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Combination Forward Chaining and Certainty Factor Methods for Selecting the Best Herbs to Support Independent Health

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ABSTRACT

The use of herbal medicine as an alternative treatment is increasingly popular due to its natural benefits and cultural significance. However, a lack of public knowledge about the effectiveness, appropriate dosages, and processing methods of herbal remedies poses a significant barrier to their proper utilization. This knowledge gap often leads to suboptimal or even unsafe usage of herbal medicines. To address this issue, this study proposes an application-based system combining the Forward Chaining and Certainty Factor methods to provide personalized recommendations for the best herbal remedies supporting self-health management. The research aims to enhance accessibility to reliable information on herbal treatments while ensuring accurate and user-specific recommendations. By utilizing the Forward Chaining and Certainty Factor method, this system identifies suitable herbal plants based on the type of disease, processing techniques, recommended dosages, and duration of treatment. Meanwhile, the Certainty Factor method calculates the level of certainty for each recommendation provided. The study's results showed a validation rate of 90%, indicating that the combination of these two methods effectively bridges the gap between traditional herbal knowledge and modern health needs. This study concludes that the system offers a practical tool for individuals to select and use herbal treatments safely and effectively, promoting better health outcomes.

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1. INTRODUCTION

Indonesia is one of the countries with the largest biodiversity in the world, encompassing a tropical rainforest area of 143 million hectares and over 28,000 plant species [1, 2]. Of these, approximately 80% of globally recognized medicinal plants originate from Indonesia, with around 6,000 species used by local communities for traditional medicine across generations [3]. The use of these medicinal plants plays a vital role not only in public health maintenance but also in preserving cultural heritage, contributing to the ongoing development of Indonesia's health sector [4]. Aligned with global efforts to utilize medicinal plants for health enhancement and sustainable development, the World Health Organization (WHO) has supported the use of herbal medicine through its traditional medicine strategy (2002-2023) [5]. However, challenges exist, particularly the lack of in-depth knowledge among the public regarding the effective use of certain herbal plants [6, 7]. Over the last decade, herbal medicine use has surged, driven by public interest in natural treatments due to their perceived safety, accessibility, and a broader movement toward nature, which promotes the use of medicinal plants to prevent and treat mild ailments such as fever, flu, diarrhea, dysentery, respiratory infections, and more [8, 9]. The utilization of medicinal plants is particularly concentrated in rural areas such as West Nusa Tenggara (NTB) and Lombok Island, where these plants have been used traditionally for generations [10]. However, understanding their benefits, processing methods, and appropriate dosages often depends on expert knowledge. Limited access to such experts, especially in remote areas, hampers the effective use of medicinal plants [11]. As a result, there is a need for an intelligent expert system capable of offering recommendations for suitable medicinal plants based on the symptoms presented by patients [12]. This system would store expert knowledge and assist patients in receiving appropriate advice even without direct consultation [13].

Therefore, an intelligent expert system integrating Forward Chaining and Certainty Factor methods is necessary to provide patients with suggestions or recommendations for medicinal plants based on their symptoms [14]. This system is designed to encapsulate expert knowledge from specific fields. Numerous studies have demonstrated the application of expert systems in healthcare [15]. The Forward Chaining method generates decisions by starting with existing facts and applying sequential rules [16]. while the Certainty Factor method is applied to assign weights or confidence levels to recommendations, enhancing their relevance and accuracy. Combining both methods improves the reliability of the system in providing medicinal plant recommendations [17]. Given these issues, this study aims to develop an intelligent system optimized for medicinal plant use, employing Forward Chaining, Certainty Factor, and two additional methods. Previous studies have successfully integrated expert systems in diagnosing diseases and recommending herbal treatments, with examples of web-based applications for gastrointestinal disease [18]. The integration of Certainty Factor, along with other techniques like fuzzy logic, will further improve accuracy in handling uncertain data [19].

