Rule-Based Myanmar Herbal Recommendation System Using Ontology

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***Abstract*—Myanmar herbal medicine is recognized as a vital component of traditional healthcare; however, its documentation remains disorganized and primarily available in the local language. Identifying appropriate herbs for individual users from existing records is inefficient and may result in medication errors. This study presents a formalized, digitized representation of Myanmar herbal knowledge using an ontology-based framework that enables precise and efficient herb identification and recommendation. The ontology and rule-based recommendation system were developed through literature review, expert consultation, and analysis of volumes 1 and 2 of *Medicinal Plants of Myanmar*. The system's performance was evaluated by three experts from the University of Traditional Medicine in Mandalay. The constructed ontology models 119 herbs, 17 plant parts, 12 distribution regions, 256 disease symptoms, and 23 adverse effects. Seven inference rules were defined to generate recommendations based on seven benchmark questions. The system achieved an average accuracy of 95% and a recall of 96% in recommending herbs based on symptoms, plant parts used, location, plant family, adverse effects, combinations of users' symptoms and location, and combinations of symptoms and adverse effects through rule-based evaluations. The proposed system provides a formalized structure for preserving Myanmar herbal knowledge and offers reliable recommendations within the scope of a limited dataset and a rigid ontology structure.**

Keywords*—*Myanmar herbal medicine; ontology; recommendation system

I. Introduction

Traditional herbal medicine has been an essential component of healthcare due to its accessibility, affordability, and minimal side effects. It has been used worldwide for over 6,000 years, including nearly 5,000 years in regions such as China, Egypt, and India, and around 2,500 years in Greece and Central Asia [1]. According to the World Health Organization (WHO), more than 80% of the global population relies on traditional medicine for healthcare, and its popularity continues to grow [2], [3].

In Myanmar, the adoption of Good Manufacturing Practice (GMP) standards since 2018 has significantly improved the quality of pharmaceutical production in both public and private sectors. Concurrently, the quality and availability of materials used in alternative and traditional medicine have also improved, supported by dedicated hospitals and clinics across the country [4]. Herbal medicine plays a vital role in public health by promoting lifelong well-being and disease prevention in both urban and rural communities.

Historically, herbal knowledge in Myanmar was recorded on palm leaves and preserved in institutions such as the University Central Library in Yangon. Some of this knowledge has been transmitted orally across generations. Despite demonstrated treatment efficacy, concerns remain regarding the declining reliability of information and the urgent need to preserve this traditional knowledge. Existing research on traditional medicine in Myanmar has largely focused on chronic diseases such as diabetes [5] and other long-term illnesses [6]. Additionally, several studies have concentrated on specific ethnic groups and regions, including Chin [7], Sagaing [8], and Shan [9].

Although Myanmar's traditional medicine is considered effective and widely relied upon, the documentation of herbal knowledge—particularly regarding structured identification and classification—remains limited. Most of this knowledge has not been digitized, indicating the need for a comprehensive information system that leverages current technologies to assist in identifying and recommending suitable herbal remedies. At present, no formal information or recommendation system exists for Myanmar herbal medicine.

Various intelligent systems, including expert systems [10], Information Systems [11], decision support systems [12], and recommendation systems [13] have been proposed in other countries to support knowledge preservation and herbal recommendations. Notable initiatives have been undertaken in China [14], Indonesia [15], and Thailand[16]. However, these systems often lack clear semantic knowledge and may produce inaccurate herbal information. A more structured approach with accurate semantic knowledge representation is needed to enable reliable identification and recommendation. Ontology is selected as the preferred knowledge representation method due to its ability to enhance domain conceptualization, reduce ambiguity, and improve accuracy and consistency [17].

Recommender systems have been widely applied in domains such as social networks [18], fashion [19], education [20], tourism [21] , agriculture[22], and wellness [23], using collaborative filtering, matrix factorization, and hybrid approaches. While data-driven techniques such as weighted matrix factorization and hybrid filtering improve personalization, they often lack semantic reasoning and explainability. Social- and personality-based recommendation systems enhance user engagement but are unsuitable for healthcare-critical applications. In the healthcare and nutrition domain, ontology-based recommendation systems have been adopted to structure domain knowledge and support decision-making [24].

