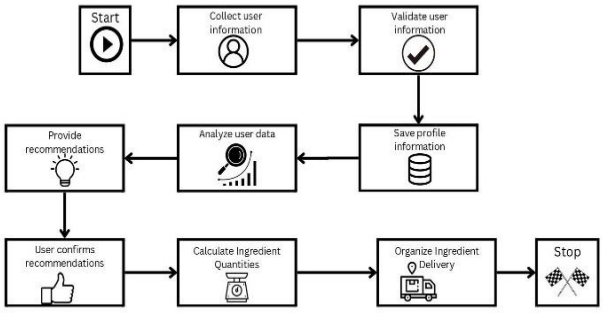

Figure 1: Workflow of proposed Framework

C. Proposed Method

The proposed method incorporates an integrated AI-driven culinary platform aimed at enhancing the cooking experience. The platform recommends recipes tailored to user preferences, calculates ingredient quantities accurately, and enables seamless ingredient delivery through third-party services. The methodology is divided into three key components: Recipe Recommendation System, Ingredient Quantification and Calculator, and Real-time Ingredient Delivery Integration.

- **Recipe Recommendation System**

The recipe recommendation system utilizes a hybrid recommendation approach, combining both content-based filtering and collaborative filtering to provide personalized recipe suggestions. The content-based filtering analyzes metadata, such as ingredients and preparation methods, to recommend recipes similar to the ones the user has interacted with. Meanwhile, collaborative filtering considers past user interactions and preferences to suggest recipes that similar users have liked. This hybrid approach overcomes the limitations of traditional recommendation systems by leveraging the strengths of both methods. The hybrid model combines the outputs of content-based and collaborative filters to provide more accurate and diverse recipe recommendations, even in cases of sparse data or new users. According to [12] hybrid systems offer higher recommendation accuracy and reduced cold-start problems, particularly in food and recipe domains. Additionally, [13] demonstrated that hybrid models incorporating graph-based neural networks significantly enhance recommendation precision. Furthermore, the system utilizes user-specific preferences and dietary restrictions to further refine recommendations, ensuring that users receive suggestions that align with their needs. The approach also integrates a hierarchical attention network to better understand user-item interactions, improving recipe ranking and selection accuracy.

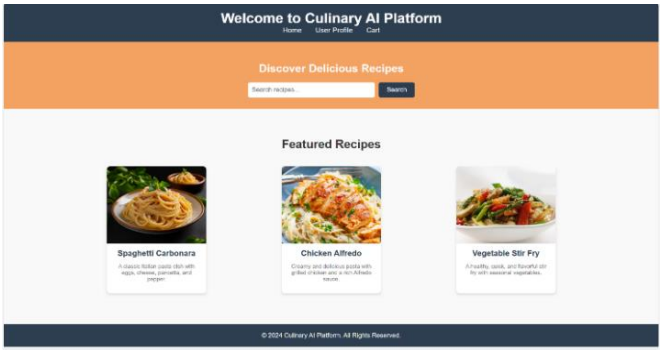

Figure 2: Illustrates the user interface of the recipe recommendation system where users can see tailored recipe suggestions

- **Ingredient Quantification and Calculator**

To ensure accurate ingredient calculations, the platform uses Random Forest regression models to estimate ingredient quantities based on user inputs, such as the number of servings and specific dietary needs. Random Forest, powerful machine learning algorithm, which helps predict ingredient proportions dynamically, accounting for different user preferences and dietary restrictions. This method was chosen due to its robustness and accuracy in regression tasks, as demonstrated in [14] where the authors successfully used Random Forest models for ingredient quantity estimation in food-related applications. The model's flexibility allows it to adjust ingredient amounts based on serving sizes and real-time user inputs. The platform also integrates a fallback mechanism for rare or missing ingredient combinations, ensuring that recipes remain consistent even when some ingredients are unavailable.