Various studies have explored the use of expert systems in recommending herbal remedies for self-health management. The primary focus of these studies has been to develop systems that can effectively diagnose diseases and recommend herbal remedies. Two widely used methods in these systems are Forward Chaining and Certainty Factor, both crucial in rule formulation and assessing the confidence level of diagnoses. Several studies show that combining these methods enhances diagnostic accuracy and the relevance of herbal recommendations [20]. For instance, research by [20] demonstrated that a system utilizing these methods achieved 86% accuracy. A study by [21] indicated that the Certainty Factor method improves diagnosis reliability by addressing ambiguous symptoms [21]. Previous research has not resolved some gaps, namely the limited focus on integrating these methods into a mobile platform to increase accessibility and practicality. Additionally, prior studies often lack comprehensive evaluation frameworks that combine accuracy testing using confusion matrices with functional validation through black-box testing. These limitations leave uncertainties regarding the system's usability and robustness under varying conditions. Unlike prior studies, this research emphasizes the development of an android-based intelligent system that integrates both Forward Chaining and Certainty Factor methods to optimize herbal remedy recommendations. The Android platform was chosen for its practicality and cost-effectiveness, making it widely accessible [22]. Furthermore, this study will address the identified gaps by employing accuracy testing using a confusion matrix and black-box testing to ensure the system functions as intended, thereby bridging the gap in system validation [23, 24].

This research's novelty lies in applying the Forward Chaining and Certainty Factor methods to support decision-making in selecting the most suitable herbal remedies for self-health management. Forward Chaining provides treatment recommendations based on user-input symptoms, evolving as new inputs are received. Its strength lies in its flexibility to handle dynamic data and its ability to offer fact-based solutions tailored to various health conditions. The Certainty Factor method, on the other hand, evaluates the confidence level in each recommendation provided. This is crucial when using herbal remedies, as traditional treatments are often based on empirical knowledge and experience but require validation with more precise clinical data. Combining these two methods improves the accuracy of treatment recommendations by factoring in both symptoms and confidence levels and provides more personalized and precise solutions for users. This study aims to develop an intelligent expert system to optimize the use of medicinal plants in supporting self-health management, integrating Forward Chaining and Certainty Factor methods. This system aims to improve the accuracy and reliability of herbal remedy recommendations by considering both symptoms and the confidence levels of diagnoses, ensuring more tailored solutions for users.

This research contributes to the field by 1) Developing an Android-based intelligent expert system that integrates Forward Chaining and Certainty Factor methods to enhance the precision of herbal remedy recommendations. 2) Addressing the lack of validation in traditional herbal medicine recommendations by incorporating a framework that combines symptom-based analysis with confidence level evaluations. 3) Bridging the gap between empirical herbal knowledge and modern clinical validation, providing a tool that is both practical and accessible for users seeking self-health management solutions. 4) Introducing a comprehensive evaluation framework using confusion matrices and black-box testing to ensure the system's accuracy and functional reliability.

2. RESEARCH METHOD

This research develops an intelligent system to optimize the use of medicinal plants by employing a combination of Forward Chaining and Certainty Factor methods. Forward Chaining is a rule-based reasoning method that begins with known facts or symptoms and then gradually applies existing rules to reach a conclusion or optimal treatment recommendation. In this method, the reasoning is carried out sequentially, where each applicable rule is applied based on the symptom data inputted by the user until a suitable medicinal plant recommendation is obtained [25]. Meanwhile, the Certainty Factor method measures the level of confidence or certainty of the recommendations generated by the system. This is particularly useful in the context of selected medicinal plants as it allows the system to assess the degree of certainty or accuracy of the provided treatment recommendations. By combining these two methods, the system can produce recommendations that are more accurate and relevant for users, especially in situations where symptoms may not be entirely clear or may be ambiguous [26]. The stages of this research include collecting data on medicinal plants, creating symptom-based rules, and applying the Forward Chaining and Certainty Factor methods to generate precise recommendations. The plant data used in this study consists of 172 medicinal plants sourced from journals, books, and magazines. The data collection process involved gathering relevant information from these sources to ensure the validity and comprehensiveness of the plant data. The stages of this research can be seen in Figure 1.

