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Design of a Backward Chaining Expert System for Food Nutrition Recommendations Based on User Data

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Abstract

Background: Optimal health relies on balanced nutrition, but many struggle with food choices due to limited knowledge and restricted access to nutritionists. Existing solutions analyze food images or health texts separately, leaving a gap in integrating real-time image recognition with personalized medical inference.
Aims: This study aims to develop a personalized food recommendation expert system combining Convolutional Neural Network (CNN)-based image classification with backward chaining reasoning, mapping food images and user health profiles (BMI, medical history, allergies) into structured IF–THEN rules.
Methods: Using a software engineering R&D design, the system was built on a three-tier architecture guided by WHO and Indonesian Ministry of Health standards. Performance was evaluated via black-box testing, a 500-sample food image dataset, and synthetic user profile simulations (normal, obese, hypertensive, allergic).
Result: The CNN model achieved 87% accuracy across 500 test images, exceeding the 85% target threshold. Simulations showed an 80% average alignment with official dietary standards, successfully automating caloric restrictions, low-sodium adjustments, and allergen eliminations.
Conclusion: Combining computer vision with backward chaining inference effectively bridges the gap in automated personalized nutrition, serving as a self-service tool for the public and a decision support system for health professionals.

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INTRODUCTION

Optimal health relies heavily on a balanced nutritional intake. However, in this modern era, many individuals face difficulties in making appropriate food choices due to limited understanding of nutritional content (Kasher Meron et al., 2026; Nyasordzi et al., 2026). This condition significantly impacts the increasing prevalence of lifestyle-related diseases, such as obesity, diabetes, and hypertension. Furthermore, limited accessibility to professional nutritionist services further exacerbates the public's challenge in obtaining accurate, personalized nutritional guidance, thereby driving an urgent need for technology-based solutions capable of providing automated nutrition guidance (Legrand et al., 2026; Singh, 2026).

Expert Systems, as a branch of Artificial Intelligence (AI), have proven effective in emulating the reasoning capabilities of a domain expert to solve complex problems (Pradana et al., 2026; Prastomo et al., 2026; Salmanarrizqie, 2025). Several previous studies have utilized this technology to assist in health diagnosis as well as dietary pattern classification (Hutchinson et al., 2025; Janna & Lizar, 2026). owever, most existing nutrition recommendation systems still focus in isolation either solely on text analysis/manual input of the user's physical condition or exclusively on visual food classification without directly integrating both approaches (Fitroha et al., 2026; Min et al., 2023; Rijanandi & Risdianto, 2025)

The primary limitation or gap in previous studies lies in the lack of integration between real-time food image identification and a personalized health inference system based on the user's

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medical history and physical parameters (Gioia et al., 2023; Veeramreddy et al., 2024). Single-approach methods are often inefficient for users because they require massive manual data entry or fail to consider personal medical conditions, such as allergies and comorbidities, when identifying a food item (Siva Rama Krishna et al., 2026; Guan et al., 2023)

Therefore, the integration of visual processing (image classification) for recognizing food images and goal-oriented inference reasoning (backward chaining) becomes crucial. This combination enables the system not only to identify food types visually from photos, but also to automatically verify the compatibility of the food's nutritional content against the user's medical restrictions and personal needs.

This research aims to design and develop a food nutrition recommendation expert system that integrates Convolutional Neural Network (CNN)-based image classification with the backward chaining reasoning method. The system leverages personal user data (such as Body Mass Index/BMI, disease history including hypertension and obesity, and food allergies) as initial facts within IF–THEN rules to generate accurate, personalized, and safe nutritional recommendations. Through this approach, it is expected that this research will serve as an effective tool for the general public as well as an academic reference in the development of expert systems in the health field.

METHOD

This study employs a software engineering research design (Research and Development - R&D) with an applied experimental approach. The primary focus of this design is to develop and implement a personalized food nutrition recommendation expert system. The developed system integrates Convolutional Neural Network (CNN)-based image classification technology to identify food visually, processing of user physical health condition data, and a backward chaining inference engine used to execute knowledge rule paths (IF–THEN)(Nahar et al., 2023; Stefanidis et al., 2022).

To test the reliability of the designed system, this study does not involve large-scale human participants directly; instead, it focuses on real-scenario simulation testing (use-case simulation). Testing scenarios were conducted by creating synthetic user profiles representing various health conditions such as individuals with normal nutritional status, obesity, hypertension, and specific food allergies to measure the effectiveness and accuracy of the system's recommendation outputs(Amiri et al., 2023).