There are four main approaches to herbal and health recommendation: rule-based [25], text mining [26], machine learning and deep learning [27], and SPARQL query-based methods [28]. The rule-based approach is particularly advantageous because it can derive inferences from heterogeneous data sources and manage multiple conditions simultaneously. Its simplicity and transparency make it well-suited for the current system, which is not based on large-scale data. Therefore, the proposed system adopts a fully rule-based recommendation architecture using ontology to ensure domain accuracy, transparency, and explainability. This system aims to formalize and digitize Myanmar herbal knowledge through an ontology-based recommendation model to identify and recommend suitable herbs based on user-defined queries.

II. Methods

The methodology of this study comprises two primary components: ontology modeling and rule-based reasoning. These components are integrated to represent domain knowledge related to medicinal herb identification and to enable the generation of appropriate herbal recommendations in response to user queries.

A. Ontology Modeling

The Myanmar herbal ontology was developed using Web Ontology Language 2 (OWL 2) to represent domain knowledge. The complete ontology modeling process is illustrated in Fig. 1. The development process involved four main stages: 1) selection of herbal documents, 2) data preprocessing, 3) ontology construction, and 4) verification of the constructed ontology according to the practical guide [29].

The source of knowledge for this study is the traditional medical texts, which are Volumes 1 and 2 of Medicinal Plants of Myanmar, published by the Department of Traditional Medicine, Ministry of Health. Volume 1 contains information on 60 herbs [30], while Volume 2 includes 59 herbs [31]. During the data preprocessing stage, relevant information was manually extracted and standardized into uniform data fields. These included family names, scientific names, English names, Myanmar names, indications (disease symptoms), plant parts used, cultivated regions, and reported adverse effects.

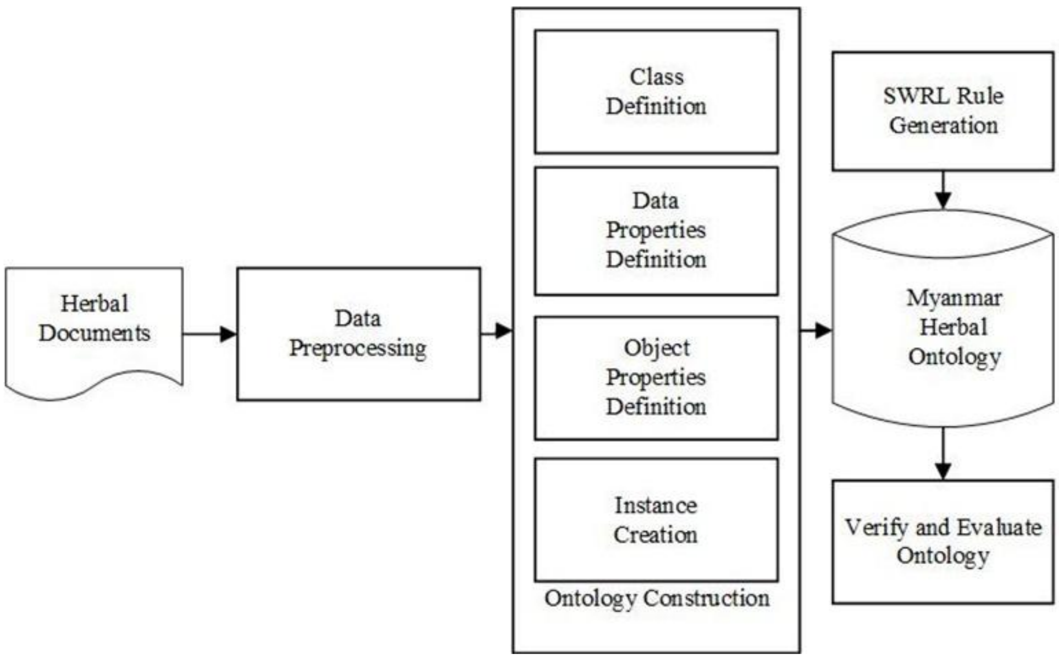

Fig. 1. Conceptual model of the Myanmar herbal ontology.