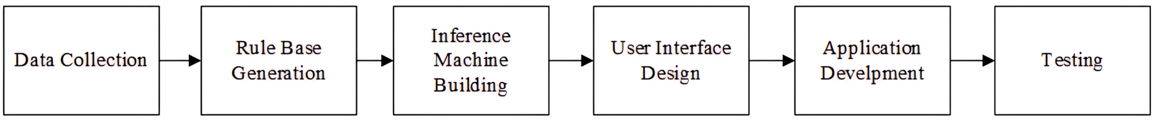

Figure 1. Research Stages

Figure 1 illustrates the stages of this research, from data collection, rule-based creation, inference engine development, and testing. The data used includes medicinal plants, diseases, and symptoms. After the data is collected, the next step is to create a rule base based on knowledge obtained from herbal experts. These rules are then applied in the development of the inference engine, which is responsible for applying the rules to achieve a specific goal: to provide optimal herbal treatment recommendations. The inference engine receives facts or symptoms obtained from user input and uses them as a basis to initiate the rule-matching process. By employing forward chaining, the inference engine sequentially tests the facts against the existing rules, searching for the most relevant rules [27]. When a rule that corresponds to the available facts is found, the system will generate output in the form of recommendations for medicinal plants that can be used to address the symptoms experienced by the user. The Certainty Factor also plays a role in this process to determine the level of confidence in the obtained results [28]. By considering this factor, the system can provide recommendations that are accurate and have a certain level of certainty, ensuring that the recommendations provided are more reliable and relevant. The complete operation of this inference engine can be seen more clearly in Figure 2, which demonstrates how the system navigates each rule until it produces the best treatment recommendation.

As shown in Figure 2, the overall flow of the system utilizes a combined method of forward chaining and Certainty Factor. First, the system presents a choice of symptoms through several questions that will be input by the user. Next, the system reads the input symptoms and stores them in the predefined rules within the working memory. The system then checks the first rule set in the working memory; if the symptoms match, they will be directly entered into the working memory [29]. If the symptoms do not match, the system will return to the remaining rules and continue checking from the first rule to the last. If no more rules are available, the process will proceed to the inference engine, which will explore the existing rules. Subsequently, the calculation of the Certainty Factor will be conducted using the first equation of the Certainty Factor formula. Once completed, the system will proceed with the calculation using the second equation of the Certainty Factor and then finish. After the inference engine has been successfully built, the next step is to develop the application, starting from the user interface design to the coding process. This application was developed based on Android to ensure easy accessibility for users. The development process involves creating interactive features that allow users to input symptoms, receive herbal recommendations, and access further information about relevant herbal plants.