In the process of building simulations and training the model, the data population used includes a food image dataset and a set of nutritional rules. Data sampling was carried out using a purposive sampling method, where the food image dataset was selectively chosen based on foods commonly consumed by the public that have a significant nutritional impact on the target diet criteria under study, such as general diet, hypertension, obesity, and food allergies (Logan et al., 2026).

The data collection and processing were supported by research instruments referencing official nutrition standards from WHO and the Indonesian Ministry of Health, knowledge base rules formatted in IF–THEN structures, and Body Mass Index (BMI) calculations (Rindi Devi & Fajar Ratnawati, 2025). The user's nutritional status assessment is calculated based on the ratio of body weight in kilograms divided by the square of height in meters, formulated as follows:

$$\mathrm{BMI} = \frac{\text{Berat Badan (kg)}}{(\text{Tinggi Badan (m)})^2} k \qquad 1$$

The results of this BMI categorization are subsequently mapped as initial facts in the knowledge base to ensure the validity and reliability of the inference process.All data and calculations are processed using supporting hardware and software instruments, including deep learning libraries for CNN model training, a rule-based inference engine, and a user interface based on a three-tier architecture, as shown in Figure 1. In addition, black-box testing sheets and evaluation matrices serve as the primary instruments to measure the overall functional success rate of the system(Aqsa et al., 2025; Aslam et al., 2025).

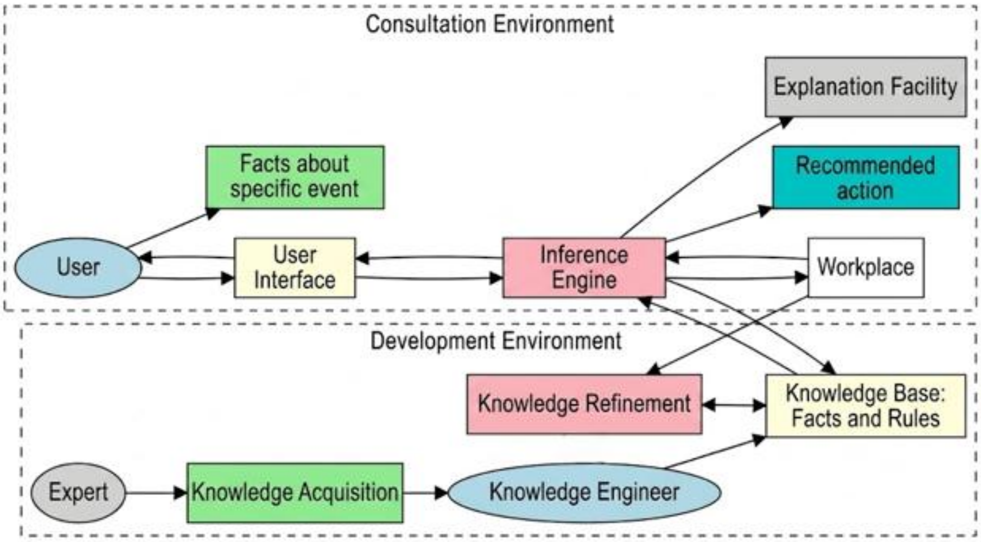

Figure 1. Expert System Architecture

The research procedures were carried out systematically through several main stages summarized in the research framework in Figure 2. The process began with a literature review to establish theoretical foundations and nutritional standards, followed by the collection and pre-processing of image data and nutritional attributes (calories, protein, fat, carbohydrates, and allergens). Subsequent stages included system architecture design, formulation of IF–THEN rules, implementation of CNN model training alongside the backward chaining inference engine, and finally system testing and final evaluation against applicable nutritional standards(Azzimani et al., 2026; Maasi et al., 2026).