The ontology construction followed four key steps:

1) Defining classes from terms: Terms identified in herbal documents were manually used to define ontology classes. These classes included:

- Herb: Represents general herbal information.
- Distribution: Corresponds to geographic regions within Myanmar where herbs are found or cultivated.
- Adverse Effect: Captures contraindications or negative side effects.
- Indication: Refers to symptoms or conditions the herb is used to treat.
- Used Part: Specifies plant parts employed for therapeutic purposes.

2) Definition of data properties: Data properties were specified for each class to define their attributes. These are represented as directional arrows in the ontology diagram. For example, the *Herb* class includes the following data properties:

- Scientific Name
- Family Name
- English Name
- Myanmar Name

Each data property uses basic data types such as string, integer, or float.

3) Definition of object properties: Object properties were created to define relationships between different classes and support rule-based recommendation logic. These relationships are bidirectional. For instance:

- LocatedIn(Herb, Distribution)
- IsLocationOf(Distribution, Herb) (inverse of LocatedIn)

4) Instance creation: The final step involved the instantiation of classes and the assignment of values to their data and object properties. This process occurred in three sub-stages:

- Class Selection
- Individual Creation
- Value Assertion

For example, the *Herb* class includes an instance with the following data values:

- Scientific Name: *Acacia concinna*
- Family Name: *Mimosaceae*
- Myanmar Name: *Kim-Mum-Gyin*
- English Name: *Soap Acacia*

The ontology was constructed manually, including the creation of instance values for both data and object properties.

Fig. 2 presents examples of the herbal ontology's properties and instances, showing indications (e.g., abdominal_colic, eczema), plant parts used for treatment (e.g., leaves, rhizome), regions of distribution (e.g., northern_part_of_myanmar, tropical_region_of_myanmar), and any known adverse effects (e.g., vomiting_effect, drowsiness_effect).

After defining the classes, data properties, object properties, and instances, the complete structure of the Myanmar herbal ontology is presented in Fig. 3.

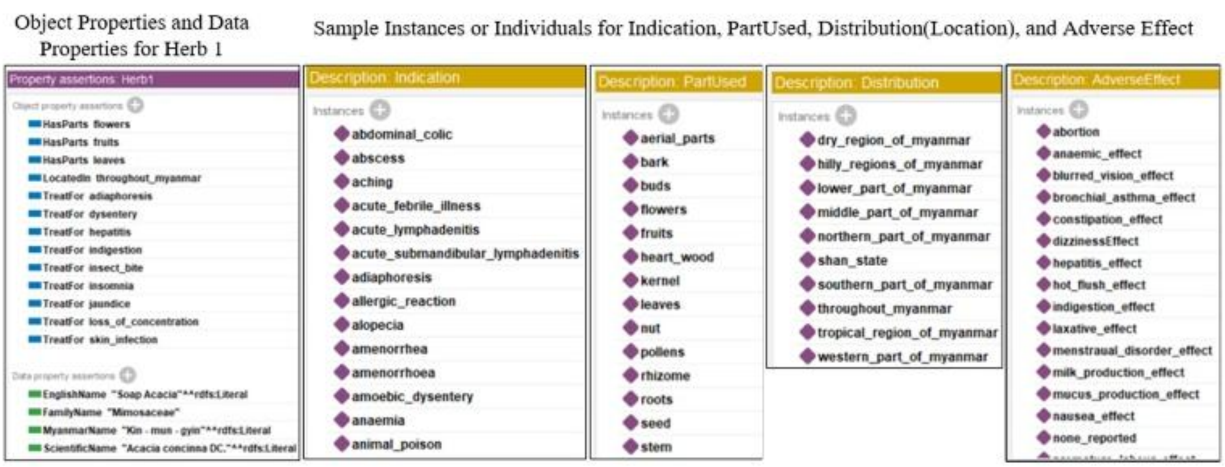

Fig. 2. Illustration of object properties, data properties, and instances in the ontology.