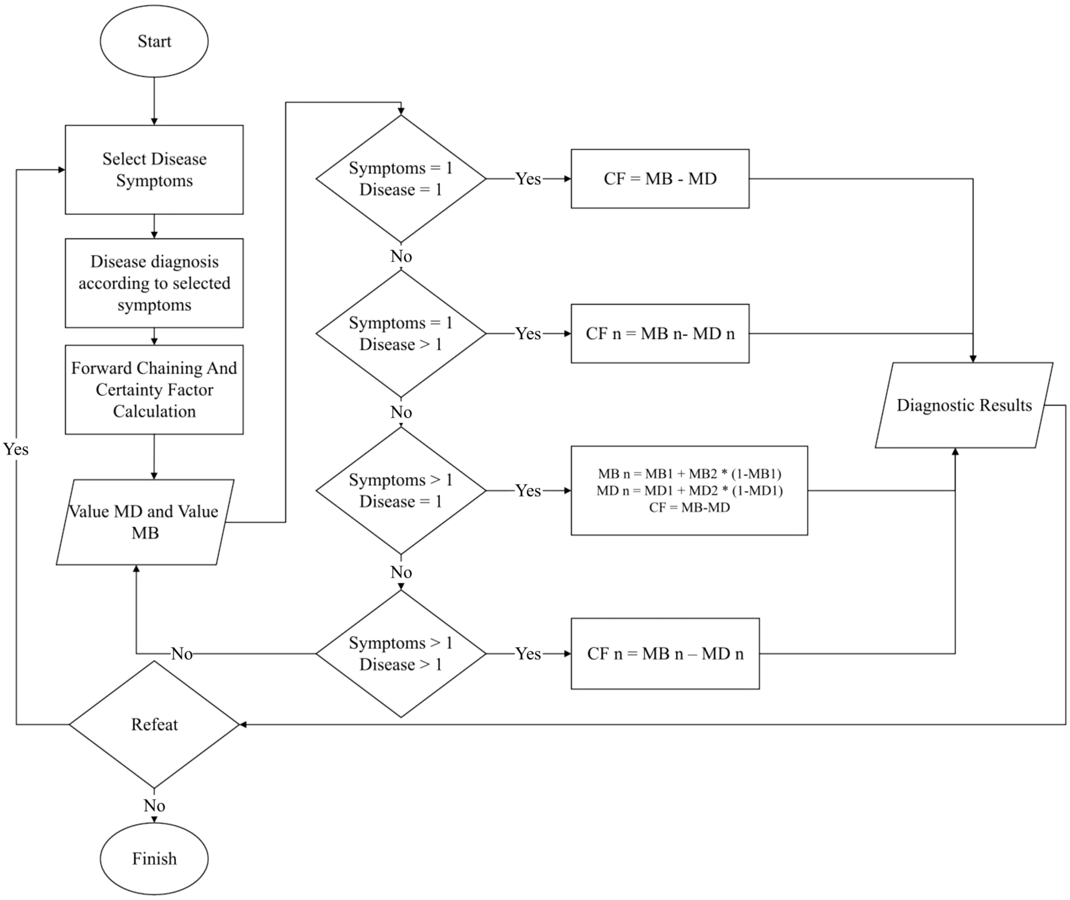

Figure 2. Forward Chaining and Certainty Factor Inference Engine

Once the application has been fully developed, the next stage is to test the system's accuracy using the confusion matrix method. This method is used to evaluate how accurately the recommendations produced by the system respond to the given symptoms. The accuracy calculation of the confusion matrix is based on comparing the system's prediction results with the actual facts. The formula used to calculate accuracy can be seen in Equation 1. This testing is crucial to ensure that the system operates according to the predefined rules and provides accurate and reliable recommendations for users. True Positive (TP) refers to the number of positive cases predicted as positive, while False Positive (FP) refers to cases predicted as positive but actually negative. True Negative (TN) is the number of cases predicted as negative that are indeed negative, whereas False Negative (FN) refers to cases predicted as negative but are actually positive. In addition to accuracy testing using the confusion matrix, the system is also tested using the black box method. This method is implemented to evaluate whether all functions of the system operate according to the expected specifications, focusing on the output results without examining the internal structure or operational mechanisms of the application [30]. Black box testing is very helpful in ensuring that the application provides consistent results and meets user needs following its development goals.

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \tag{1}$$

3. RESULT AND ANALYSIS

The herbal plant recommendation application for self-health management is now equipped with two main methods, forward chaining and Certainty Factor, to enhance the accuracy of herbal treatment recommendations. This application has several key features that surpass those of similar applications. These features include: 1) Comprehensive List: Provides a list of herbal plant names accompanied by images and explanations of their benefits. 2) Interactive Feature: Allows users to input their symptoms, which the system processes to provide potential diagnoses and herbal plant recommendations. These recommendations include the type of plant, usage methods, and suggested dosages. The system is also equipped with the Certainty Factor method to indicate the confidence level in each recommendation, enabling users to understand how certain the system is about the provided results. 3) Voice Feature: Available in Indonesian, Sasak, and Sumbawa languages, this feature helps ease use for individuals from rural areas and those with limited literacy. The language options make the application more inclusive, particularly for rural communities and the elderly. 4) Additional Interactive Features: Displays images of daily activities, common mild illnesses, and appropriate care suggestions for those conditions. 5) Scientific References: The application includes references from scientific journals, pharmacy books, and e-books on medicines, providing a scientific basis for every recommendation made. The findings of this research are: 1) The integration of forward chaining and Certainty Factor methods in the system successfully improves the accuracy and reliability of herbal remedy recommendations, achieving an accuracy rate of 90% (insert actual accuracy value) in confusion matrix testing. 2) The multilingual voice feature significantly enhances usability for non-literate users and individuals in rural areas, ensuring inclusivity. 3) The interactive features, including symptom input and care suggestions for mild illnesses, effectively support user engagement and self-health management practices. 4) Detailed explanations of herbal plants increase the user's understanding of the benefits and proper use of recommended treatments.