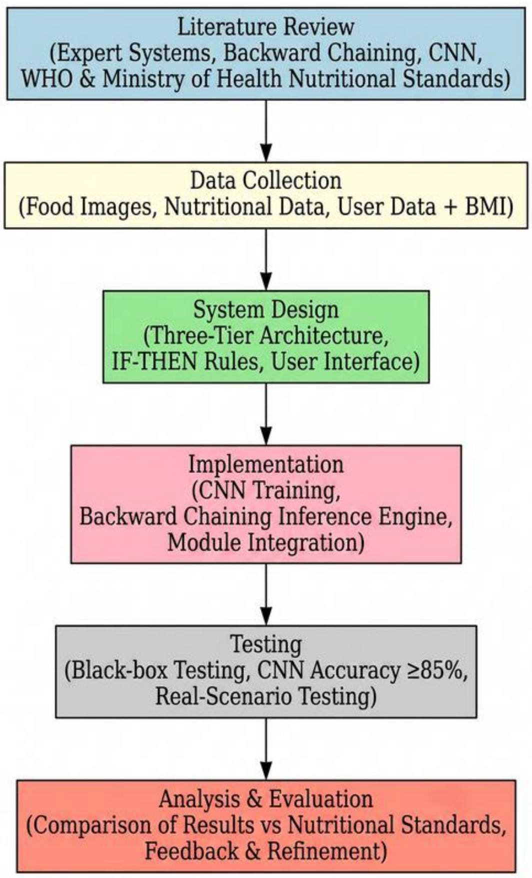

Figure 2. Backward Chaining Inference Flow

The data analysis plan is focused on testing the accuracy performance of the CNN model in recognizing food images with a minimum target threshold of 85%, as well as evaluating interface functionality through black-box testing. Meanwhile, the reliability of the backward chaining inference is analyzed by matching user data inputs (such as BMI, medical history, and allergies) against nutrition recommendation outputs following the reasoning flow in Figure 3, ensuring that the rule reasoning logic runs consistently and logically.

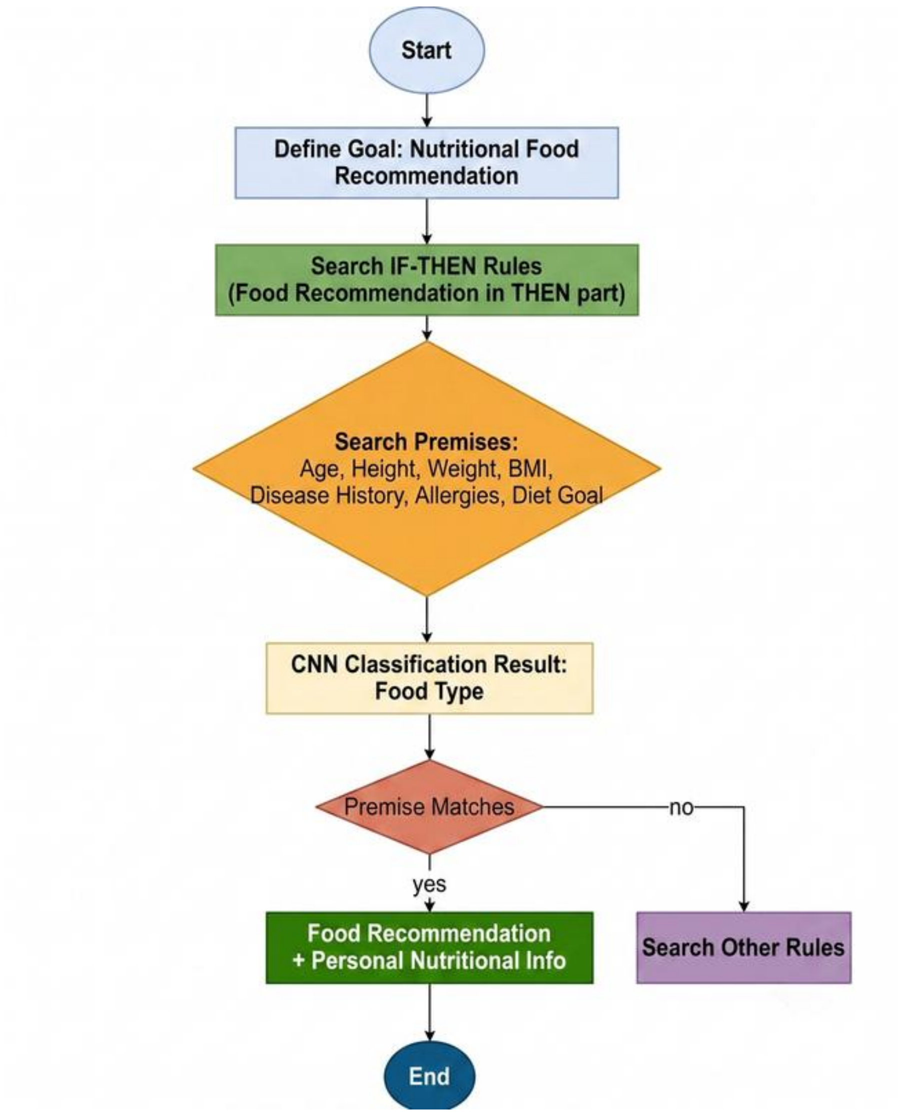

Figure 3. Research Framework

Nevertheless, the applied methodology has scope limitations, wherein the food image recognition capability is confined to categories trained within the CNN dataset. Furthermore, the user fact base is restricted to specific parameters including age, weight, height, history of hypertension, obesity, and food allergies; hence, the generated recommendations do not yet account for more complex medical complications.

