Heliyon 11 (2025) e42470

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

Culinary and medicinal wonders of the wild: An ethnobotanical review of native herbs and spices in Thailand

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ARTICLE INFO

Keywords:
Ethnobotany
Medicinal plants
Aromatic plants
Herbs
Traditional knowledge

ABSTRACT

This ethnobotanical review explores the culinary and medicinal uses of wild herbs and spices in Thailand, with an emphasis on documenting traditional knowledge and their ethnomedicinal uses. Analyzing 76 ethnobotanical studies, we identified 248 use reports encompassing 46 species, 10 families, and 26 genera, predominantly focusing on the flora of northern Thailand. The most frequently utilized wild herbs and spices include *Alpinia galanga* (64.5 %), *Persicaria odorata* (34.2 %), *Litsea cubeba* (32.9 %), *Citrus hystrix* (31.6 %), *Boesenbergia rotunda*, *Piper sarmentosum* (14.5 %), *Elsholtzia griffithii* (11.8 %), *Zingiber kerrii* (11.8 %) and *Zanthoxylum armatum* (10.5 %). Notably, 41 out of 46 investigated species were acknowledged for their ethnomedicinal properties, contributing to a total of 688 use reports in 22 categories, with a significant emphasis on their role in treating digestive and infection-related disorders. The wild herbs and spices with the highest use value include *Acorus calamus* (1.72), *Alpinia galanga* (0.79), *Piper sarmentosum* (0.76), *Cinnamomum iners* (0.63), *Melicope pteleifolia* (0.57), *Citrus hystrix* DC. (0.51), and *Kaempferia parviflora* Wall. ex Baker (0.51). These findings highlight the potential of wild Thai herbs and spices as nutraceuticals and enhance the understanding of Thailand's botanical heritage in traditional healthcare practices. The study highlights the importance of preserving traditional knowledge and promotes further research into the sustainable use of these valuable plant resources.

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https://doi.org/10.1016/j.heliyon.2025.e42470
Received 4 July 2024; Received in revised form 3 February 2025; Accepted 4 February 2025
Available online 6 February 2025

1. Introduction

Spices have been a cornerstone in human cultural evolution, with archaeological evidence suggesting their use as early as 4000 BCE in the Indian subcontinent and neighboring Chinese regions [1]. In Egypt, garlic, cumin, coriander, and other spices have been utilized since at least 1500 BCE, and their use was also prevalent in ancient Greece and Rome [2]. The use of spices in Southeast Asia has a rich history intertwined with global trade and cultural exchanges. Evidence from the Oc Eo site in southern Vietnam shows the use of spices such as turmeric, ginger, fingerroot, sand ginger, galangal, clove, nutmeg, and cinnamon around 2000 years ago, likely introduced by South Asian migrants or visitors during early trade contacts via the Indian Ocean [3]. Similarly, archaeological findings from Quseir al-Qadim, an ancient port on the Red Sea coast of Egypt, reveal the presence of tropical spices like black pepper, ginger, cardamom, and turmeric, indicating their use in various contexts including ritual, perfumery, and medicinal remedies, with a significant increase in their culinary use by the medieval period [4]. In Thailand, the historical lineage of spice usage is evidenced by the discovery of *Piper* sp. seeds in northern Thai caves, with archaeological investigations dating their use back to over 6000 BCE [5].

Presently, spices extend their utility beyond gastronomy into sectors like cosmetics, perfumery, and pharmaceuticals, attributable to their inherent antioxidant, antimicrobial, antibiotic, and preservative properties [6]. Common spices such as black pepper (*Piper nigrum* L.), known as the "king of spices," and saffron (*Crocus sativus* L.), the most expensive spice, are widely recognized and utilized across various cuisines and cultures [7,8]. Turmeric (*Curcuma longa* L.), a key ingredient in South Asian cuisine, and ginger (*Zingiber officinale* Roscoe) are valued for their significant medicinal properties, including anti-inflammatory and antioxidant effects [8]. Cinnamon (*Cinnamomum* spp.) is popular globally for its flavor and health benefits, including regulating blood sugar levels, while clove (*Syzygium aromaticum* (L.) Merr. & L. M.Perry) is known for its aromatic qualities and medicinal properties such as antiseptic and analgesic effects. Nutmeg (*Myristica fragrans* Houtt.) and cardamom (*Elettaria cardamomum* (L.) Maton), known as the "queen of spices," are prized for their unique flavors and medicinal properties, used extensively in both culinary and traditional medicine applications [9,10]. These common spices drive significant international trade and contribute to global culinary diversity.

However, wild spices and herbs, particularly those utilized by ethnic groups, remain largely unexplored and underrepresented in ethnobotanical research, highlighting a crucial area for future investigation. These wild plants are vital to traditional gastronomy, appearing in many local dishes and contributing to the cultural identity of certain regions [11]. For a product to be deemed traditional, it must be tied to a specific territory and part of a tradition, ensuring its continuity over time. These species help preserve family and local traditions and add variety to the daily diet [12]. Additionally, wild plants offer significant economic opportunities for local gatherers and communities [13]. Leveraging these resources could establish a socio-economically sustainable activity in regions with less favorable farming conditions, aiding in population stabilization in rural areas. Thus, wild herbs and spices present a pathway to developing a healthy diet that combines gastronomy, health, and sustainability. Furthermore, they hold considerable cultural significance, playing crucial roles in local traditions, rituals, and daily life. While common spices contribute to a global culinary language and significant economic activity, wild spices preserve the unique flavors and cultural heritage of their regions, remaining central to the identity and health practices of local communities.

Thailand is a country with a wide range of ecosystems and a rich variety of plant life, including over 11,000 species of vascular plants. The variety of plants and animals differs throughout the country [14]. Geographically located in Southeast Asia, Thailand is part of a region known for its rich biodiversity, called the Indo-Burmese Region [15]. The country is also culturally diverse, with more than 30 different ethnic groups. This combination of many types of plants and diverse cultures makes Thailand an important place for studying how people use plants [16]. Recent research reviewing the use of ethnomedicinal plants in Thailand has identified over 2000 species [17], accounting for about 20 % of the total flora. Furthermore, in Northern Thailand alone, over 1000 species have been reported as edible plants [18]. Continuous ethnobotanical research on specific taxonomic groups, such as Fabaceae [19], Zingiberaceae [20] and *Litsea* [89], has also significantly contributed to the expansion of ethnobotanical knowledge in Thailand.

The main goal of this study is to conduct a systematic ethnobotanical review that presents the utilization of wild plants as traditional herbs and spices within Thai folk cuisine. Specifically, this research aims to: (a) document the traditional knowledge associated with wild herbs and spices in Thailand; (b) to answer what is the most important wild herb and spice, and which taste and scent are the favorites of Thailand and (b) to describe how these wild herbs and spices are used for medicinal purposes. This study is significant as it bridges the gap between traditional knowledge and modern scientific understanding, highlighting the crucial role of wild herbs and spices in Thai cuisine and medicine. The findings have the potential to contribute to the conservation of botanical biodiversity and cultural heritage in Thailand, while offering insights for future research in ethnobotany and sustainable use of plant resources.

2. Materials and methods

2.1. Data source

Data for this review were meticulously gathered from 76 distinct references, including academic theses, journal articles, conference proceedings, and unpublished reports covering various provinces in Thailand. The majority of these references were sourced from master's and doctoral theses conducted at the Ethnobotany and Northern Thai Flora Laboratory, Department of Biology, Chiang Mai University, which has been a central hub for ethnobotanical research in northern Thailand over the last two decades. Additionally, the Sanga Sabhasri Library at the Queen Sirikit Botanic Garden, a repository for a vast array of documents pertaining to the flora and ethnobotany of northern Thailand, served as a significant source.

Systematic searches were conducted in various databases using keywords such as "Ethnobotany" and "Thailand." Google Scholar, PubMed, Scopus, and the Web of Science were extensively utilized to ensure comprehensive coverage of relevant ethnobotanical

studies. The Thai Library Integrated System (www.tdc.thailis.or.th) was another crucial resource, providing access to numerous master's and doctoral theses from Thai universities.

To maintain data integrity and avoid duplication, when identical data appeared in both theses and journal articles, priority was given to the information from the initial source. Complete details and a full list of all the references used in this study are included in the supplementary materials section of this publication.

In addition to the sources and methods, it's important to clarify the specific focus of our data collection in this study. Our emphasis was exclusively on ethnobotanical data derived from scientific research. Consequently, the criteria for selecting references were stringent. Each reference had to be an original work, providing clear and detailed information on several key aspects: the scientific name of the plant, the geographic area of the study, the date of the research, and the ethnic groups involved. This level of detail is crucial for ensuring the accuracy and reliability of our data. In line with this focus, we excluded sources such as cooking books and other non-scientific publications that did not specify the scientific names of plants. Such sources, while valuable in cultural and culinary contexts, did not meet the scientific rigor required for this ethnobotanical review. This approach underscores our commitment to a high standard of scholarly research and contributes to the reliability and validity of our findings.

2.2. Data management

In our research, the term 'spice' is specifically defined in line with the Economic Botany Data Collection Standard (EBDCS) as per [21], particularly under the category 'Food Additives' at Level 1. Within this category, 'spice' encompasses any flavoring agent, which includes plants classified as herbs or spices according to the EBDCS framework.