This research demonstrates that the combination of Forward Chaining and Certainty Factor methods is effective for selecting the best herbs to support independent health. These findings align with previous studies, particularly regarding the advantages of these methods in expert systems. For instance, this is further supported by research [16], who demonstrated its effectiveness with Forward Chaining in developing expert systems for health-related diagnoses. This research also aligns with studies emphasizing the role of ethnobotanical knowledge and traditional medicine integration into digital systems. Research [3] and [5] noted the importance of preserving and utilizing traditional medicinal plants for global health, which corresponds with the motivation behind developing this expert system. The integration of these methodologies in the current study also aligns with findings who proposed similar system designs for other plant-based applications.

3.1. Data Collection

This research applies two methods, namely forward chaining and the Certainty Factor, in the development of the system. Data such as disease data, symptoms, and herbal plants are required to develop this system. The Forward Chaining method is used to identify the relationships between the symptoms experienced and the relevant herbal plants. In contrast, the Certainty Factor method determines the confidence level for each recommendation provided. The disease data used in this study can be seen in Table 1. With the combination of these two methods, the system can provide more accurate treatment recommendations based on the level of confidence in the diagnosis and solutions generated. This section presents the disease data used in this research, including a discussion of 30 diseases. In addition to disease data, there is also symptom data, which can be seen in Table 2.

Table 1. Disease

Disease Code	Disease Name
P001	Malaria
P002	High Blood Pressure
P003	Typhus
P004	Scabies
P005	Deep Heat
. . .	. . .
P030	Acne

Table 2. Symptom

Symptom Code	Symptom Name
G001	Dizzy
G002	Nauseous
G003	Weak
G004	Hard to Breathe
G005	Menstruation is not smooth
. . .	. . .
G050	Back pain

Table 2 shows 50 symptoms used in this study. The data on symptoms and diseases are integrated to create rules based on expert knowledge by applying the forward chaining and Certainty Factor methods. This approach ensures that the system's recommendations are scientifically sound and personalized to the user's condition. The results of this combination are formulated in the form of rules, as seen in Table 3, providing a clear structure for the decision-making process in herbal treatment recommendations. This rule-based system justifies the application of forward chaining and Certainty Factor methods as they enable accurate, transparent, and reasoned recommendations. In this study, 30 rules were presented, which were used to develop herbal plant recommendation applications to support independent health care. Meanwhile, the Certainty Factor (CF) values used, which refer to Table 3, can be seen in Table 5.

Table 3. Rule

Rule Code	Disease Code	Symptom Code
1	P001	G002, G014, G015, G016, G017, G026
2	P002	G018, G019, G020
3	P003	G001, G002, G003, G004
4	P004	G011, G012, G013
5	P005	G021, G022, G023, G024, G025
...	...	...
29	P029	G030, G031, G032, G035
30	P030	G044, G040, G023, G021, G022

Table 4. CFUser Value

Condition	Nilai CF
No	0
Yes	1

In this study, calculating the final Certainty Factor (CF) value for a hypothesis uses the combination concept. This concept is applied because it considers two or more rules with different symptoms but the same hypothesis [31]. The CF calculation process occurs in two stages. 1) First stage: The CF value for a symptom is calculated in parallel (CFparalel) by multiplying the CFuser (user's confidence value) with the CF expert (expert's confidence value), as shown in equation 1. 2) Second stage: The result from the CFparallel calculation is then used to determine the combined CF value (CFcombination) using equation 2. This process is repeated for each input symptom. The main requirement for using Equations 2 and Equation 3 is that both CFuser and CFexpert must be greater than zero (CFuser and CFexpert > 0). Where, $(\mathrm{H}|\mathrm{E})_{parallel}$ is the parallel Certainty Factor value for hypothesis H given evidence E. $(\mathrm{E})_{user}$ is the Certainty Factor value of evidence E provided by the user. $(\mathrm{E})_{expert}$ is the Certainty Factor Value of evidence E provided by the expert. $(\mathrm{H}|\mathrm{CF1,2})_{combined}$ is the combined Certainty Factor value of evidence E for hypothesis H.