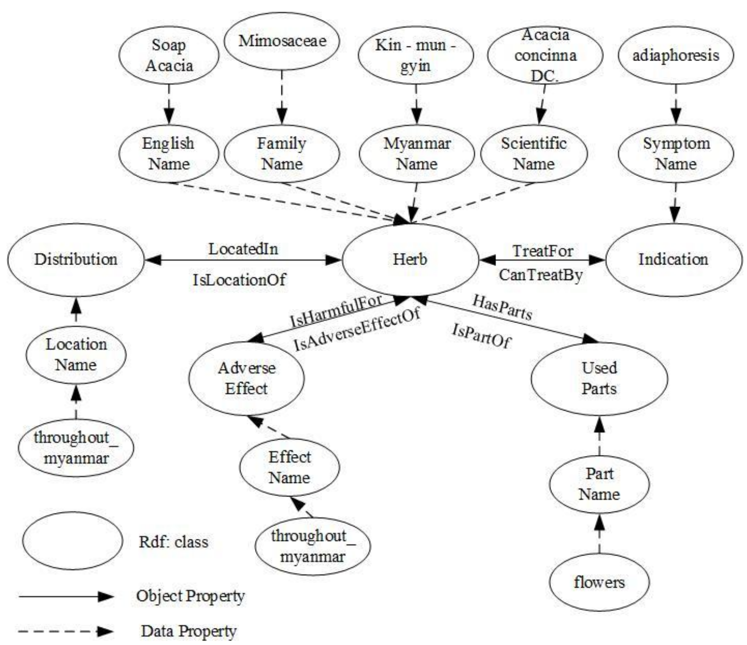

Fig. 3. Structure of the Myanmar herbal recommendation ontology.

In the ontology diagram, classes are represented as ellipses, data properties are shown either as subclasses or as instances connected by dotted lines, and object properties are indicated by directed arrows. The *Herb* class encapsulates core information related to herbal concepts. Its associated data properties—*English Name*, *Family Name*, *Myanmar Name*, and *Scientific Name*—are depicted as subclasses and linked with dotted lines.

B. Questionnaire Development to Establish Rules for Verification of the Constructed Ontology

The evaluation of an ontology-based system is typically measured by its ability to answer competency questions, which assess whether the ontology can provide accurate responses to defined user queries. To validate the constructed ontology, seven benchmark questions were formulated based on its content and a review of related studies [28].

Other studies established questionnaires using herb, taste, application, action, element, and ailment in creating rules [32], [33]. Information related to taste, person, and elements is not included in our knowledge source. Instead, we included the location or distribution of the herbs.

Table I shows the seven questionnaires based on five core elements: herbs (including their family), distribution, adverse effects, indications, and plant parts used. We considered combinations of these elements according to the following derivation process by referencing previous studies and information contained in our knowledge source [32], [33].

- Derive the herb based on indication, distribution, used parts, herb family, and adverse effects.
- Identify the herbs based on the indication and distribution, as well as symptoms and adverse effects.

TABLE I. SEVEN QUESTIONS TO IDENTIFY APPROPRIATE HERBS

No:	Questions
1.	What are the herbs that can treat specific symptoms?
2.	Which herbs are available in the user's location?
3.	Which herbs use specific parts of the plant (for example, leaves) for treating diseases?
4.	Which herbs are not contraindicated for certain conditions?
5.	Which herbs belong to a specific plant family?
6.	Which herbs can treat specific symptoms and are available in a specific user location?
7.	Which herbs can treat specific symptoms and are not contraindicated for certain adverse effects?

The proposed system adopts a rule-based approach from existing recommendation techniques, which is efficient when working with a limited number of herbal instances. Fig. 4 presents an overview of the Myanmar herbal recommendation system. When a user submits a query, the recommendation module selects the appropriate rule, applies it to the ontology, and returns the relevant herbs. Each of the seven user-oriented questions corresponds to a specific rule implemented using the Semantic Web Rule Language (SWRL) [34].

These rules incorporate key information, such as disease symptoms, geographic location, plant family, used parts, and adverse effects, to provide personalized and accurate recommendations. The details of the herbal ontology and corresponding rules are outlined in the following section.