In this study, we begin by providing broad definitions of both herbs and spices. Herbs are typically the leafy green parts of plants, used fresh or dried for their aromatic, culinary, and medicinal properties. Spices, on the other hand, are derived from various other parts of the plant, such as roots, bark, seeds, flowers, fruit, and stems, and are usually used in dried form for their flavor, color, or preservative qualities, as well as their medicinal properties. However, the distinction between these two groups is not always clear-cut. Therefore, we use the terms "herb" and "spice" interchangeably to refer to this group of plants, without attempting to differentiate between them. This approach acknowledges the overlap in their uses and parts of the plant from which they are derived.

For botanical nomenclature consistency, we utilized the Plants of the World Online (POWO: powo.science.kew.org). Validation of plant names was further conducted using the Flora of Thailand, recent Thai plant taxonomic literature. The classification of plants into native or exotic species was based on the Thai plant names from Tem Smitinand's Thai Plant Name [22], POWO, and other contemporary taxonomic sources.

2.3. Data analyses

In this study, a 'plant use' for a particular species is identified as a use that is linked with a distinct combination of specific use to specific part to specific to a certain ethnic group. A ′use-report' refers to the mention of a 'plant use' in a scholarly source [23]. For instance, consider a spice plant, species A. If in the literature, the leaves of species A are documented as being used for flavoring meat dish by one ethnic group and as its fruits used as spice in cooking (culinary spice) by another ethnic group, this would be recorded as two separate use-reports for species A.

The important wild herbs and spices utilized in culinary applications were analyzed based on their percentage frequency of use. For those used in medicinal contexts, the analysis was conducted using the Use Value (UV) [24]. Statistical analyses were conducted using R version 4.2.2. The distribution of genus, species, and use reports among key plant families, as well as their taste and scent, was analyzed using a Venn diagram, created with the 'vegan' package in R. Additionally, a Chord diagram, created with the 'circlize' package in R, was employed to analyze the relationships between plant families and ethnomedicinal categories.

3. Results

3.1. Diversity of Thai wild herbs and spices

This comprehensive review revealed a total of 46 distinct herbs and spices distributed across Thailand (Table 1). In total, 248 use reports were documented, encompassing 10 families and 26 genera. The Zingiberaceae family emerged as the most significant, boasting the highest number of use reports, genera, and species. Specifically, the genus *Alpinia,* within the Zingiberaceae family distinguished itself by garnering the highest number of use reports (53) and encompassing four species, the most within this family. Other notable families with a high number of use reports included Rutaceae (41 use reports), Lauraceae (32 use reports), and Polygonaceae (26 use reports), as illustrated in Fig. 1.

Further analysis revealed strong correlations within the dataset: a Spearman correlation coefficient of 0.742 between genus and species, 0.629 between genus and use reports (UR), and 0.733 between species and UR.

3.2. Most frequently used Thai wild herbs and spices

In this comprehensive review, nine wild species were cited with the highest frequency include *Alpinia galanga* (64.5 %), *Persicaria odorata* (34.2 %), *Litsea cubeba* (32.9 %), *Citrus hystrix* (31.6 %), *Boesenbergia rotunda* (14.5 %), *Piper sarmentosum* (14.5 %), *Elsholtzia griffithii* (11.8 %), *Zingiber kerrii* (11.8 %) and *Zanthoxylum armatum* (10.5 %) (Table 1).

Table 1
Overview of native plant species utilized as herbs and spices in Thailand.

Species [no. of use report]	Family	% Frequency of use	Part	Scent	Taste	Use purpose	Ethnicity	References
Acmella paniculata (Wall. ex DC.) R.K. Jansen [2]	Asteraceae	2.6	Leaves	citrus, spicy, earthy	Pungent	Used to enhance vegetable spicy soup with a pungent flavor	Lawa Thai Yuan	[42] [42]
Acorus calamus L [3].	Acoraceae	3.9	Leaves	citrus, spicy, woody	Spicy	Amplifies dish aromatics and lessens fishy tastes	Hmong	[43]
			Whole plant	citrus, spicy, woody	Spicy	Amplifies dish aromatics and lessens fishy tastes	Hmong	[44]
Acorus gramineus Aiton [4]	Acoraceae	5.3	Leaves	citrus, spicy	Spicy	Amplifies dish aromatics in traditional chicken soup	Hmong Mien	[43,45] [43]
Alpinia galanga (L.) Willd [49].	Zingiberaceae	64.5	Rhizomes	citrus, spicy, woody	Spicy	Add aromatic essences and fine spicy taste to traditional spicy soup	Karen Thai Yuan	[46,47,48] [49]
						Adds aromatic essences and fine spicy taste to variety of traditional dish	Akha Hmong H'tin Karen Kayah Khamu Lahu Lawa Lisu Mien Shan Tai Lue Thai Thai Yuan Yunnan Chinese	[50,51] [43,44,52] [53,54] [52,55,56,57,58,59] [59] [43,53] [52] [42,43,52,53,60,61,62,63] [52] [43] [59,64,65] [49,51,66] [67] [42,52,59] [52]
						Adds aromatic essences to traditional spicy minced pork/meat salad	Hmong	[66]
						Amplifies dish aromatics and lessens beefy tastes	Lahu	[68]
						Amplifies dish aromatics and lessens fishy tastes	Akha	[69]
			Shoots	citrus, spicy, woody	Spicy	Add aromatic essences and fine spicy taste to traditional spicy soup	Kachin Lahu	[70] [70]
Alpinia malaccensis (Burm.f.) Roscoe [2]	Zingiberaceae	2.6	Rhizomes	citrus, spicy, woody	Spicy	Adds aromatic essence to spicy soup and chili paste	Karen Lawa	[71] [71]
Alpinia roxburghii Sweet [1]	Zingiberaceae	1.3	Entire fruits	citrus, spicy, woody	Spicy	Adds aromatic essence to chili paste	Lisu	[72]
Alpinia zerumbet (Pers.) B.L.Burtt & R.M. Sm [1].	Zingiberaceae	1.3	Rhizomes	citrus, spicy, woody	Spicy	Adds aromatic essence to spicy soup	Mien	[66]
Amomum dealbatum Roxb [1].	Zingiberaceae	1.3	Rhizomes	earthy	Pungent	Adds aromatic essence to chili paste	Hmong	[44]

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Table 1 (*continued*)

Species [no. of use report]	Family	% Frequency of use	Part	Scent	Taste	Use purpose	Ethnicity	References
Boesenbergia rotunda (L.) Mansf. [11]	Zingiberaceae	14.5	Roots	spicy	Spicy	Used in a variety of dishes, especially spicy soup with meat, to provide a fragrant aroma and a hint of spiciness	Hmong Karen Khamu Lawa Tai Lue Thai Thai Yuan	[52] [47,48] [43] [43,54,63] [49] [67,73] [52]
Boesenbergia thorelii (Gagnep.) Loes [2].	Zingiberaceae	2.6	Roots	spicy	Spicy	Adds aromatic essence in traditional chicken soup	Hmong	[43,45]
Cinnamomum bejolghota (Buch.-Ham.) Sweet [1]	Lauraceae	1.3	Barks	spicy, edible, woody	Spicy	Adds aromatic essence	Shan	[65]
Cinnamomum iners (Reinw. ex Nees & T.Nees) Blume [3]	Lauraceae	3.9	Barks	spicy, edible, woody	Spicy	Adds aromatic essence	Karen Khamu Lawa	[71] [43] [43]
Citrus hystrix DC [24].	Rutaceae	31.6	Epicarp	citrus	Pungent	Used in a variety of dishes, particularly in meat-based curries, to impart a fragrant aroma	Akha Lawa Thai Yuan	[50] [42] [42]
			Leaves	citrus	Pungent	Used in a variety of dishes, particularly in meat-based curries, to impart a fragrant aroma	Akha Hmong H'tin Karen Khamu Lawa Mien Shan Tai Lue Thai Thai Yuan	[51] [43,74] [75] [48,55,59] [43] [42,43] [43] [64] [49,51] [67] [42,49]
						Used to add aromatic essence to tradition dishes	Thai	[76]
Curcuma aeruginosa Roxb [1].	Zingiberaceae	1.3	Rhizomes	spicy, edible, earthy	Spicy	Adds aromatic essence	Thai Yuan	[77]
Curcuma campanulata (Kuntze) Škorničk [3].	Zingiberaceae	3.9	Leaves	green	Pungent	Adds aromatic essence to traditional chicken soup	Hmong	[43,45]
			Rhizomes	spicy, edible, earthy	Spicy	Adds aromatic essence to traditional chicken soup	Hmong	[45]
Curcuma parviflora Wall [2].	Zingiberaceae	5.3	Leaves	green	Pungent	Adds aromatic essence to traditional food	Hmong	[45]
			Rhizomes	spicy, edible, earthy	Spicy	Adds aromatic essence to traditional food	Hmong Lawa	[45] [42]
			Whole plant	spicy, edible, earthy, green	Spicy, Pungent	Adds aromatic essence to traditional food	Hmong	[45]
Elsholtzia blanda (Benth.) Benth [1].	Lamiaceae	1.3	Leaves	green, edible	Spicy	Adds aromatic essence to traditional chicken soup	Lawa	[43]
Elsholtzia griffithii Hook.f [9].	Lamiaceae	11.8	Leaves	green, edible	Spicy	Adds aromatic essence to traditional spicy soup	H'tin Karen Shan Tai Lue	[78] [56,57,59,79,80] [64] [49]