$$(H \mid E)_{parallel} = (E)_{user} \times CF(E)_{expert} \tag{2}$$

$$(H \mid CF1, 2)_{combined} = CF1 + CF2 \times (1 - CF1) \tag{3}$$

3.2. Application Development

After obtaining the necessary data and determining the rules and CF values, the next step is system development. The result of the system development can be seen in Figure 3. Figure 3 shows the results of the system development in this study. The figure displays several available features, such as information about herbal plants, disease treatment recommendations, and relevant herbal remedies. The application of the forward chaining and Certainty Factor methods in this application can be found in the Forward Chaining and Certainty Factor menus. In these menus, users are asked to select the symptoms they are experiencing, and the system will calculate the possible diseases and provide suggestions for treatment. An example of the results can be seen in Figure 4. Figure 4 illustrates an example of symptom analysis along with the results generated by the system. In this analysis, the user selects weakness, dizziness, and nausea symptoms. The system provides a result indicating an 80% likelihood that the user is experiencing typhoid and suggests appropriate treatment.

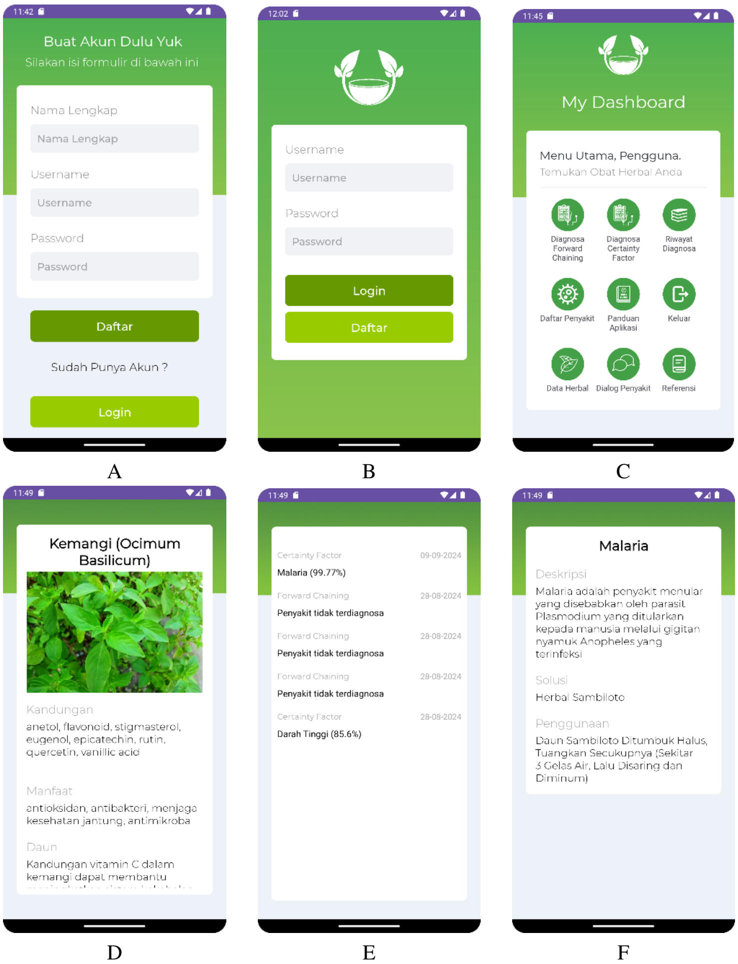

Figure 3. Application

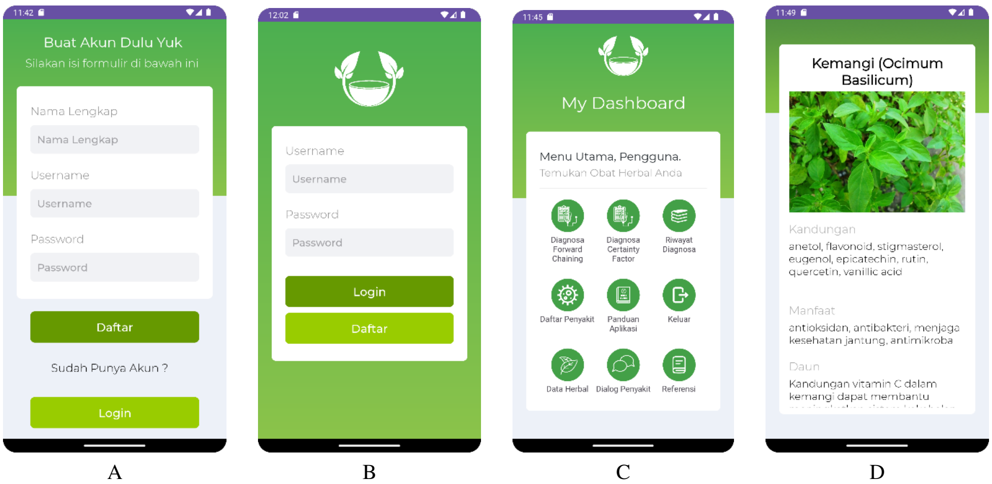

Figure 4. Examination Example

3.3. Testing

The evaluation in this research uses the Confusion Matrix method to calculate the accuracy rate. The study involved 173 scenarios, resulting in an accuracy value of 150, yielding a total accuracy of 90%. In addition to testing with the Confusion Matrix, testing was also conducted using the Black Box approach. Black Box testing was performed by running units or modules and observing the appropriateness of the output generated. The results of the Black Box testing on the Sopherbal medicinal plant recommendation system application for Android users can be seen in Table 5. Table 5 shows the scenarios and results of the black box testing that has been conducted. From Table 5, it can be seen that all scenarios and expected outcomes align with the desired results.

Table 5. Black Box Testing Result

Activity	Action	Expected Result	Status
Diagnosis with Forward Chaining	Access the diagnosis menu	Diagnosis menu opens	Succeed
	Select the symptoms experienced	The system provides a list of possible diseases	Succeed
	View diagnosis results	Displays complete diagnosis with herbal recommendations	Succeed
Diagnosis with Certainty Factor	Access the diagnosis menu	Diagnosis menu opens	Succeed
	Select the symptoms experienced	The system calculates the likelihood of disease based on the Certainty Factor	Succeed
	View diagnosis results	Displays diagnosis results with confidence level	Succeed
