

Expert System for Safety Recommendations of Active Ingredients Combinations Based on Skin Conditions Using a Rule-Based System

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Abstract: The growth of skincare products increases the need for easily accessible information regarding the safety of active ingredient combinations based on skin conditions. This study aims to develop an expert system that provides recommendations for the safety of active ingredient combinations based on the user's skin condition. The study used a system development method with a Rule-Based System approach and the Forward Chaining inference method. The study did not use conventional human populations and samples, but rather used peer-reviewed literature data from 2022–2025 and expert validation. The research instrument consisted of 25 condition rules covering six active ingredients, five skin conditions, and 15 unique active ingredient pairs. Data analysis was carried out through content analysis and expert validation using a four-level scale. The results showed that the system was able to generate recommendations in three categories: Recommended, Caution, and Not Recommended. Black Box testing showed that the authentication, knowledge base management, consultation, combination analysis, and prediction history functions ran as needed. In conclusion, the developed system can be used as an initial consultation medium to provide structured and easily accessible information on active ingredient safety.

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Introduction

The development of the skincare industry in Indonesia has led to a growing number of products with diverse ingredients, functions, and usage instructions. The Coordinating Ministry for Economic Affairs of the Republic of Indonesia recorded an increase in the number of cosmetics companies from 913 in 2020 to more than 1,010 by mid-2023. This situation has expanded product choices while increasing the information users need to understand, particularly regarding active ingredients and their use.

Skincare information is available through various sources, such as packaging, the

internet, social media, apps, and user experiences. However, this information is not always consistent and relevant to users' skin conditions. A 2022 Jakpat survey showed that 58% of skincare users in Indonesia experience confusion in determining safe active ingredient combinations. The 2024 ZAP Beauty Index also showed that young consumers tend to choose products based on trends and digital recommendations.

This problem highlights a gap between the abundance of information available and users' ability to determine the right combination of active ingredients. Users are still required to independently search and compare various sources, requiring time and an understanding of technical terms. This can lead to decisions about using different active ingredients that may not be aligned with their skin's needs.

Consulting with a dermatologist can provide more accurate information, but it requires cost, time, and access that is not always readily available. Some users ultimately choose to search for information online and try products independently. The use of digital health technology can help provide more accessible initial information (World Health Organization, 2021; Ministry of Health of the Republic of Indonesia, 2021). Tele dermatology research also shows that digital services can save time and travel costs in certain situations (Lopez-Villegas et al., 2022; Skinner et al., 2022; Chow et al., 2022).

Conventional database-based systems are unable to reason based on user conditions without a knowledge base, rules, and an inference engine. Expert systems can be used to represent expert knowledge and generate recommendations based on user facts (Russell & Norvig, 2021). This study used a Rule-Based System with a Forward Chaining mechanism to match skin conditions and active ingredients with available rules, resulting in recommendations of Recommended, Caution, or Not Recommended.

This study aims to design and implement a Rule-Based System and Forward Chaining-based expert system in a web application to assess the safety of Active Ingredients combinations based on skin conditions. The urgency of the research lies in the need for structured and easily accessible initial information. The novelty of the study lies in the pairwise analysis of six active ingredients, namely Retinol, Vitamin C, Niacinamide, Alpha Hydroxy Acid (AHA), Beta Hydroxy Acid (BHA), and Benzoyl Peroxide, which produces 15 unique pairs and recommendations in three categories based on the knowledge base and expert validation.

Research Methods

This study used a rule-based system (RUS) approach to develop an expert system for recommending the safety of active ingredient combinations based on skin conditions. The system utilizes a forward chaining inference method that processes facts such as skin conditions and active ingredients to generate recommendations based on IF–THEN rules (Russell & Norvig, 2021).

The research instrument consisted of 25 skin condition rules and active ingredients. Data were obtained through peer-reviewed literature studies from 2022–2025, including Reynolds et al. (2024), Correia & Magina (2023), Mambwe et al. (2025), Almeman (2024), Tempark et al. (2024), Alvarez et al. (2025), Dréno et al. (2022), and Kontzias et al. (2023). Analysis was conducted through content analysis and expert validation using a scale of 4 to 1 through consultations with dermatologists, venereologists, and aestheticians through Alodokter.

This study did not use a population or sample of respondents because it focused on developing a knowledge-based system. The research data consisted of scientific literature and expert validation. The system's scope encompasses six active ingredients: Retinol, Vitamin C, Niacinamide, AHA, BHA, and Benzoyl Peroxide, five skin conditions, and 15 unique active ingredient pairs.