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Table 1 (*continued*)

Species [no. of use report]	Family	% Frequency of use	Part	Scent	Taste	Use purpose	Ethnicity	References
							Thai Yuan	[59]
Elsholtzia stachyodes (Link) Raizada & H.O.Saxena [1]	Lamiaceae	1.3	Leaves	green, edible	Spicy	Adds aromatic essence to traditional spicy soup	Shan	[81]
Etlingera coccinea (Blume) S.Sakai & Nagam [2].	Zingiberaceae	2.6	Entire fruits	citrus, spicy	Spicy	Adds aromatic essence to traditional spicy soup	H'tin Lawa	[53] [53]
Hedychium flavum Roxb [1].	Zingiberaceae	1.3	Rhizomes	spicy	Bitter	Adds aromatic essence to traditional chicken soup	Hmong	[43]
Hedychium stenopetalum G. Lodd [1].	Zingiberaceae	1.3	Rhizomes	spicy	Bitter	Adds aromatic essence to traditional chicken soup	Hmong	[45]
Kaempferia parviflora Wall. ex Baker [2]	Zingiberaceae	2.6	Leaves	spicy, green	Spicy	Adds aromatic essence to traditional chicken soup	Hmong	[45]
			Rhizomes	spicy	Spicy	Adds aromatic essence to traditional dishes	Lawa	[43]
Kaempferia rotunda L [2].	Zingiberaceae	2.6	Rhizomes	spicy	Spicy	Adds aromatic essence to traditional chicken soup	Hmong	[45]
						Adds aromatic essence to traditional spicy soup or chili paste	Karen	[57]
Lanxangia coriandriodora (S. Q.Tong & Y.M. Xia) M.F.Newman & Škorničk [3].	Zingiberaceae	3.9	Leaves	spicy, green	Pungent	Adds aromatic essence to traditional soup or spicy soup	Hmong	[45]
			Rhizomes	spicy	Pungent	Adds aromatic essence to traditional soup or spicy soup	Hmong	[45]
Limnophila laotica Bonati [1]	Plantaginaceae	1.3	Leaves	citrus, spicy	Spicy	Adds aromatic essence to traditional dishes	Karen	[80]
Limnophila rugosa (Roth) Merr [2].	Plantaginaceae	2.6	Leaves	citrus, spicy	Spicy	Adds aromatic essence to traditional dishes	Hmong Thai Yuan	[45] [42]
Lipoblepharis urticifolia (Blume) Orchard [1]	Asteraceae	1.3	Leaves	spicy, green	Spicy	Used to enhance vegetable spicy soup with a pungent flavor	Thai Yuan	[42]
Litsea cubeba (Lour.) Pers [25].	Lauraceae	32.9	Entire fruits	citrus	Spicy	Adds aromatic essence to spicy bamboo soup	Hmong	[45]
						Used as piper (Piper nigrum) substitute	Lisu	[82]
						Used to add aromatic essence to chili paste	Akha Karen	[69] [58]
						Used to add aromatic essence with fine spicy taste to spicy bamboo soup	Karen	[46]
						Used to add aromatic essence	H'tin Karen Lahu	[53,78] [57,59,63,71,83] [70]

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Table 1 (*continued*)

Species [no. of use report]	Family	% Frequency of use	Part	Scent	Taste	Use purpose	Ethnicity	References
						with fine spicy taste to tradition dishes	Lawa	[43,53,60,61,71, 84,85]
							Shan	[59]
Litsea elongata (Nees) Hook.f [1].	Lauraceae	1.3	Entire fruits	citrus	Spicy	Used to add aromatic essence with fine spicy taste to tradition dishes	Lawa	[84]
Melicope pteleifolia (Champ. ex Benth.) T.G. Hartley [5]	Rutaceae	6.6	Entire fruits	citrus	Bitter	Adds aromatic essences to spicy meat soup	Thai Yuan	[42]
			Leaves	citrus	Bitter	Adds aromatic essence to chili paste	Lahu	[68]
						Adds aromatic essence to chili paste or spicy soup	Karen	[56,59]
						Adds aromatic essences to spicy meat soup	Thai Yuan	[42]
Neolitsea zeylanica (Nees & T.Nees) Merr [1].	Lauraceae	1.3	Whole plant	spicy	Spicy	Used to add aromatic essence with fine spicy taste to tradition dishes	Thai Yuan	[42]
Oenanthe javanica (Blume) DC [3].	Apiaceae	3.9	Leaves	edible	Sweet	Adds aromatic essence to traditional spicy soup	Hmong	[43]
							Lawa	[43]
						Used to add aromatic essence to tradition dishes	Hmong	[52]
Persicaria odorata (Lour.) Soják [26]	Polygonaceae	34.2	Leaves	spicy	Pungent	Adds aromatic essences to traditional spicy minced pork/meat salad	Hmong	[43,52]
							Karen	[47,48,52,55,79]
							Khamu	[43]
							Lawa	Pongamornkul (2006a) [60], [43], [62], [52], [42]
							Mien	[43,59,66]
							Shan	[64,65]
							Tai Lue	[49,66]
							Thai Yuan	[42,49,52,86]
							Yunnan Chinese	[70]
Phoebe lanceolata (Nees) Nees [1]	Lauraceae	1.3	Entire fruits	spicy	Bitter	Used to add aromatic essence with fine spicy taste to tradition dishes	Lawa	[84]
Piper pedicellatum C.DC [1].	Piperaceae	1.3	Leaves	spicy	Spicy, Pungent, Bitter	Used to add fine spicy taste to tradition dishes	Lahu	[68]
Piper ribesioides Wall [3].	Piperaceae	3.9	Stems	spicy	Spicy, Pungent, Bitter	Add aromatic essences and fine spicy taste to traditional spicy soup	Mien	[66]
						Used to add fine spicy taste to tradition dishes	Thai Yuan	[42,87]
Piper sarmentosum Roxb [11].	Piperaceae	14.5	Leaves	spicy	Spicy, Pungent, Bitter	Add aromatic essences and fine spicy taste to Karen traditional spicy rice soup “Khao Ber"	Karen	[79]
						Adds aromatic essence to	H’tin	[75]
							Karen	[56,88]
							Lawa	[60]

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Table 1 (*continued*)

Species [no. of use report]	Family	% Frequency of use	Part	Scent	Taste	Use purpose	Ethnicity	References
						traditional spicy soup	Thai Yuan	[59]
						Adds aromatic essences to spicy bamboo soup	Mien	[59]
							Tai Lue	[66]
						Used to add aromatic essence with fine spicy taste to tradition dishes	Hmong	[44]
							Karen	[48,52]
Piper wallichii (Miq.) Hand.-Mazz [2].	Piperaceae	2.6	Stems	spicy	Spicy, Pungent, Bitter	Used to add fine spicy taste to tradition dishes	Lawa	[62]
							Thai Yuan	[52]
Psammogeton involucratus (Roxb.) Mousavi, Mozaff. & Zarre [4]	Apiaceae	5.3	Leaves	Aromatic	edible	Adds aromatic essence to traditional spicy soup	Khamu	[43]
							Lawa	[43]
							Mien	[43]
							Yunnan Chinese	[52]
Wurfbainia testacea (Ridl.) Škorničk. & A.D.Poulsen [3]	Zingiberaceae	3.9	Entire fruits	spicy	Spicy	Used to add aromatic essence with fine spicy taste to tradition dishes	Karen	[48]
Wurfbainia vera (Blackw.) Škorničk. & A.D. Poulsen [1]	Zingiberaceae	1.3	Seeds	spicy	Spicy	Used to add aromatic essence with fine spicy taste to tradition dishes	Karen	[88]
Wurfbainia villosa (Lour.) Škorničk. & A.D.Poulsen var. *xanthioides* (Wall. ex Baker) Skornick. & A.D. Poulsen [2]	Zingiberaceae	2.6	Entire fruits	spicy	Spicy	Used to add aromatic essence with fine spicy taste to tradition dishes	Karen	[52]
Zanthoxylum acanthopodium DC [4].	Rutaceae	5.3	Entire fruits	spicy, citrus, green	Spicy, Pungent	Adds aromatic essences to traditional spicy minced pork/meat salad	Karen	[59]
						Used to add aromatic essence with fine spicy taste to tradition dishes	Hmong	[43]
							H'tin	[78]
							Lawa	[53]
Zanthoxylum armatum DC [8].	Rutaceae	10.5	Entire fruits	spicy, citrus, green	Spicy, Pungent	Adds aromatic essences to traditional spicy minced pork/meat salad	Karen	[56]
						Used to add aromatic essence with fine spicy taste to tradition dishes	Akha	[51]
							Karen	[71]
							Lawa	[70]
							Tai Lue	[51]
							Yunnan Chinese	[70]
			Leaves	spicy, citrus, green	Spicy, Pungent	Adds aromatic essence to traditional spicy soup	Lawa	[71]
						Adds aromatic essences to traditional spicy minced pork/meat salad	Karen	[56]
Zingiber kerrii Craib [9]	Zingiberaceae	11.8	Leaves	spicy	Spicy	Adds aromatic essence to traditional spicy soup	Khamu	[43]
							Lawa	[43]
							Mien	[43]

(*continued on next page*)

Table 1 (*continued*)

Species [no. of use report]	Family	% Frequency of use	Part	Scent	Taste	Use purpose	Ethnicity	References
						Adds aromatic essences to spicy bamboo soup	Mien	[59]
						Used to add aromatic essence with fine spicy taste to tradition dishes	Thai Yuan	[52]

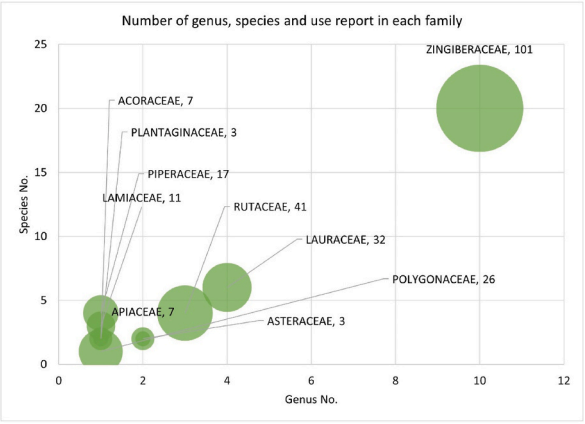

Fig. 1. Bubble chart illustrating the distribution of genus, species, and use reports among key plant families in Thailand's ethnobotany. Each bubble's size represents the number of use reports.