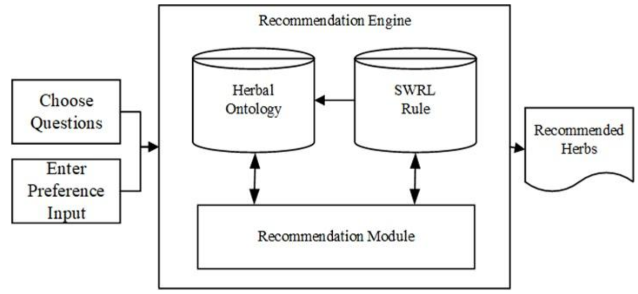

Fig. 4. Overview of the Myanmar herbal recommendation system.

C. Inference Rules

Inference rules enable reasoning within the recommendation process by applying logic-based conditions to the ontology data. SWRL is used to define rules using a structure composed of an antecedent (body) and a consequent (head). When the conditions in the body are satisfied, the head is executed, producing one or more inferred instances. If the body is unsatisfied or invalid, no output is generated. Seven rules were developed to correspond to the competency questions introduced in Section B. These rules were implemented using Protégé.

Rule-1 is designed to identify herbs that can treat specific symptoms and corresponds to competency question 1. It is defined as:

Herb(?h) ^ TreatFor (?h,?i) ^ Indication(?i)

⇒HerbsForIndication(?h, ?i)

In this rule, ?h represents herb instances, and ?i represents instances of disease symptoms from the *Indication* class. The rule infers that if a herb instance ?h has a TreatFor relationship with a symptom ?i, and ?i is classified under *Indication*, then ?h is inferred as suitable for treating that symptom. When the condition in the rule body is satisfied—i.e., when the herb is linked to the specified symptom through the defined ontology relationships—the system returns HerbsForIndication as the result. This rule enables the system to recommend herbs based on the symptom information provided by the user.

Rule-2 addresses the recommendation of herbs based on geographic accessibility, corresponding to competency question 2. The rule is defined as:

Herb(?h) ^ LocatedIn(?h,?l) ^ Distribution(?l)

⇒HerbForPreferredLocation(?h,?l)

In this rule, ?h represents herb instances and ?l represents location instances from the *Distribution* class. If a herb ?h is associated with a location ?l through the LocatedIn relationship, and ?l is recognized as a valid distribution region, the system infers that the herb is available in that location. When the user specifies a location in their query, the system applies this rule to return herbs that are accessible in the requested region. This supports location-based filtering of herbal recommendations to enhance relevance and practical availability.

Rule-3 supports herb recommendations based on specific plant parts used for treatment, corresponding to competency question 3. The rule is defined as:

Herb(?h) ^ HasParts(?h,?p) ^ UsedParts(?p)

⇒HerbForPreferredPart(?h,?p)

In this rule, ?h denotes herb instances and ?p represents parts of the herb, such as root, leaf, or bark, defined in the *UsedParts* class. If a herb ?h is linked to a particular part ?p through the HasParts relationship, and that part is specified by the user, the rule condition is satisfied. The system then returns herbs that include the specified part for therapeutic use. This rule enables the identification of herbs based on user preferences for specific plant parts in the healing process.

Rule-4 identifies herbs that are not suitable due to specific adverse effects, aligning with competency question 4. The rule is defined as:

Herb(?h) ^ IsHarmfulFor(?h,?a)^AdverseEffect(?a)

⇒HerbDuetoAdverseEffect(?h)

In this rule, ?h refers to herb instances and ?a represents instances from the *AdverseEffect* class. If a herb has an IsHarmfulFor relationship with an adverse effect specified by the user, and this effect is recognized within the ontology, the rule is triggered. The system then identifies and returns herbs that are considered unsuitable due to their known negative effects for the specified condition. This rule supports safety-aware filtering in the recommendation process by excluding herbs that may be harmful based on the user's input.

Rule-5 enables the identification of herbs based on their botanical family, corresponding to competency question 5. The rule is defined as:

Herb(?h) ^ Family(?h,?f)

⇒HerbDuetoFamily(?h)

In this rule, ?h denotes herb instances and ?f represents a family name. If a herb instance has a Family relationship with the specified family name provided by the user, the condition of the rule is satisfied. The system then returns herbs that belong to the requested plant family. This rule allows users to filter herbal recommendations based on taxonomic classification.