The research procedure includes domain definition, literature review, identification of active ingredient relationships, compilation of facts and IF–THEN rules, and expert validation. Rules requiring improvement are adjusted based on validation results, taking into account tolerance and

skin barrier conditions. Next, the system applies a Rule-Based System and Forward Chaining to process skin conditions and exactly two active ingredients to produce a Recommended, Caution, or Not Recommended category, along with an explanation.

Results and Discussion

Implementation of Rule-Based System

The method used in this research is a Rule-Based System. This method works by matching user-entered data with rules contained in the knowledge base. Rules are represented in the form of IF–THEN statements as follows:

Rule 1 IF Skin Type = Dry AND Skin Condition = Dull Skin THEN Active Ingredient = Vitamin C AND Recommendation = Caution Rule 2 IF Skin Type = Oily AND Skin Condition = Acne / Clogged Pores THEN Active Ingredient = BHA AND Recommendation = Caution Rule 3 IF Active Ingredient 1 = Retinol AND Active Ingredient 2 = AHA THEN Status = Not Recommended Rule 4 IF Active Ingredient 1 = Retinol AND Active Ingredient 2 = Niacinamide THEN Status = Caution Rule 5 IF Active Ingredient 1 = AHA AND Active Ingredient 2 = Benzoyl Peroxide THEN Status = Not Recommended

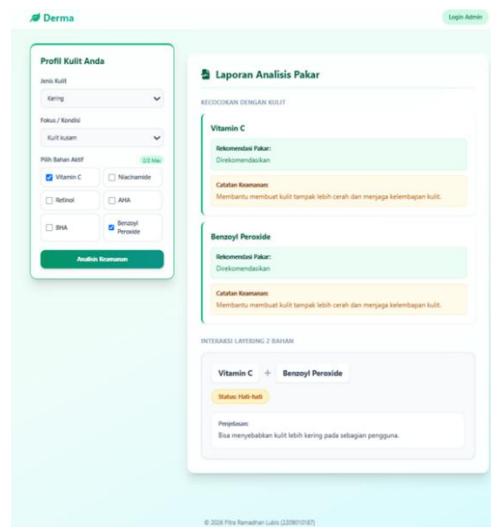
The system will match the available rules to produce recommendations that suit the user's conditions.

Administrator Interface Implementation



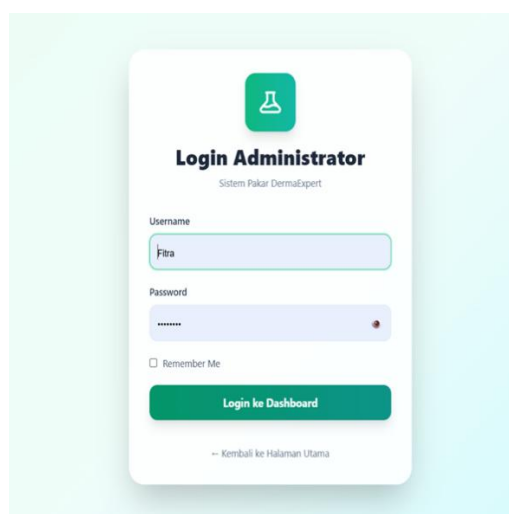
Picture1Website Home

Figure 1 displays the Main Page of the expert system application, which serves as the user's initial access point. This page provides navigation, application functions to provide safety guidance for skincare active ingredient combinations based on skin condition, and the use of the Rule-Based System method. The "Start Analysis" button makes it easy for users to begin the safety checking process.



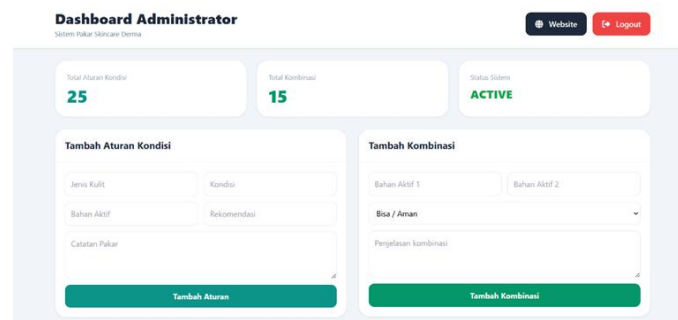
Picture2Consultation Page

Figure 2 displays the consultation results page, which displays inference results based on user input. The system analyzes dry skin, dull skin, and the combination of Vitamin C and Benzoyl Peroxide. The analysis results include the compatibility of each ingredient and its layering interaction, with a "Caution" status and explanation. This display demonstrates the Rule-Based System's ability to provide specific and easy-to-understand skincare safety recommendations.