Alpinia galanga is a rhizomatous spice commonly grown in home gardens and used by many ethnic groups to add aromatic essences and a refined spicy flavor to traditional spicy soup and various other dishes. It also helps to diminish strong beefy and fishy tastes. *Alpinia galanga* serves a dual function as both a spice and an herbal medicine. It is a nutraceutical plant, meaning it offers medical or health benefits, particularly for digestive system disorders such as flatulence, constipation, and other carminative issues.

Persicaria odorata is a small potted spice commonly found in home gardens. Many ethnic groups use its fresh leaves to add aromatic essences to traditional spicy minced pork or meat salads.

Litsea cubeba is a seasonal spice found in forests whose fresh or dried fruits add an aromatic essence to spicy bamboo soup, chili paste, and traditional dishes. Many ethnic groups, especially in northern Thailand, use it as a substitute for black pepper (*Piper nigrum*).

Citrus hystrix is a thorny shrub or small tree grown in home gardens whose fresh or dried leaves and epicarp are used in various dishes, particularly meat-based curries, to impart a fragrant aroma. It is also utilized for its benefits in activating the circulatory system and serving as a carminative.

Boesenbergia rotunda is a rhizomatous spice found in both home gardens and forests. Its fresh roots and rhizomes are used in various dishes, especially spicy meat soups, to provide a fragrant aroma and a hint of spiciness.

Piper sarmentosum is a perennial herb with creeping rhizomes commonly grown in home gardens. Its fresh leaves add aromatic essences and a refined spicy flavor to traditional spicy soups, including the Karen traditional spicy rice soup "Khao Ber."

Elsholtzia griffithii is a seasonal spice extensively cultivated in upland rice fields by ethnic peoples of northern Thailand. Its fresh or dried leaves and flowers add aromatic essence to traditional spicy soups.

Zingiber kerrii is a rhizomatous spice native to forests. Its fresh leaves impart aromatic essences to spicy bamboo soup and add a refined spicy taste to traditional dishes. All parts of this plant are used in traditional medicine to treat flatulence, diarrhea, act as a carminative, relieve headaches, and detoxify mushrooms.

Zanthoxylum armatum is a seasonal wild spice traditionally used in northern Thailand. Local people use its fruits and seeds to add aromatic essences and a refined spicy flavor to traditional dishes like spicy minced pork or meat salad and spicy soup. Related to the Chinese Sichuan pepper (*Z. simulans* Hance) but less pungent.

3.3. Tastes and scents of Thai wild herbs and spices

A comprehensive review identified a total of 46 distinct wild herbs and spices distributed across Thailand, classified into four basic taste categories: bitter, spicy, sweet, and pungent. Some wild herbs and spices exhibit more than one taste. Thai wild herbs and spices are predominantly known for their spicy tastes (35 species) and pungent tastes (13 species) (Table 1 and Fig. 2). Eight species exhibit

both spicy and pungent tastes, including *Curcuma campanulata*, *C. parviflora*, *Piper pedicellatum*, *P. ribesioides*, *P. sarmentosum*, *P. wallichii*, *Zanthoxylum acanthopodium*, and *Z. armatum*. Four species offer spicy, pungent, and bitter tastes: *P. pedicellatum*, *P. ribesioides*, *P. sarmentosum*, and *P. wallichii*.

A total of 46 distinct wild herbs and spices classified into five basic scent categories: woody, spicy, green, earthy, and citrus. Some wild herbs and spices exhibit more than one scent. Thai wild herbs and spices are predominantly known for their spicy scents (36 species) and citrus scents (24 species) (Table 1 and Fig. 3). Twelve species exhibit both spicy and citrus scents, including *Acmella paniculate*, *Acorus calamus*, *A. gramineus*, *Alpinia galanga*, *A. malaccensis, A. roxburghii, A. zerumbet, Etlingera coccinea, Limnophila laotica, L. rugosa, Zanthoxylum acanthopodium, Z. armatum*. Five species offer spicy, citrus, and woody scents: *Acorus calamus*, *Alpinia galanga*, *A. malaccensis, A. roxburghii, A. zerumbet*.

3.4. Ethnomedicinal properties of Thai herbs and spices

In the course of our investigation, it was found that 41 out of the 46 species of Thai herbs and spices examined had been reported for their ethnomedicinal properties, as evidenced by a compilation of 688 use reports spanning 22 distinct categories (Supplementary Table 1).

The analysis revealed that the predominant categories of plant use included treatments for digestive system disorders, with 29 species supported by 174 use reports; infection-related disorders, addressed 18 species with 92 use reports; muscle-related disorders, addressed by 21 species with 60 use reports; and body strengthening, for which 20 species had been cited in 58 use reports (Fig. 4).

Among the significant spice families with noted ethnomedicinal properties, the Zingiberaceae family was predominant, with 272 use reports, primarily for treating digestive system disorders (Fig. 5). This was followed by the Acoraceae family, with 145 use reports, where *Acorus calamus* was particularly highlighted for its use in treating digestive and infectious disorders. Other notable families included Rutaceae, Lauraceae, and Piperaceae, with 87, 86, and 69 use reports respectively (Supplementary Table 1).

The three spices with the highest number of medicinal use reports were *Acorus calamus, Alpinia galanga*, and *Piper sarmentosum*. *Acorus calamus*, an aromatic plant, was reported in 131 use reports, predominantly for fever conditions and digestive system disorders. *Alpinia galanga*, with 60 use reports, was chiefly employed for digestive disorders, such as flatulence. *Piper sarmentosum,* documented in 58 use reports, was recognized for its versatility in treating a range of conditions, including digestive disorders, as a tonic, and used for enhancing the circulatory system (Supplementary Table 1).

4. Discussion

4.1. Cultural significance of wild herbs and spices in Thailand

Wild herbs and spices hold profound cultural significance in local areas of Thailand, deeply intertwined with the culinary traditions and medicinal practices of various ethnic groups. Some native herbs and spices are used based on their presence in different regional territories [11]. For example, *Elsholtzia* spp. and *Zanthoxyllum* spp. are found in both natural forests and cultivated upland rice fields [25,26], but only in the highlands of northern Thailand. Additionally, certain species such as *Alpinia roxburghii*, *Amomum dealbatum*, and *Phoebe lanceolata* etc. are uniquely utilized by specific ethnic groups, reflecting the rich biodiversity and cultural diversity of the region.

The entwined history of Thai cuisine with non-native spices reveals a complex tapestry of cultural exchange and adaptation. Iconic Thai dishes, renowned worldwide, often incorporate ingredients like lemongrass (*Cymbopogon citratus*), shallot (*Allium ascalonicum*), and chili (*Capsicum annuum*), which, despite their integral role in Thai cuisine, are not indigenous to the country. This highlights a dynamic aspect of Thailand's culinary heritage, where the assimilation of foreign spices has enriched its gastronomic identity [27].

However, data from comprehensive reviews show a relatively modest number of distinct spice and herb species within Thailand's ethnobotanical studies, especially compared to the extensive catalog of medicinal plants [17]and food plants [18] documented in the

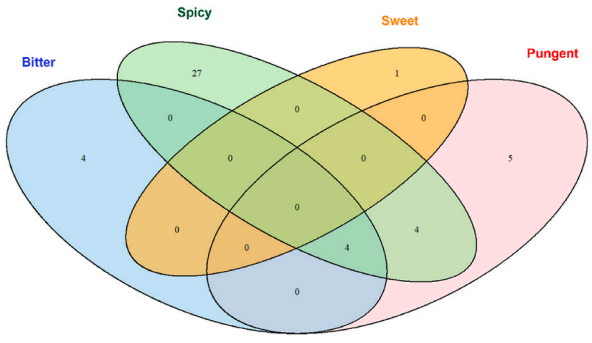

Fig. 2. Venn diagram illustrating the tastes of Thai wild herbs and spices (**Bitter:** Lauraceae, Piperaceae, Rutaceae, Zingiberaceae; **Spicy:** Acoraceae, Asteraceae, Lamiaceae, Lauraceae, Piperaceae, Plantaginaceae, Rutaceae, Zingiberaceae; **Sweet:** Apiaceae; **Pungent:** Piperaceae, Polygonaceae, Rutaceae, Zingiberaceae).