Rule-6 combines symptom-based and location-based criteria to recommend herbs that meet both conditions, addressing competency question 6. The rule is defined as:

Herb(?h) ^ TreatFor(?h,?i) ^ Indication (?i) ^ LocatedIn(?h,?)^ Distribution(?I)

⇒HerbForIndication(?h,?i) ^ HerbforPreferredLocation(?h,?I)

⇒HerbforIndicationAndPreferredLocation(?h)

In this rule, ?h represents herb instances, ?i indicates symptoms from the *Indication* class, and ?l corresponds to instances from the *Distribution* class. The rule is satisfied when a herb both treats the specified symptom and is available in the specified location. It integrates the logic of Rule-1 and Rule-2, enabling the system to return only those herbs that fulfill both the treatment and geographic availability requirements as specified by the user.

Rule-7 combines treatment effectiveness with safety considerations by integrating Rule-1 and Rule-4, corresponding to competency question 7. The rule is defined as:

Herb(?h) ^ TreatFor(?h,?i) ^IsHarmfulFor(?h,?a)^ AdverseEffect(?a)
⇒HerbforIndication(?h,?i)^HerbNotProhibitedFor(?h,?a)

⇒HerbForIndicationAndNoProhibitedfor(?h)

In this rule, ?h denotes herb instances, ?i represents symptoms from the *Indication* class, and ?a refers to instances of adverse effects. The rule is satisfied when a herb treats the specified symptom and is not associated with any harmful effects relevant to the user's condition. By ensuring that the herb meets the treatment criteria (from Rule-1) and avoids contraindications (not triggering Rule-4), the system returns herbs that are both effective and safe. This rule supports more reliable recommendations by filtering out herbs with adverse effects while still addressing the user's intended symptom.

III. RESULT

The experimental results are organized into three subsections: dataset, data analysis, and evaluation. The proposed rule-based Myanmar herbal recommendation system was implemented on a machine with an Intel® Core™ i7-7500U processor (2.7–2.9 GHz, 2 cores, 4 logical processors) running Microsoft Windows 10 Pro. The Myanmar herbal ontology was developed using Protégé 5.5, the OWL API (OWL 2), and Apache Jena.

A. Dataset

Table II presents the summary of the instances by class of the proposed Myanmar herbal ontology. The evaluation dataset consists of 119 herb types, 256 disease symptoms, 23 adverse effects, 17 usable plant parts, and 12 geographic distributions.

TABLE II. DISTRIBUTION OF INSTANCES BY CLASS IN THE MYANMAR HERBAL ONTOLOGY

No.	Classes	Number of Instances
1	Herb	119
2	Symptom	256
3	Adverse Effects	23
4	Used Parts	17
5	Distribution	12

The Indication class in the ontology includes symptom names such as menstrual disorder, dyspepsia, and nasal discharge. The Used Parts class captures plant parts—such as leaves, fruits, and rhizomes—that are applied in treating these disease symptoms. In clinical recommendations, herbs without adverse effects related to the patient's symptoms are generally preferred. When multiple herbs can address the same symptom, the system prioritizes those without adverse effects, enhancing treatment suitability. For users with additional symptoms or sensitivities, herbs that may cause adverse effects related to those symptoms are excluded from the recommendations. The

Distribution class specifies geographic locations within Myanmar where each herb is found or cultivated. This enables users to search for herbs available in their respective regions. While most herbs in the dataset are distributed nationwide, some are region-specific, found only in particular areas such as the upper, lower, or northern parts of Myanmar. To assess the system's accuracy, the outputs from queries based on the seven benchmark questions were compared against expert-validated ground truth data.

B. Rule-Based Recommendation System Operation Process

Fig. 5 shows the seven rules that are provided as input options on the main menu of the website. Users can select the desired option to search for herbs by choosing a menu and entering the symptoms of the disease as input to the system. The system then recommends appropriate herbs when the user presses the Find button.

The following example illustrates the system's performance in applying Rule-1, which corresponds to Question 1: recommending herbs for a specific symptom. The rule is defined as:

Herb ^ TreatFor ^ Indication("diabetes")

⇒ HerbsForIndication ("Neem", "Periwinkle", "Queen Crape Myrtle", "Coral Jessamine", "Java Tea", and "King of Bitters.")