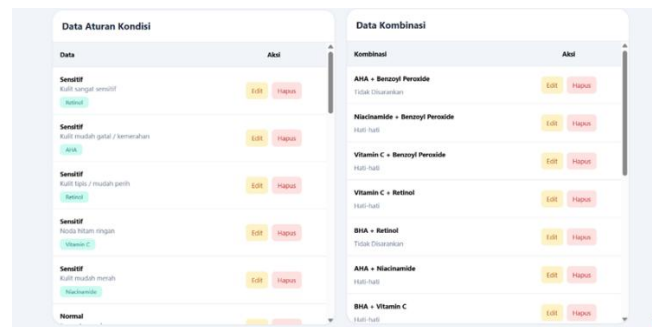
Picture3Admin Login

The image shows the DermaExpert Expert System administrator authentication page, which provides access to the back-end dashboard. This page provides a username and password form, a "Remember Me" option, a "Login to Dashboard" button, and a "Return to Home Page" link for easy user navigation.



Picture4Admin Dashboard

Figure 4 displays the Derma Skincare Expert System Administrator Dashboard, the central knowledge base management tool. The dashboard provides a summary of the number of condition rules, combinations, and system status, as well as features for adding skin condition rules and active ingredient layering combinations, along with their safety status. Additionally, there is a "Website" button to access the public page and a "Logout" button to end the administrator session.



Picture5Condition Rules and Combination Data

Figure 5 displays the knowledge base management page containing Condition Rules Data and Combination Data. The first panel contains rules based on skin type and condition and active ingredients, while the second panel contains layering interaction rules and their safety status. Each record has "Edit" and "Delete" features to facilitate rule maintenance.

No	Jenis Kulit	Kondisi Kulit	Bahan Aktif	Rekomendasi	Tanggal
1	Kering	Kulit kusam	Vitamin C, Benzoyl Peroxide	Hati-hati	2026-06-25 22:50:26
2	Kering	Noda hitam / bekas jerawat	Vitamin C, Benzoyl Peroxide	Hati-hati	2026-06-24 14:38:19
3	Berminyak	Jerawat / pori tersumbat	Vitamin C, AHA	Hati-hati	2026-06-24 13:51:13
4	Berminyak	Jerawat / pori tersumbat	Vitamin C, AHA	Hati-hati	2026-06-24 13:49:21
5	Kering	Noda hitam / bekas jerawat	Vitamin C, AHA	Hati-hati	2026-06-24 13:23:41

Picture6User Prediction History

Figure 6 displays the User Prediction History page, which serves as a track record of the expert system's consultation activity. This page displays data on skin type, skin condition, active ingredients tested, system recommendations, and the consultation date. This data can be used by administrators to monitor and audit system activity.

System Testing

Table 1 Login Page Testing

No	Testing Scenario	Input	Expected results	Test Results	Status
1	Login with correct data	Valid username and password	The system displays the admin dashboard	As expected	Succeed
2	Login with wrong password	Username is correct and password is incorrect	The system displays an error message	As expected	Succeed
3	Login without filling in data	Username and password are empty	The system displays validation	As expected	Succeed

Table 2 Testing Data Condition Rules

No	Testing Scenario	Expected results	Test Results
1	Adding condition rule data	Data saved successfully	As expected
2	Changing condition rule data	Data updated successfully	As expected
3	Deleting condition rule data	Data deleted successfully	As expected

Table 3 Combination Rule Data Testing

No	Testing Scenario	Expected results	Test Results	Status
1	Add combination data	Data saved successfully	As expected	Succeed
2	Changing combination data	Data updated successfully	As expected	Succeed
3	Deleting combination data	Data deleted successfully	As expected	Succeed

Table 4 Recommended Testing of Active Ingredients

No	Input	Expected Output	System Output	Status
1	Skin type = Dry, Condition = Dull skin	Vitamin C, Be Careful	Vitamin C, Be Careful	Succeed

No	Input	Expected Output	System Output	Status
2	Skin type = Oily, Condition = Acne/Clogged pores	BHA, Be Careful	BHA, Be Careful	Succeed
3	Skin type = Sensitive, Condition = Thin skin / easily irritated	Retinol, Not Recommended	Retinol, Not Recommended	Succeed
4	Skin type = Normal, Condition = Fine lines/Uneven texture	Retinol, Be Careful	Retinol, Be Careful	Succeed