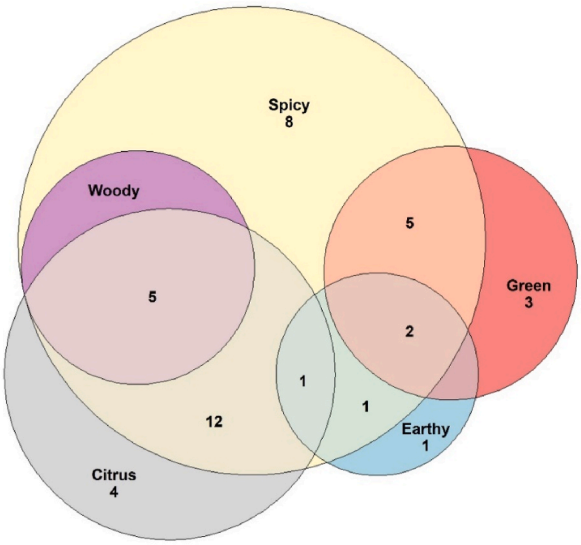

Fig. 3. Venn diagram illustrating the scents of Thai wild herbs and spices (**Woody:** Acoraceae, Lauraceae, Lauraceae, Zingiberaceae; **Spicy:** Asteraceae, Lauraceae, Lauraceae, Lauraceae, Piperaceae, Plantaginaceae, Polygonaceae, Rutaceae, Zingiberaceae; **Green:** Asteraceae, Lamiaceae, Rutaceae, Zingiberaceae; **Earthy:** Asteraceae, Zingiberaceae; **Citrus:** Acoraceae, Asteraceae, Lauraceae, Plantaginaceae, Rutaceae, Zingiberaceae).

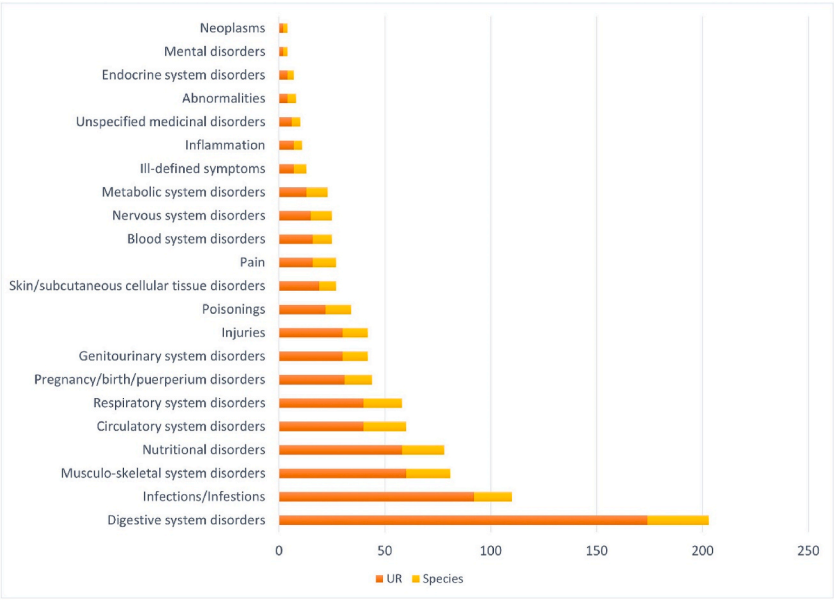

Fig. 4. Comparing the number of use report and diversity of wild spices and herbs in treating various disease categories.

region. This discrepancy underscores a notable gap in ethnobotanical studies in Thailand, where spices have historically been overlooked or submerged within broader food plant categories. The importance of delineating spices from general food plants lies in recognizing their unique cultural, medicinal, and culinary roles, a distinction underscored in seminal works such as those by Cook [21]. This separation facilitates a deeper understanding of the specific uses and significances of spices beyond their nutritional value, aligning with global ethnobotanical practices that appreciate the multifaceted contributions of spices to health, cuisine, and culture [1].

4.2. Most favored tastes and scents of Thai wild herbs and spices

Thai wild herbs and spices are predominantly known for their spicy and pungent tastes, as well as their distinctive spicy and citrus scents. Most of them are fragrant due to the presence of terpenes, which are scent molecules found in all plants and serve as a major

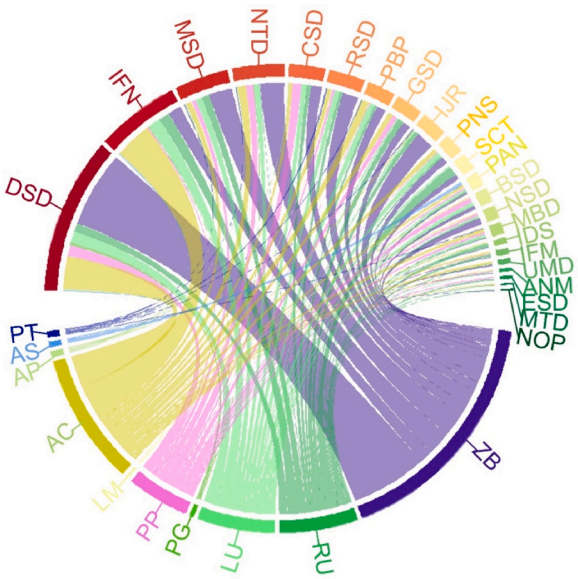

Fig. 5. Chord diagram illustrate the relationships between plant families and ethnomedicinal categories (**Plant family** ZB: Zingiberacece; RU: Rutaceae; LU: Lauraceae; PG: Polygonaceae; PP: Piperaceae; LM: Lamiaceae; AC: Acoraceae; AP: Apiaceae; AS: Asteraceae; PT: Plantaginaceae; **Ethnomedicinal categories** DSD: Digestive system disorders; IFN: Infections/Infestions; MSD: Musculo-skeletal system disorders; NTD: Nutritional disorders; CSD: Circulatory system disorders; RSD: Respiratory system disorders; PBP: Pregnancy/birth/puerperium disorders; GSD: Genitourinary system disorders; IJR: Injuries; PSN: Poisonings; SCT: Skin/subcutaneous cellular tissue disorders; PAN: Pain; BSD: Blood system disorders; NSD: Nervous system disorders; MBD: Metabolic system disorders; IDS: Ill-defined symptoms; IFM: Inflammation; UMD: Unspecified medicinal disorders; ANM: Abnormalities; ESD: Endocrine system disorders; MTD: Mental disorders; NOP: Neoplasms).

component of essential oils. Spicy tastes are deeply embedded in Thai culinary traditions, prominently featuring many wild herbs and spices. The hot and humid climate of Thailand also contributes to this preference, as spicy foods can induce sweating, helping to cool the body. Additionally, spicy foods are believed to offer several health benefits, including boosting metabolism, reducing inflammation, and acting as natural preservatives. However, the spicy taste from native Thai herbs and spices is increasingly being replaced by exotic species like chili peppers. It is crucial to address this trend to preserve valuable traditional knowledge. Therefore, the promotion and further study of these wild herbs and spices are essential.

4.3. Ethnomedicinal use of spices and herbs in Thailand

Despite the documentation of ethnomedicinal properties in 41 out of 47 species examined, the correlation between their usage as food flavoring agent and for medicinal purposes was notably low (r = 0.34) (Fig. 6). This finding indicates a limited quantitative

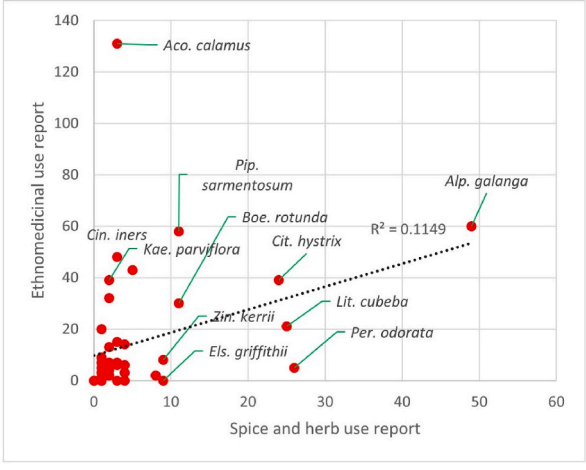

Fig. 6. Correlation between the use of species as spice and herb and their ethnomedicinal applications.

association between the culinary and medicinal recognition of these plants in Thai ethnobotanical studies.

For example, *Acorus calamus*, was reported only three times for its use as an aromatic ingredient to mitigate fishy tastes in dishes in Hmong dishes (Table 1). However, this plant is widely utilized by various ethnic groups for treating a variety of ailments, particularly those related to the digestive system and fever (Fig. 4). The rhizome extract of *Acorus calamus* contains Asarone as the major compound which substantially enhanced ampicillin efficacy through its primary mode of action, bacterial membrane damage [28]. This disparity suggests that the comprehensive medicinal uses of spices and herbs are not fully captured through their culinary applications alone.