When the user queries for herbs that treat the symptom diabetes, the system applies the rule and returns the following recommended herbs: Neem, Periwinkle, Queen Crape Myrtle, Coral Jessamine, Java Tea, and King of Bitters. These results demonstrate the rule's ability to infer appropriate herbs based on symptom-based relationships defined in the ontology, as shown in Fig. 6.

Fig. 5. User input for diabetes symptoms using rule-1.

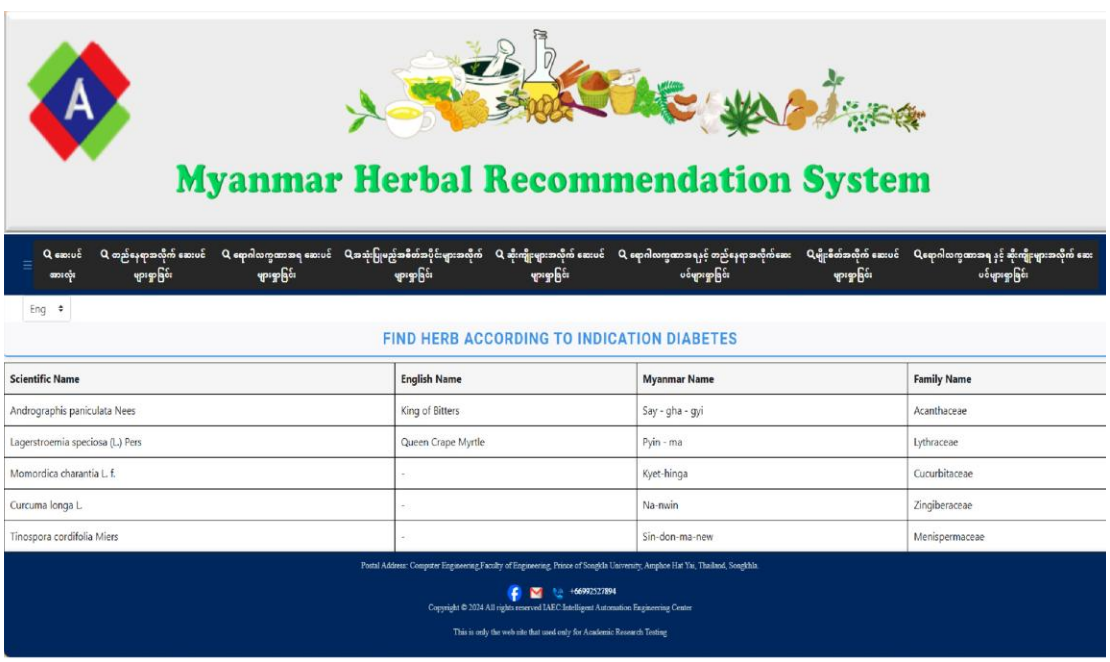

Fig. 6. Herbs recommended for diabetes symptoms using rule 1.

C. Evaluation of the Performance of the Rule-Based Recommendation System

The data used to construct the Myanmar herbal ontology were organized and presented as the instance counts. System outputs generated through rule evaluation were compared against expert-reviewed results for validation. Three experts from the University of Traditional Medicine in Mandalay reviewed the recommendations, and their assessments were recorded.

The system's performance was evaluated using accuracy and recall, calculated according to Eq. (1) and Eq. (2):

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \quad (1)$$

$$\text{Recall} = \frac{TP}{TP+FN} \quad (2)$$

Accuracy measures the proportion of correctly identified herbs—both recommended and not recommended—relative to the expert-validated ground truth. Recall assesses the completeness of the system's recommendations by determining how many of the correct herbs were successfully retrieved from the knowledge base.

The following definitions were used in performance evaluation:

TP (True Positive): Herbs recommended by the system that match the expert-validated herbs.

TN (True Negative): Herbs not recommended by the system and correctly excluded based on the expert reference.

FP (False Positive): Herbs recommended by the system that do not appear in the expert-validated list.

FN (False Negative): Herbs not recommended by the system that should have been recommended according to expert evaluation.

Additionally, the constructed ontology was evaluated using the OntOlogy Pitfall Scanner! (OOPS!) tool [35] to assess structural and semantic quality.