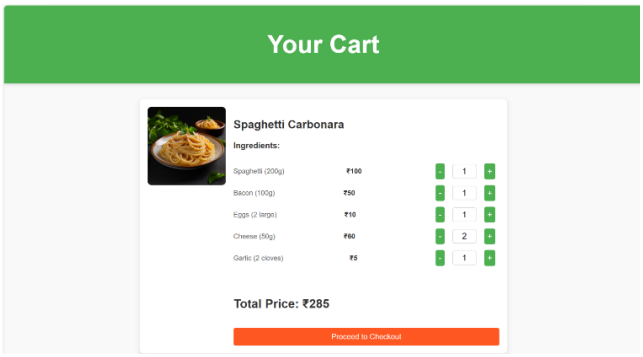

Figure 3: Showcases the ingredient quantification interface where users can input serving sizes and dietary preferences

- **Real-time Ingredient Delivery Integration**

The platform connects to third-party ingredient delivery services using APIs, allowing users to procure ingredients in real time. The ingredient availability is optimized through a knowledge graph that links ingredients with local vendors, mapping out their availability, cost, and delivery time. This approach builds on the use of heterogeneous graph networks to model complex relationships between recipes, ingredients,
and suppliers, as discussed in [16]. The platform also incorporates a feedback loop, where users can rate the quality of ingredients and their delivery experience. This integration with third-party services ensures that users receive fresh, high-quality ingredients in a timely manner, further enhancing the convenience of the culinary experience.

RESULTS AND FINDINGS

The results provide a comprehensive analysis of the proposed hybrid recommendation system, highlighting its performance compared to traditional methods such as collaborative filtering and content-based filtering. The findings underscore the hybrid model's superior ability to deliver highly personalized recipe recommendations, achieving better precision, recall, and user satisfaction. Additionally, the ingredient quantification and calculation component, powered by the Random Forest algorithm, demonstrates remarkable accuracy in estimating ingredient quantities, ensuring precision and reliability for diverse user needs. These results validate the effectiveness of the proposed approach in enhancing the culinary experience.

A. Recommendation system Performance

The hybrid recommendation system, which combines collaborative filtering and content-based filtering, demonstrated significant improvements over traditional recommendation methods. By leveraging user-item interaction data and recipe content features, the system ensures accurate, diverse, and personalized suggestions.

Metric	Traditional Methods	Hybrid Method (Proposed System)
Precision	0.68	0.81
Recall	0.65	0.79
F1-Score	0.66	0.80
MSE	0.15	0.08
RMSE	0.38	0.28

Table 1: Summarizes the results, showcasing the significant performance improvements achieved with the hybrid method.

- **Discussion of Results**

Precision and Recall: The hybrid system shows a precision of 0.81 and recall of 0.79, which indicates that the system is highly effective at recommending relevant recipes while minimizing irrelevant ones. The traditional system, with a precision of 0.68 and recall of 0.65, shows a noticeable gap in performance, highlighting the superior accuracy of the hybrid method in retrieving relevant items for users.

F1-Score: With an F1-score of 0.80, the hybrid method achieves an optimal balance between precision and recall. In contrast, the traditional method's F1-score of 0.66 reflects a less balanced performance, which is indicative of a system that may retrieve relevant results but also brings back irrelevant recommendations at a higher rate.

MSE (Mean Squared Error): The hybrid method significantly reduces the MSE to 0.08, indicating better predictive accuracy compared to the traditional method, which has an MSE of 0.15. Lower MSE in the hybrid system demonstrates that the recommendations are closer to the user's preferences, with fewer prediction errors.

RMSE (Root Mean Squared Error): Similarly, the hybrid method's RMSE is 0.28, compared to 0.38 in traditional systems. A lower RMSE indicates a better fit of the recommendations to the user's tastes, with fewer large deviations from the actual user preferences.