Table 5 Testing of Active Ingredients Combination

No	Combination Input	Expected Output	System Output	Status
1	Retinol + AHA	Not Recommended	Not Recommended	Succeed
2	Retinol + Niacinamide	Be careful	Be careful	Succeed
3	BHA + Niacinamide	Be careful	Be careful	Succeed
4	Vitamin C + Niacinamide	Be careful	Be careful	Succeed
5	AHA + Benzoyl Peroxide	Not Recommended	Not Recommended	Succeed

Table 6 Prediction History Testing

No	Testing Scenario	Expected results	Test Results	Status
1	Conducting consultation	Data is saved to the history_prediction table	As expected	Succeed
2	Displays prediction history	History data appears on the admin page	As expected	Succeed
3	Delete prediction history	Data deleted successfully	As expected	Succeed

Based on the results of tests that have been carried out using the Black method Box Testing, all functions in the system run according to the requirements that have been set. The system is capable of performing admin authentication, knowledge base management, providing active ingredient recommendations based on skin conditions, analyzing the safety of active ingredient combinations, and storing prediction history effectively. Thus, the system can be declared to be functioning according to its intended purpose. research and ready to be used as a safety consultation medium for active skincare ingredient combinations.

System Suitability to User Needs

An expert system for recommending the safety of active ingredient combinations in skincare was developed to assist users in selecting active ingredients appropriate to their skin condition and to determine the safety level of certain active ingredient combinations. Based on

implementation and testing results, the developed system has successfully performed its core functions according to the requirements identified during the analysis phase.

Before this system was developed, users often struggled to determine which active ingredients were appropriate for their skin type. Furthermore, many users didn't understand the safety of using multiple active ingredients together, potentially causing irritation, redness, dryness, and other skin problems. Therefore, a system that could provide quick and easy-to-understand recommendations was needed.

The system developed in this research is capable of providing active ingredient recommendations based on the skin type and condition selected by the user. The recommendation process is carried out by utilizing a knowledge base stored in the `rules_conditions` table. Each rule in the knowledge base contains a relationship between skin type, skin condition, the recommended active ingredient, and a supporting explanation. With these rules, the system can provide more targeted recommendations tailored to the user's needs.

In addition to providing active ingredient recommendations, the system is also capable of performing safety analysis of active ingredient combinations. The analysis is performed using data stored in the `combination_rules` table. The system matches the selected active ingredient combination with the rules available in the knowledge base, then generates a recommendation status of Recommended, Caution, or Not Recommended. Each result is accompanied by an explanation so users can understand the rationale for the system's recommendations.

ResultsBlack Box Testing demonstrated that all of the system's main features functioned effectively. The administrator login feature successfully authenticated users based on the data stored in the database. The conditional and combination rule management features also performed seamlessly adding, modifying, and deleting data. Furthermore, the user consultation process generated recommendations consistent with the rules contained in the knowledge base.

The system also successfully saves consultation results to the `prediction_history` table. This feature allows administrators to review recommendations previously generated by the system. Storing this history can aid in monitoring system usage and simplify the management of user consultation data.

Based on the implementation and testing results, it is clear that the system has met the functional requirements planned during the analysis phase. The system is able to assist users in obtaining recommendations for active ingredients appropriate to their skin condition and provides information on the safety of the active ingredient combinations used. Therefore, the developed expert system can be used as a consultation tool to help users understand the safe and appropriate use of active skincare ingredients according to their skin condition.

Conclusion

This research produces an expert system for recommending the safety of Active Ingredients combinations based on skin conditions using the Rule-Based System approach and the Forward Chaining method. The system is able to provide recommendations for active ingredients based on skin type and condition and analyze the safety of active ingredient combinations in the Recommended, Caution, and Not Recommended categories. Black Box Testing results show that all main functions, including administrator authentication, knowledge base management, consultation processes, combination analysis, and prediction history storage, run as needed.

The limitations of this study lie in the system's scope, which only covers six active ingredients, five skin conditions, and combinations of two active ingredients, thus not covering all possible uses of Active Ingredients. Future research is recommended to expand the knowledge base, add a variety of active ingredients and skin conditions, and develop testing

with a wider user base and expert validation. Practically, this system can be a medium for initial consultation that helps users understand the suitability of active ingredients and the safety of their combinations more quickly, in a targeted, and easily understood manner, as well as assisting administrators in monitoring and managing system knowledge.

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