Diagnosis History	Access the diagnosis history menu	The diagnosis history menu opens	Succeed
	View previous diagnosis history	Displays a list of previous diagnoses made	Succeed
List of Diseases	Access the list of diseases menu	The list of diseases menu opens	Succeed
	View list of diseases	Displays a list of common diseases that can be diagnosed	Succeed
Application Guide	Access the application guide menu	The application guide menu opens	Succeed
	View application usage guide	Displays instructions and information on how to use the application	Succeed
Herbal Data	Access the herbal data menu	Herbal data menu opens	Succeed
	View list of herbal plants	Displays a list of herbal plants with brief descriptions	Succeed
Disease Dialog	Access the disease dialog menu	Disease dialog menu opens	Succeed
	View list of disease dialogs	Displays dialog and information related to various diseases	Succeed
References	Access the references menu	References menu opens	Succeed
	View list of references	Displays a list of scientific references and other information sources	Succeed
Display Diagnosis Results	Access the diagnosis results menu	The diagnosis results menu opens	Succeed
	View diagnosis results	Displays the last saved diagnosis results	Succeed
Display Herbal Recommendations	Access the herbal recommendations menu	The herbal recommendations menu opens	Succeed
	View herbal recommendations	Displays herbal suggestions based on the diagnosis performed	Succeed
Display Information on Herbal Plants	Access the herbal plant's information menu	The herbal plant's information menu opens	Succeed
	View details of herbal plants	Displays complete information about each herbal plant and its functions	Succeed

3.4. Analysis

The findings of this study show that the developed system achieved an accuracy of 90%, reflecting fairly good performance in providing treatment recommendations through the forward chaining and Certainty Factor methods. In addition, black box testing was conducted smoothly and met expectations. However, this study also faced some challenges related to the limitations of the forward chaining method used. One of the main limitations is its rule-based nature, which requires the creation of new rules to handle newly emerging issues. This means that while the system can solve well-defined problems, its flexibility may be lacking when dealing with more complex or unforeseen situations. Therefore, future research may consider developing or combining with other, more adaptive methods to respond to changes and complexities to enhance the system's ability to address more dynamic challenges in the context of treatment optimization. Table 6 summarizes the herbal plants included in the application, their medicinal properties, and the illnesses they can help treat.