However, certain species, such as *Alpinia galanga*, *Citrus hystrix*, and *Litsea cubeba*, have been frequently acknowledged for both their culinary and medicinal benefits, indicating some level of recognition of their dual utility. The GC-MS analysis revealed that *Alpinia galanga* rhizome extract is a rich source of β-turmerone and α-turmerone, demonstrating cytotoxic, antibacterial, and antioxidant properties that reduce the risk of complex diseases and promote apoptosis in MCF-7 and HepG2 cells, highlighting its potential as a bioactive natural product for pharmaceutical applications, though further in-depth studies are required to explore its mechanisms and therapeutic effects [29]. Phytochemical compounds, including β-pinene, sabinene, citronellal, and citronellol, have been detected in the *Citrus hystrix*; and its extract exhibited potential antidiabetic, antihyperlipidemic and anti-obesity activity, as well as prevention of development of hypertension [30]. Antinociceptive activities were documented for various major compounds of the *Litsea cubeba* as good sources of antinociceptive compounds that can be further developed to complement or substitute prescription drugs for pain management [31].

These examples highlight the dual functionality of these species, underscoring their culinary significance and medicinal applications. Other species, such as *Piper sarmentosum* and *Boesenbergia rotunda*, further exemplify this versatility. Their bioactive compounds contribute not only to enhancing flavors but also to addressing various health conditions, demonstrating the immense potential of these plants as natural resources for both gastronomy and therapeutic innovation.

On the other hand, a herb like *Persicaria odorata* is well known for its use as an aromatic herb, but its ethnomedicinal properties are not widely recognized. However, the phytochemical study showed that *Persicaria odorata* leaves contained lots compounds such as alkaloids, tannins, anthraquinone, flavonoids, terpenoids, coumarins, saponins and reducing compounds. The study showed that in ethanolic and aqueous extracts the medicinal potential of *Persicaria odorata* leaves and the positive relation between the total content of polyphenols and antioxidant activities [32].

The disconnect between culinary and medicinal use reports could be attributed to a general lack of awareness about the medicinal properties of spices and herbs. Additionally, this disparity may also stem from ethnobotanical research methodologies that primarily focus on documenting medicinal properties, with fewer studies exploring the uses of spices and herbs. This focus could possibly result in an underrepresentation of the health benefits of these plants in ethnobotanical literature.

Many studies focus primarily on either culinary or medicinal uses, without explicitly investigating the overlap or separation of knowledge domains. For instance, an ethnobotanical survey of culinary herbs and spices in Nkonkobe Municipality, South Africa [33], examined both culinary and medicinal uses of herbs and spices. The study revealed a significant overlap, with plants such as *Lippia javanica* utilized for both purposes [33]. However, the analysis did not address whether the knowledge of these dual uses resided with the same informants or whether expertise in culinary and medicinal applications was compartmentalized among different individuals.

Similarly, a study on the Calabrian villages in Southern Italy [34] observed that ethnobotanical knowledge was better preserved when linked to household food security or recreational foraging activities [34]. This suggests that culinary knowledge, which is closely tied to daily sustenance or social practices, may be more robust due to its regular use and communal nature. In contrast, medicinal plant knowledge, which may often be reserved for traditional healers or specific situations, could be at greater risk of erosion if it is less frequently utilized or shared outside specialist contexts. These differences in preservation underscore the potential compartmentalization of knowledge within communities, where culinary uses are widely distributed, but medicinal knowledge may be more isolated and specialized. This highlights the need for further research to explicitly investigate how knowledge about the dual uses of plants is organized and transmitted among different social groups.

Further research should also explore the role of social factors in shaping knowledge organization. Gender roles, age, and social status likely influence access to and transmission of specific types of knowledge. Investigating how these factors interact to compartmentalize or integrate culinary and medicinal plant knowledge could provide deeper insights into the dynamics of ethnobotanical knowledge systems.

Highlighting the medicinal properties of spices and herbs could significantly promote public health [35], encouraging the use of local ingredients. This approach not only supports health benefits associated with these plants but also contributes to lowering both the carbon and biodiversity footprints by advocating for the utilization of locally sourced botanical resources [36]. By emphasizing these benefits, there's potential to foster a greater appreciation for the medicinal uses of spices and herbs, promoting a more sustainable and health-conscious approach to using local botanicals.

Digestive system ailments emerge as a primary focus of treatment with spices and herbs within the Thai ethnobotanical context. This prominence is likely due to the dominance of the Zingiberaceae family among the reported species, a family well known for its properties in treating digestive system disorders [20,37,38].

The volatile oils present in spices and herbs, which provide aromatic scents, are favored not only for culinary use to enhance dish aromatics but are also recognized for their effectiveness in treating digestive system disorders [39]. Therefore, besides the Zingiberaceae family, many other plants with aromatic volatile oils have been reported for their use in treating digestive disorders, e.g., *Acorus calamus* (Acoraceae), *Piper sarmentosum* (Piperaceae), and *Melicope pteleifolia* (Rutaceae). These plants, spanning a variety of families, leverage the therapeutic properties of their essential oils to aid in digestion, alleviate gastrointestinal discomfort, and address a range of digestive system ailments, showcasing the widespread applicability of aromatic compounds in ethnobotanical medicine.

Additionally, fever treatment, particularly highlighted by the use reports from *Acorus calamus* (40 out of 92), underscores the

plant's significant role in traditional medicine. *Acorus calamus* is widely used for fever treatment across various ethnic groups in Thailand, a practice that is echoed in other countries as well [40]. Its widespread use could be attributed to its proven efficacy in reducing fever, supported by pharmacological studies that identify its bioactive compounds with antipyretic properties [40,41].

Moreover, the capacity of many spices and herbs to address a spectrum of health conditions illustrates the complex phytochemical profiles of these plants. Such versatility in treatment efficacy highlights the deep-rooted knowledge within Thai traditional medicine and the holistic approach to health that characterizes the local culture. This underscores the importance of further research to explore the full ethnomedicinal potential of these species, ensuring their benefits are comprehensively understood and leveraged for broader health applications.

5. Conclusions

This ethnobotanical review highlights the rich tradition and widespread use of native herbs and spices across various regions of Thailand. Despite their significant cultural and culinary importance, the study identifies a relatively limited representation of these species in ethnobotanical literature, especially compared to the extensive documentation of medicinal and food plants in the region. These findings underscore the importance of adopting a more detailed approach in ethnobotanical research, one that distinguishes between the culinary and medicinal roles of spices and herbs. Such an approach is crucial for fully understanding and preserving their unique contributions to both dietary practices and traditional medicine in Thailand.

The study's focus on the ethnomedicinal uses of spices and herbs highlighted their significant role in treating ailments, especially digestive system disorders and fevers, attributed largely to the therapeutic properties of volatile oils present in these plants. However, the correlation between their use as food flavoring agents and for medicinal purposes was notably low, indicating a disconnect in the recognition of these plants' dual utility within the existing body of research. This discrepancy points towards both a lack of awareness and a methodological bias in ethnobotanical studies, which have traditionally emphasized medicinal over culinary uses.

In conclusion, this review calls for an expansion of ethnobotanical research to cover the diverse geographical and cultural landscapes of Thailand. By adopting a more inclusive and differentiated approach to the study of wild herbs and spices, future research can uncover the untapped potential of these plants, contributing to the global appreciation of traditional botanical knowledge and supporting the conservation of medicinal plant use in Thailand. Further exploration is essential not only to bridge the existing knowledge gaps but also to promote the sustainable and health-conscious use of local botanical resources, thereby enhancing public health and preserving the rich tapestry of Thailand's ethnobotanical heritage.

CRediT authorship contribution statement

Angkhana Inta: Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Prateep Panyadee:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Ratchuporn Suksathan:** Writing – review & editing, Investigation. **Wittaya Pongamornkul:** Writing – review & editing, Investigation. **Kittiyut Punchay:** Writing – review & editing, Investigation. **Terd Disayathanoowat:** Writing – review & editing, Investigation. **Natcha Chaisoung:** Writing – review & editing, Formal analysis, Conceptualization. **Thirawut Phichonsatcha:** Writing – review & editing, Investigation. **Katesarin Maneenoon:** Writing – review & editing, Investigation. **Lixin Yang:** Writing – review & editing, Investigation.

Data and code availability

Data included in the article/supplementary material is referenced in the article.

Funding

This research was funded by the Suvannabhumi Project provided by the Thailand Academy of Social Sciences, Humanities and Arts (TASSHA), Ministry of Higher Education, Thailand Science Research and Innovation. In addition, Chiang Mai University partially supported this study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

We would like to acknowledge the Suvannabhumi Project provided by the Thailand Academy of Social Sciences, Humanities and Arts (TASSHA), Ministry of Higher Education, Thailand Science Research and Innovation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2025.e42470.