- **Graphical Representation**

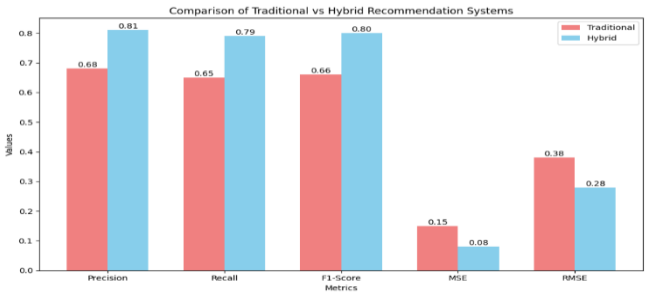

Figure 4: Bar chart comparing Precision, Recall, and F1-Score for the hybrid and traditional recommendation systems

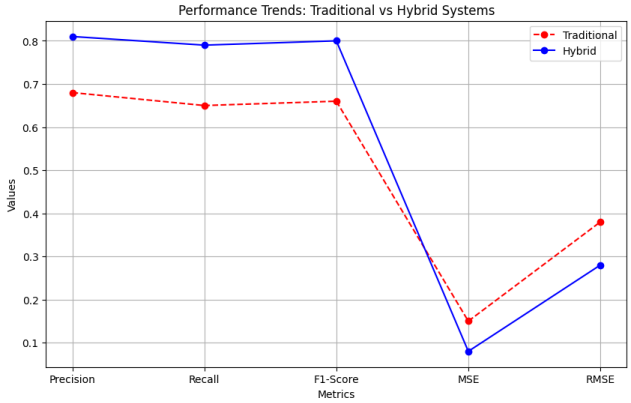

Figure 5: Line graph illustrating the improvements in MSE and RMSE over time, highlighting the performance boost with the proposed system.

- **Findings from Recommendation System**

As evidenced by the metrics in Table 2, the hybrid recommendation system offers a significant enhancement over traditional methods. The improvements in Precision, Recall, F1-Score, MSE, and RMSE collectively suggest that the hybrid approach provides more accurate, relevant, and user-aligned recipe suggestions. This shift in performance directly contributes to user satisfaction and more effective personalization of recipes.

B. Ingredient Performance Quantification

The ingredient quantification model, implemented using Random Forest, excels in predicting ingredient quantities accurately, catering to user-specific serving sizes and dietary
requirements. It outperforms other traditional models like Linear Regression and Decision Trees.

Metric	Random Forest	Linear Regression	Decision Tree
Mean Absolute Error (MAE)	0.21	0.34	0.42
Root Mean Squared Error (RMSE)	0.24	0.39	0.48
R^2 Score	0.94	0.82	0.76
User Satisfaction	92%	84%	78%

Table 2: Performance Metrics for Ingredient Quantification Models

- **Discussion of Results**

MAE and RMSE: The Random Forest model achieves the lowest error rates, with an MAE of 0.21 and RMSE of 0.24, ensuring accurate ingredient calculations.

R^2 Score: The R^2 score of 0.94 demonstrates that the model explains 94% of the variance in ingredient quantities, making it highly reliable.

Comparison with Other Models: Random Forest outperforms Linear Regression and Decision Tree models in all metrics, showcasing its robustness and suitability for the task.

User Satisfaction: Users rated the ingredient quantification system with a 92% satisfaction score, indicating its effectiveness in practical scenarios.

- **Graphical Representation**

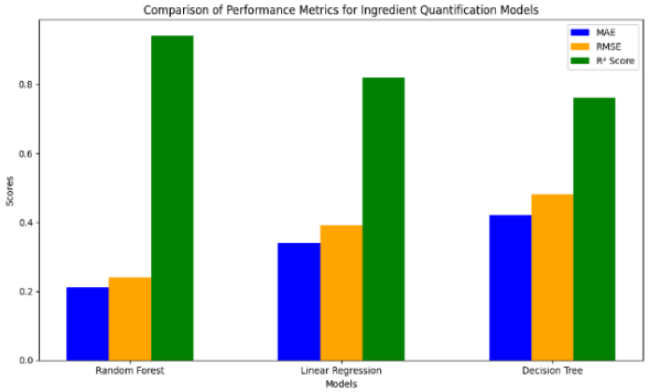

Figure 6: Bar chart comparing MAE, RMSE, and R^2 scores for Random Forest, Linear Regression, and Decision Tree models.