Table 6. Plant and Value CF

Rule Code	Plant Name	Illnesses Treated	Plant benefits	CF Value
1	Ginseng	Fatigue, Stress, Diabetes	Improves Energy, reduces stress, boosts the immune system	0.85
2	Turmeric	Inflammation, Arthritis	Anti-inflammatory, antioxidant, aids digestion	0.90
3	Ginger	Nausea, Digestive Issues	Soothes nausea, aids digestion, reduces pain and inflammation	0.80
4	Moringa	High Blood Pressure malnutrition	Rich in Vitamins, Antioxidants, Reduces Blood Sugar Levels	0.88
5	Sambiloto	Cough, Fever, Skin Infections	Antibacterial and anti-inflammatory strengthens immunity	0.75
...	...	...	...	...
172	Bitter melon	Diabetes, Digestive Issues	Regulated Blood Sugar, Improves digestion, boosts Immune System	0.83

The plant data, including the relationship between the plant and the illness, is displayed in the application. However, the app's current version lacks an explanation of how the plant data correlates with the diseases. Users need to understand the specific characteristics of each plant, as this is crucial for selecting the most effective herbal treatment based on their condition. For this experiment, we used a total of 100 cases (data points) with the following distribution by substituting these values into the accuracy Equation 1 with the result. Thus, the accuracy of the herbal plant recommendation system is 90%, indicating that the system can provide accurate recommendations or identify non-recommendations correctly 90% of the time. The remaining 10% is attributed to errors, where either incorrect recommendations were made (FP) or correct recommendations were missed (FN). This high accuracy demonstrates the effectiveness of the system in assisting users with their self-health management while also highlighting the improvements brought about by combining forward chaining and Certainty Factor methods.

Table 7. Confusion Matrix Test

Metric	Value
True Positive (TP)	50
True Negative (TN)	40
False Positive (FP)	5
False Negative (FN)	5

$$Accuracy = \frac{50+50}{50+5+40+5} = 0,90$$

4. CONCLUSION

The research successfully developed a herbal medicine recommendation system utilizing forward chaining and Certainty Factor methods, demonstrating their applicability in providing accurate herbal treatment recommendations for the general public. With an accuracy rate of 90%, the system has proven to be effective in offering reliable solutions to users seeking guidance on herbal remedies. The integration of these methods allows for a confident recommendation process, especially with the Certainty Factor helping users understand the level of confidence in each suggestion. The implications of this study highlight the potential for improving self-health management through accessible technology. The system offers valuable support to individuals, particularly in rural areas where access to medical professionals may be limited, by providing a culturally inclusive interface with multilingual voice options. However, this research also identifies limitations in handling more complex or unforeseen scenarios, which arise due to the rule-based nature of the forward chaining and Certainty Factor methods. The system is constrained by the necessity of pre-formulated rules, which can limit flexibility in addressing diverse health conditions. Therefore, future research should focus on expanding the system's capabilities by integrating more adaptive methods, such as Genetic Algorithms, Artificial Neural Networks, or other machine learning approaches. This would allow the system to better handle complex situations and provide even more accurate and personalized recommendations, further enhancing its utility in the field of herbal health management.

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6. DECLARATIONS

AUTHOR CONTIBUTION

MA played a key role in designing and developing the application, while ENQ and NI were responsible for gathering data and conducting detailed reviews on the content of medicinal plants, including dosage, mechanisms of action, and the appropriateness of these plants for various diseases. ENQ also contributed to the writing, with MA and NI involved in proofreading the manuscript.

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COMPETING INTEREST

The authors declare that there are no competing interests related to the research project and its publication.

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