References

[1] T.R. Ramkumar, S. Karuppusamy, Plant diversity and ethnobotanical knowledge of spices and condiments, in: Bioprospecting of Plant Biodiversity for Industrial Molecules, 2021, pp. 231–260.
[2] M.N. García-Casal, J.P. Peña-Rosas, H.G.-. Malavé, Sauces, spices, and condiments: definitions, potential benefits, consumption patterns, and global markets, Ann. N. Y. Acad. Sci. 1379 (2016) 3–16, https://doi.org/10.1111/nyas.13045.
[3] W. Wang, K.T.K. Nguyen, C. Zhao, H.-c. Hung, Earliest curry in Southeast Asia and the global spice trade 2000 years ago, Sci. Adv. 9 (2023) eadh5517, https://doi.org/10.1126/sciadv.adh5517.
[4] M. Van der Veen, J. Morales, The Roman and Islamic spice trade: new archaeological evidence, J. Ethnopharmacol. 167 (2015) 54–63, https://doi.org/10.1016/j.jep.2014.09.036.
[5] C.F. Gorman, Excavations at Spirit Cave, North Thailand: Some Interim Interpretations, 1972.
[6] L. Diniz do Nascimento, A.A.B.d. Moraes, K.S.d. Costa, J.M. Pereira Galúcio, P.S. Taube, C.M.L. Costa, J. Neves Cruz, E.H. de Aguiar Andrade, L.J.G.d. Faria, Bioactive natural compounds and antioxidant activity of essential oils from spice plants: new findings and potential applications, Biomolecules 10 (2020) 988.
[7] K.P.P. Nair, 1 - the agronomy and economy of black pepper (*piper nigrum* L.)—the "king of spices", in: K.P.P. Nair (Ed.), Agronomy and Economy of Black Pepper and Cardamom, Elsevier, London, 2011, pp. 1–108.
[8] B. Kabak, A.D.W. Dobson, Mycotoxins in spices and herbs–An update, Crit. Rev. Food Sci. Nutr. 57 (2017) 18–34, https://doi.org/10.1080/10408398.2013.772891.
[9] K.P.P. Nair, 2 - the agronomy and economy of cardamom (*elettaria cardamomum* M.): the "queen of spices", in: K.P.P. Nair (Ed.), Agronomy and Economy of Black Pepper and Cardamom, Elsevier, London, 2011, pp. 109–366.
[10] Y.R. Sarma, K.N. Babu, S. Aziz, Spices and aromatics, in: N.K. Van Alfen (Ed.), Encyclopedia of Agriculture and Food Systems, Academic Press, Oxford, 2014, pp. 211–234.
[11] R. Motti, Wild plants used as herbs and spices in Italy: an ethnobotanical review, Plants 10 (2021) 563, https://doi.org/10.3390/plants10030563.
[12] Ł. Łuczaj, A. Pieroni, J. Tardío, M. Pardo-de-Santayana, R. Sõukand, I. Svanberg, R. Kalle, Wild food plant use in 21st century Europe: the disappearance of old traditions and the search for new cuisines involving wild edibles, Acta Soc. Bot. Pol. 81 (2012) 359–370.
[13] A. Pieroni, S. Nebel, R.F. Santoro, M. Heinrich, Food for two seasons: culinary uses of non-cultivated local vegetables and mushrooms in a south Italian village, Int. J. Food Sci. Nutr. 56 (2005) 245–272, https://doi.org/10.1080/09637480500146564.
[14] J. Maxwell, A synopsis of the vegetation of Thailand, Tropical Natural History 4 (2004) 19–29.
[15] P.C. van Welzen, A. Madern, N. Raes, J. Parnell, D. Simpson, C. Byrne, T. Curtis, J. Macklin, A. Trias-Blasi, A. Prajaksood, The current and future status of floristic provinces in Thailand. In *Land use, climate change and biodiversity modeling: perspectives and applications*, IGI Global (2011) 219–247.
[16] S. Hidayati, F.M. Franco, R.W. Bussmann, Ready for phase 5-current status of ethnobiology in Southeast Asia, J. Ethnobiol. Ethnomed. 11 (2015) 17.
[17] M. Phumthum, K. Srithi, A. Inta, A. Junsongduang, K. Tangjitman, W. Pongamornkul, C. Trisonthi, H. Balslev, Ethnomedicinal plant diversity in Thailand, J. Ethnopharmacol. 214 (2018) 90–98, https://doi.org/10.1016/j.jep.2017.12.003.
[18] P. Panyadee, P. Wangpakapattanawong, A. Inta, H. Balslev, Very high food plant diversity among ethnic groups in northern Thailand, Diversity 15 (2023) 120.
[19] N. Sutjaritjai, P. Panyadee, M. Phumthum, A. Inta, H. Balslev, High diversity of medicinal uses of Thai legumes (Fabaceae) and their potential in public herbal medicine, Diversity 14 (2022) 588.
[20] A. Inta, C. Trisonthi, W. Pongamornkul, P. Panyadee, Ethnobotany of Zingiberaceae in Mae Hong Son, northern Thailand, Biodiversitas 24 (2023) 2114–2124, https://doi.org/10.13057/biodiv/d240422.
[21] F.E.M. Cook, *Economic Botany Data Collection Standard*; Whitstable Litho: Kent, Great Britain, 1995.
[22] R. Pooma, S. Suddee, *Thai Plant Names Tem Smitinand Revised Edition 2014*; Office of the Forest Hrbarium, Department of National Park, Ildlife and Plant Conservation, Bangkok, 2014.
[23] R. Cámara-Leret, Z. Dennehy, Indigenous knowledge of new Guinea's useful plants: a Review1, Econ. Bot. 73 (2019) 405–415, https://doi.org/10.1007/s12231-019-09464-1.
[24] B. Hoffman, T. Gallaher, Importance indices in ethnobotany, Ethnobot. Res. Appl. 5 (2007) 201–218.
[25] B. Bongcheewin, P. Chantaranothai, Two new records of *Elsholtzia* willd. (Lamiaceae) for Thailand, Tropical Natural History 8 (2008) 1–5.
[26] A. Junsongduang, H. Balslev, A. Inta, A. Jampeetong, P. Wangpakapattanawong, Karen and Lawa medicinal plant use: uniformity or ethnic divergence? J. Ethnopharmacol. 151 (2014) 517–527, https://doi.org/10.1016/j.jep.2013.11.009.
[27] T. Phichonsatcha, D. Pentrakoon, N. Gerdsri, A. Kanjana-Opas, Extending indigenous knowledge to unveil the evolutionary journey of food preferences and socio-cultural phenomena, Appetite 170 (2022) 105884, https://doi.org/10.1016/j.appet.2021.105884.
[28] B. Kongkham, P. Duraivadivel, P. Hariprasad, *Acorus calamus* L. rhizome extract and its bioactive fraction exhibits antibacterial effect by modulating membrane permeability and fatty acid composition, J. Ethnopharmacol. 331 (2024) 118323, https://doi.org/10.1016/j.jep.2024.118323.
[29] I.M. Aziz, A.A. Alfuraydi, O.M. Almarfadi, M.A.M. Aboul-Soud, A.K. Alshememry, A.N. Alsaleh, F.N. Almajhdi, Phytochemical analysis, antioxidant, anticancer, and antibacterial potential of *Alpinia galanga* (L.) rhizome, Heliyon 10 (2024) e37196, https://doi.org/10.1016/j.heliyon.2024.e37196.
[30] H.N. Siti, S. Mohamed, Y. Kamisah, Potential therapeutic effects of *Citrus hystrix* DC and its bioactive compounds on metabolic disorders, Pharmaceuticals 15 (2022), https://doi.org/10.3390/ph15020167.
[31] M.P.Y. Goh, R.N. Samsul, A.W. Mohaimin, H.P. Goh, N.H. Zaini, N. Kifli, N. Ahmad, The analgesic potential of *Litsea* species: a systematic review, Mol 29 (2024), https://doi.org/10.3390/molecules29092079.
[32] V.T. Nguyen, M.T. Nguyen, N.Q. Nguyen, T.T. Truc, Phytochemical screening, antioxidant activities, total phenolics and flavonoids content of leaves from *Persicaria odorata* Polygonaceae, IOP Conf. Ser. Mater. Sci. Eng. 991 (2020) 012029, https://doi.org/10.1088/1757-899X/991/1/012029.
[33] A.M. Asowata-Ayodele, A.J. Afolayan, G.A. Otunola, Ethnobotanical survey of culinary herbs and spices used in the traditional medicinal system of Nkonkobe Municipality, Eastern Cape, South Africa, S. Afr. J. Bot. 104 (2016) 69–75, https://doi.org/10.1016/j.sajb.2016.01.001.
[34] G. Mattalia, P. Corvo, A. Pieroni, The virtues of being peripheral, recreational, and transnational: local wild food and medicinal plant knowledge in selected remote municipalities of Calabria, Southern Italy, Ethnobot. Res. Appl. 19 (2020) 1–20.
[35] D.L.T. Jessica Elizabeth, F. Gassara, A.P. Kouassi, S.K. Brar, K. Belkacemi, Spice use in food: properties and benefits, Crit. Rev. Food Sci. Nutr. 57 (2017) 1078–1088, https://doi.org/10.1080/10408398.2013.858235.
[36] E.M.Y. Cheng, C.M.L. Cheng, J. Choo, Y. Yan, L.R. Carrasco, Biodiversity footprints of 151 popular dishes from around the world, PLoS One 19 (2024) e0296492, https://doi.org/10.1371/journal.pone.0296492.
[37] P. Panyadee, H. Balslev, P. Wangpakapattanawong, A. Inta, Medicinal plants in homegardens of four ethnic groups in Thailand, J. Ethnopharmacol. 239 (2019) 111927, https://doi.org/10.1016/j.jep.2019.111927.
[38] M. Phumthum, H. Balslev, Using ICPC-2 standard to identify Thai Zingiberaceae of pharmacological interest, Plants 9 (2020) 906, https://doi.org/10.3390/plants9070906.