The evaluation of the ontology-based recommendation system was conducted based on its ability to answer predefined competency questions. The assessment measured how effectively the existing ontology could resolve these queries. A higher success rate in answering the competency questions indicates better system performance.

Seven benchmark questions were used to evaluate the system. The system achieved an overall accuracy of 95.53% and a recall of 95.93%, based on manual evaluation by three domain experts from the University of Traditional Medicine in Mandalay. Performance metrics were calculated using the formulas for accuracy and recall described in Eq. (1) and Eq. (2) in the previous section.

Table III summarizes the accuracy and recall achieved for each rule corresponding to the seven competency questions. The system achieved perfect performance (100%) in recommending herbs based on used parts and location, due to the limited number of instances in these classes—12 locations and 15 used parts, respectively. Other recommendations, including those involving symptoms, family, and adverse effects, also showed high performance.

TABLE III. PERFORMANCE EVALUATION OF THE RULE-BASED MYANMAR HERBAL RECOMMENDATION SYSTEM

No.	Question	Accuracy	Recall
1	Symptom	0.9376	0.9405
2	Parts to be used	1.0000	1
3	Location	0.9954	1
4	Family	0.9377	0.9405
5	Adverse Effect	0.9857	0.9863
6	Symptom ∧ Location	0.8986	0.8986
7	Symptom ∧ Adverse Effect	0.9321	0.9492
	Average	0.9553	0.9593

IV. DISCUSSION

This study focused on the formalization and digitization of Myanmar herbal medicine to enable accurate identification and recommendation of medicinal herbs.

The results indicate that the system is highly effective in recommending herbs, with an overall accuracy of 95% and a recall of 96%. These metrics suggest that the developed rule-based recommendation system accurately matches expert-validated herb recommendations in most cases. The high accuracy indicates that the system reliably identifies appropriate herbs, while the high recall demonstrates its ability to correctly identify herbs for a wide range of symptoms, minimizing the risk of missing relevant recommendations. Overall, these results highlight the system's usefulness and effectiveness in assisting users with herbal recommendations [35].

This achievement represents a significant advancement in addressing the persistent challenge of limited access to traditional medicinal plant knowledge in Myanmar. Unlike static compilations of herbal data, which posed challenges for maintenance and scalability, the proposed system offers a structured, semantically rich, and computationally actionable knowledge model. The clear separation between the ontological knowledge base and the inference rules in the proposed system enhances flexibility, transparency, and extensibility.

The system successfully integrates key domain concepts, including herbs, distribution regions, adverse effects, indications, and plant parts used in treatment. These were explicitly represented within the ontology, enabling meaningful semantic relationships. The application of inference rules to this knowledge structure enables the system to deliver context-aware recommendations that inherently account for safety constraints. For example, it can avoid suggesting herbs with anti-vomiting effects to users with constipation, thus promoting safer and more effective herbal usage. This addresses a critical gap in traditional healthcare, where knowledge of therapeutic benefits is often disconnected from understanding potential risks. Furthermore, the rule-based ontology provides traceable and explainable recommendations, which are particularly valuable in health-related applications such as traditional medicine [36], [37]. Nevertheless, the current system represents a foundational model that requires further development.

Our study has some limitations. Although we included more than 100 herbs, they were obtained from only two datasets, which may not cover all Myanmar herbal medicines.

The current system covers therapeutic relevance, distribution, part used, and safety. It does not yet account for clinical factors such as dosage, taste, elements, preparation methods, or interactions between multiple herbs. The rule-based reasoning mechanism also remains static, lacking adaptability to dynamic treatment contexts. Addressing these limitations will be essential for enhancing the system's applicability in clinical and real-world scenarios. The ontology and rule set must be expanded in collaboration with domain experts to improve coverage and specificity.

V. Conclusion

The proposed system uses an ontology to formalize and preserve Myanmar herbal knowledge and provides effective herb recommendations through a rule-based approach. Although the system demonstrates strong potential, it currently operates on a limited dataset, and the data properties and instances were manually defined and integrated. Future work will focus on expanding the dataset, incorporating machine learning techniques, and automating ontology enrichment to improve the system's flexibility, scalability, and adaptability for more complex applications in traditional medicine.

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Declaration on Generative AI

This work used generative AI support for language refinement.

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