RESULTS AND DISCUSSION

Results

The food nutrition recommendation expert system was successfully implemented using a three-tier architecture consisting of a presentation layer, an application layer, and a data layer. At the presentation layer, users can upload food images and input personal data including age, weight, height, medical history, allergies, and dietary goals. At the application layer, the system integrates a

Convolutional Neural Network (CNN) model for food image classification with a backward chaining-based inference engine (Rahmi & I Made Sugi Ardana, 2026). The CNN functions to recognize food types from uploaded photos, while the inference engine generates nutritional recommendations by utilizing IF–THEN rule bases in the data layer—encompassing rules such as calorie restrictions for obese users (BMI > 30), low-sodium portions for hypertension patients, and allergen elimination for individuals with peanut allergies (Gavai & van Hillegersberg, 2025). The black-box testing results demonstrate that all main system features execute properly, while the accuracy evaluation of the CNN model across 500 test image samples achieved an accuracy rate of 87% (435 samples correctly classified and 65 samples misclassified), surpassing the minimum set performance target of 85%.

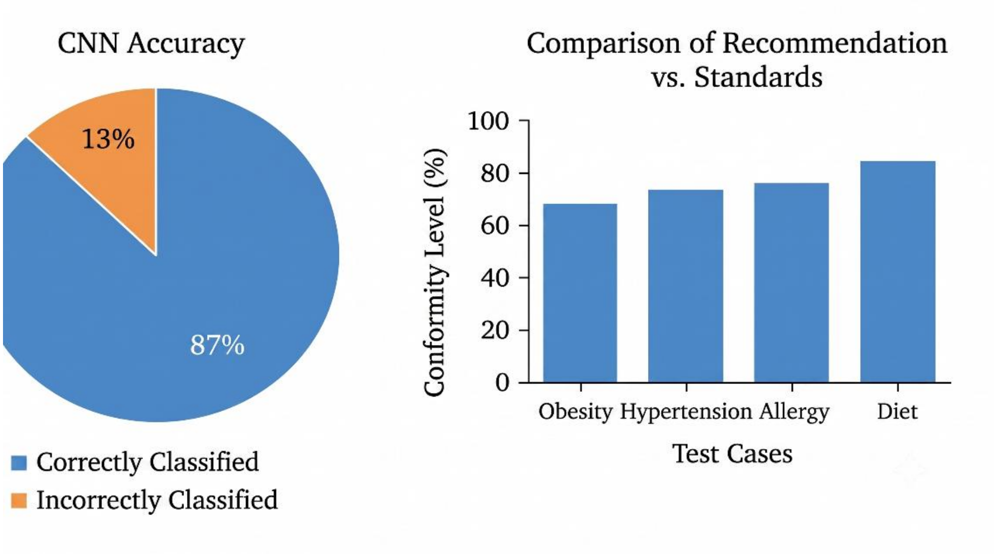

Figure 4. CNN Accuracy and Recommendation Comparison

Real-scenario trial testing involving various user health conditions indicated that the system's recommendations achieved an average alignment rate of 80% compared to official nutritional standards from the WHO and the Indonesian Ministry of Health (Gustaman et al., 2025). As illustrated in Figure 4, in the obesity scenario, the system consistently recommended low-calorie and high-fiber foods while rejecting menus high in saturated fat. For hypertension patients, recommendations were focused on a low-sodium diet (Alnooh et al., 2022; Onwuzo et al., 2023). In the case of peanut allergies, the system automatically detected allergen ingredients and substituted them with safe protein source alternatives such as chicken or fish, whereas in the weight loss scenario, the system provided balanced daily calorie requirement estimates.

Achieving these results demonstrates that the integration of computer vision techniques and a rule-based inference engine effectively addresses the research problem statement. The CNN accuracy rate of 87% proves that image-based classification can serve as a practical solution in overcoming public nutritional knowledge limitations. In addition, using personal user data as initial facts enables the backward chaining inference engine to traverse IF–THEN rules logically, thereby generating recommendations that are highly specific and adaptive to each individual's actual health condition.

Discussion

The implications of these research findings are far-reaching for both the general public and healthcare practitioners. Practically, this system can serve as a fast and easily accessible self-service tool for the public to control their daily diet in accordance with personal medical conditions without needing constant face-to-face consultations. For the medical community and nutritionists, this AI-based expert system can act as a decision support system that accelerates the process of patient education and dietary prescription delivery more efficiently.