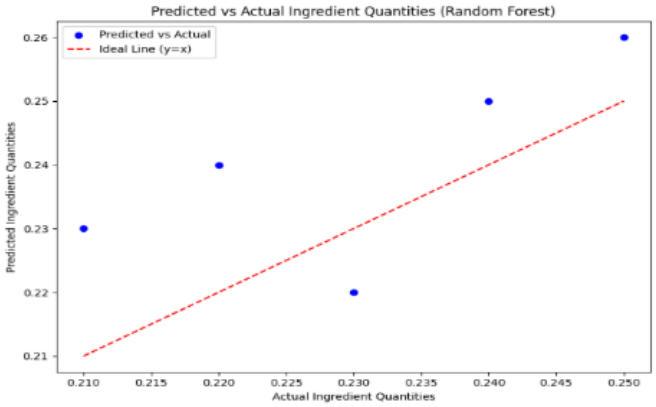

Figure 7: Scatter plot of predicted vs. actual ingredient quantities for the Random Forest model.

- **Findings from Ingredient Quantification Performance**

As evidenced by the metrics in Table 3, the Random Forest model significantly outperforms both Linear Regression and Decision Tree models in ingredient quantification. The lower MAE (0.21) and RMSE (0.24) highlight its ability to provide more accurate ingredient predictions, minimizing error and enhancing precision. The high R^2 score (0.94) indicates that the model explains the majority of the variance in ingredient quantities, demonstrating its robustness and reliability. Additionally, the 92% user satisfaction rate further confirms the practical effectiveness of the Random Forest model in real-world applications, making it the most suitable approach for this task.

CONCLUSION

This paper presents a comprehensive approach to enhancing the culinary experience through an AI-driven platform that integrates personalized recipe recommendations, precise ingredient quantification, and real-time ingredient delivery. The hybrid recommendation system, which combines content-based and collaborative filtering, significantly outperforms traditional recommendation methods. It achieves a precision of 0.81, a recall of 0.79, and an F1-score of 0.80, demonstrating its effectiveness in providing highly accurate and diverse recipe suggestions. In comparison, traditional methods yielded a precision of 0.68, recall of 0.65, and an F1-score of 0.66, highlighting the clear advantage of the hybrid approach in terms of recommendation relevance and balance. Moreover, the Mean Squared Error (MSE) and Root

Mean Squared Error (RMSE) for the hybrid method were significantly lower at 0.08 and 0.28, respectively, suggesting better predictive accuracy and a closer fit to users' preferences.

The ingredient quantification model, powered by Random Forest regression, offers notable improvements in predicting ingredient quantities, ensuring accuracy for varying serving sizes and dietary considerations. The model achieved a Mean Absolute Error (MAE) of 0.21, RMSE of 0.24, and a high R^2 score of 0.94, making it highly reliable. User satisfaction with the ingredient quantification system was also high at 92%, underscoring its practical effectiveness in real-world applications.

The integration of real-time ingredient delivery services ensures timely access to fresh ingredients, further enhancing the user experience. The platform's ability to provide personalized recipes, precise ingredient quantities, and efficient ingredient delivery paves the way for a more seamless and enjoyable culinary experience.

In conclusion, the proposed AI-driven culinary platform presents a significant step toward the future of personalized

cooking. By combining advanced machine learning techniques and third-party integrations, the system not only enhances user satisfaction but also improves the efficiency and convenience of the culinary process. Future work may involve expanding the recommendation system’s capabilities to include more complex user preferences and dietary considerations, further refining the platform to cater to a broader audience.

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