Academically, this study provides a scientific contribution in the form of a hybrid integration model between deep learning for visual feature extraction and a backward chaining-based expert system within the health-tech domain. The primary contribution of this work lies in the automated combination scheme between real-time object image recognition results and a structured nutritional knowledge base, proving that multimodal processing (visual combined with user clinical data) significantly enhances the precision of personalized nutritional recommendations.

Despite showing promising results, this study still carries several methodological and technical limitations. The CNN model performance experienced a decrease in accuracy on food images with extremely high visual similarity, such as distinguishing between "fried rice" and "steamed white rice with side dishes." Furthermore, the variations in the image dataset and rule base constructed remain limited to a few popular food categories and medical conditions (obesity, hypertension, and allergies), thus not yet covering more complex medical complication cases.

Based on these limitations, future research is recommended to expand the scope of the food image dataset and enhance the classification model architecture to recognize more complex food variations. Subsequent developments are also advised to incorporate daily or weekly continuous menu planning features (long-term meal planner), integrate automated weighting algorithms into the rule base, and involve direct clinical testing with expert nutritionists to further strengthen the validity and real-world relevance of the system in practice.

Implications

The findings of this study carry significant practical and academic implications for both healthcare practitioners and the general public. Practically, the developed expert system serves as an accessible, fast, self-service tool that enables individuals to manage their daily dietary choices according to their personal health conditions without requiring continuous face-to-face consultations. For nutritionists and medical professionals, this AI-driven system acts as a decision support framework that substantially streamlines patient education and dietary prescription delivery. Academically, the study demonstrates the feasibility of combining visual recognition with clinical data, establishing a foundation for multimodal AI integration within personal health technologies.

Research Contribution

This study contributes to the literature by introducing a novel hybrid integration model that combines Convolutional Neural Networks (CNN) for visual feature extraction with a backward chaining inference engine tailored for health technology. The primary contribution lies in the automated synthesis scheme connecting real-time image recognition outputs with a structured IF–THEN knowledge base conditioned on individual user profiles (including BMI, medical history, and allergies). This demonstrates that integrating multimodal data—specifically visual data and user clinical information—substantially enhances the precision and adaptiveness of personalized nutritional recommendations.

Limitations

Despite its promising results, the study presents several technical and methodological limitations. First, the classification performance of the CNN model experienced reduced accuracy when evaluating food items with high visual similarity, such as distinguishing between fried rice and white rice served with side dishes. Second, the scope of both the image dataset and the knowledge rule base remains restricted to selected popular food categories and specific health conditions (obesity, hypertension, and food allergies). Consequently, the system is currently unable to address more complex medical complications or multi-morbidity scenarios.

Suggestions

To address these limitations, future research should expand the scope and diversity of the food image dataset while refining the classification model architecture to better distinguish visually similar foods. Additionally, future developments should introduce continuous daily or weekly menu planning features (long-term meal planner) to support sustainable dietary management. Incorporating automated weighting algorithms into the rule base and conducting direct clinical trials with certified nutritionists are also recommended to further validate the system's real-world clinical efficacy.

CONCLUSION

This study successfully proves that the integration of Convolutional Neural Network (CNN)-based computer vision techniques and a backward chaining-based inference system effectively addresses the challenges articulated in the introduction section. The developed expert system proved reliable in visually identifying food types with a classification accuracy of 87%, while simultaneously generating personalized nutritional recommendations based on users' physical medical parameters with an 80% alignment rate against official WHO and Indonesian Ministry of Health standards. These results demonstrate a high alignment between the initial design objectives and the experimental outcome, wherein the system successfully delivers adaptive recommendations such as low-calorie menus for obesity patients, low-sodium for hypertension, and automated allergen elimination for allergy sufferers.

The prospects for the application and development of these research findings are highly promising for broad-scale implementation in the health technology sector. Practically, this system holds strong potential to be deployed as a self-service nutrition assistant application for the general public, as well as a decision support system for medical practitioners and nutritionists in delivering efficient healthy diet education. For future studies, research can be directed toward expanding the food image database, improving classification model performance to differentiate visually similar foods, and integrating long-term daily or weekly menu planning modules to enable the system to deliver a more comprehensive and sustainable health impact.

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AUTHOR CONTRIBUTION STATEMENT

AF conceptualized the research, designed the system architecture, developed the CNN model, and drafted the main manuscript. NR implemented the backward chaining inference engine, prepared the dataset, and conducted the simulation experiments. CH validated the knowledge base rules against official nutrition standards and analyzed the experimental results. NS contributed to system testing, user interface evaluation, and manuscript revision. All authors reviewed and approved the final manuscript.

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