[39] M. Tanveer, C. Wagner, M.I. ul Haq, N.C. Ribeiro, T. Rathinasabapathy, M.S. Butt, A. Shehzad, S. Komarnytsky, Spicing up gastrointestinal health with dietary essential oils, Phytochem. Rev. 19 (2020) 243–263, https://doi.org/10.1007/s11101-020-09664-x.
[40] V. Sharma, I. Singh, P. Chaudhary, *Acorus calamus* (The Healing Plant): a review on its medicinal potential, micropropagation and conservation, Nat. Prod. Res. 28 (2014) 1454–1466, https://doi.org/10.1080/14786419.2014.915827.
[41] Y. Zhao, J. Li, G. Cao, D. Zhao, G. Li, H. Zhang, M. Yan, Ethnic, botanic, phytochemistry and pharmacology of the *Acorus* L. Genus: a review, Mol 28 (2023) 7117.
[42] A. Songsangchun, Plants Usages of Khon Muang and Lawa in Phu Fah Subdistrict, Bo Klua District, Nan Province. Thesis, Chiang Mai University, Chiang Mai, Thailand, 2015.
[43] K. Srithi, Comparative Ethnobotany in Nan Province, Thailand. Dissertion, Chiang Mai University, Chiang Mai, Thailand, 2012.
[44] A. Nuammee. Ethnobotany of Hmong in Ban Pang Chang, Tambon Pong, Amphoe Santisuk, Changwat Nan, Chulalongkorn University, Bangkok, Thailand, 2012. Thesis.
[45] V. Nguanchoo, Ethnobotany of Hmong in Mae Rim District, Chiang Mai Province, Thailand. Master's Thesis, Mahidol University, Bangkok, 2014.
[46] W. Pongamornkul, N. Muangyen, *Ethnobotany Of Karen In Sop Moei District, Mae Hong Son Province*; the Botanical Garden Organization, Chiang Mai, Thailand, 2013.
[47] J. Tovaranonte, Ethnobotany of Tai Lue in Chiang Rai Province, School of Science, Mae Fah Luang University: Chiang Rai, Thailand, 2003.
[48] B. Sonsupub, Ethnobotany of Karen Community in Raipa village, Huaykhayeng subdistrict, Thongphaphume district. Kanchanaburi Province, Kasetsart University, Bankok, Thailand, 2010. Thesis.
[49] N. Muangyen, Ethnobotany of Tai Lue and Tai Yuan in Samoeng District, Chiang Mai Province. Thesis, Chiang Mai Universiy, Chiang Mai, Thailand, 2013.
[50] J. Thatsaneeyakorn, Ethnobotanical Study of the Akha at Doi Sa-Ngo Village, Chiang Rai. Special Project, Chiang Mai University, Chiang Mai, Thailand, 1997.
[51] A. Inta, Ethnobotany and crop diversity of Tai Lue and Akha communities in the upper northern Thailand and the Xishuangbanna Dai Autonomous Prefecture. China. Dissertion, Chiang Mai University, The Graduate School, 2008.
[52] P. Panyadee, Comparison of Plants Composition and Structure of Homegardens of Ethnic Groups in Chiang Mai Province, Thailand. Dissertation, Chiang Mai University, Chiang Mai, Thailand, 2017.
[53] T. Tangtragoon, Ethnobotany of the Khamu, Lawa and H'tin in Some Areas of Nan Province. Thesis, Chiang Mai University, Chiang Mai, Thailand, 1998.
[54] T. Yaso, Ethnobotany of the H'tin and Lua in Phuphaa Subdistrict, Baugleua District, Nan Province. Thesis, Chiang Mai University, Chiang Mai, Thailand, 2000.
[55] W. Pongamornkul, An Ethnobotanical Study of the Karen at Ban Yang Pu Toh and Ban Yang Thung Pong, Chiang Dao District, Chiang Mai Province, Independent Research, Chiang Mai University, Chiang Mai, Thailand, 2003.
[56] K. Khamfachuea, Ethnobotany of the Karen at Ban Chan and Chaem Luang subdistricts, Mae Chaem district. Chiang Mai Province, Chiang Mai University, Thesis, 2008.
[57] K. Kamwong, Ethnobotany of Karens at Ban Mai Sawan and Ban Huay Pu Ling, Ban Luang sub-district, Chom Thong district. Chiang Mai Province. Thesis, Chiang Mai University, Chiang Mai, Thailand, 2009.
[58] S. Kaewsangsai, Ethnobotany of Karen in Khun Tuen Noi Village, Mae Tuen Sub-district, Omkoi District, Chiang Mai Province, Chiang Mai University, Chiang Mai, Thailand, 2016. Master's Thesis.
[59] C. Trisonthi, P. Trisonthi, P. Wangpakapattanawong, P. Srisanga, Research Project on Gathering of Highland Traditional Biodiversity- and Ethnobiology-Based Knowledge, Highland Research and Development Institute (Public Organization), 2007.
[60] W. Pongamornkul, An Ethnobotanical Study of Lua in Royal Project Areas, Mae Hong Son Province. Master's Thesis, Chiang Mai University, Chiang Mai, Thailand, 2006.
[61] J. Moonjai, A. Inta, Ethnobotany of Lawa in La-Oob Village, Mae La Noi District, Mae Hong Son Province, Thai J. Bot. 8 (2016) 181–199.
[62] M. Borikut, Ethnobotany of Lua in Ban Num Phae Bo Kluea District, Nan Province. Thesis,, Chiang Mai University, Chiang Mai, Thailand, 2019.
[63] A. Bunsongthae, C. Chaiwong, Conservation and utilization of ethnic plants in some areas of Maehongson province, North. Reg. J. Sci. Technol. 3 (2010) 22–43.
[64] P. Panyadee, Plant Diversity in Homegardens of Tai Yai Communities in Pang Mapha District, Mae Hong Son Province. Thesis, Chiang Mai University, Chiang Mai, Thailand, 2012.
[65] T. Tungtragoon, Y. Tarachay, P. Hongvityakorn, V. Prokati, P. Preechawattanakorn, Ethnobotanical Studies in Ban Pong, Sansai Disrict, Chiang Mai Province, Chiang Mai, Thailand, 2004.
[66] J. Tovaranonte, Ethnobotanical Study of the Tai Lue, Hmong and Yao in Some Areas of Nan Province. Thesis, Chiang Mai University, Chiang Mai, Thailand, 1998.
[67] N. Phatlamphu, S. Saensouk, P. Saensouk, A. Junsongduang, Ethnobotany of edible plants in Muang district, Kalasin province, Thailand, Biodiversitas 22 (2021) 5432–5444, https://doi.org/10.13057/biodiv/d221225.
[68] H.A. Sellers, A Linguistic Approach to Ethnobotanical Plant Name Classification in Southern Lisu. Doctoral Dissertion, La Trobe University, Bundoora, Victoria, 2015.
[69] P. Srisanga, S. Wongpakam, W. Kamkuan, T. Pekthong, J. Tovaranonte, T. Yaso, S. Nontachaiyapoom, Ethnobotany of Akha in Huay Yuak Pa So village, Mae Fah Luang district and Ban Mai Patthana village, Mae Suai district, Chiang Rai province, Thai J. Bot. 3 (2011) 93–114.
[70] Y. Ponpim, Ethnobotany of the Hill Tribes in Kaenoy's and Nongkheuw's Royal Project in Chiang Mai. Thesis, Chiang Mai University, Chiang Mai, Thailand, 1996.
[71] K. Punchay, A. Inta, P. Tiansawat, H. Balslev, P. Wangpakapattanawong, Traditional knowledge of wild food plants of Thai Karen and Lawa (Thailand), Genet. Resour. Crop Evol. 67 (2020) 1277–1299, https://doi.org/10.1007/s10722-020-00910-x.
[72] J. Tovaranonte, Ethnobotanical study of the Lisu at Lisu lum village, Chiang Mai. Special Project, Chiang Mai University, Chiang Mai, Thailand, 1993.
[73] S. Sinworn, N. Viriyawattana, The Diversity of Medicinal Plants and Utilization in Khoa Phra, Doembangnangbuat District, Suphanburi Province, SDU Research Journal 7 (2014) 1–20.
[74] P. Noitana, S. Saipara, K. Khoomput, Ethnobotany of the Hmong at Nanoi district, Nan province, Naresuan Phayao J 6 (2013) 213–219.
[75] C. Klamwaewwong, Ethnobotanical Study of H'tin Hill Tribe at Wangsao Village, Nan. Thesis, Chiang Mai University, Chiang Mai, Thailand, 1996.
[76] U. Upho, Ethnobotany of Buddhist and Muslim Thais in some locations in the lower part of sourthern Thailand. Dissertion, Chiang Mai University, Chiang Mai, 2005.
[77] A. Inta, Analysis of traditional knowledge of plants used of the communities in the Haripunchai campus. *Chiang Mai University, Lamphun Province*; Chiang Mai University, Chiang Mai, 2011.
[78] C. Trisonthi, P. Trisonthi, Ethnobotany of Lua and H ' tin on Doi phukha , Nan province, Thai J. Bot. 3 (2011) 163–185.
[79] A. Yawutthi, Ethnobotany of Karen to study food and material plant in Ang Ka Noi village and Mae Klang Luang village, Chom Thong district. Chiang Mai Province, Chiang Mai University, Chiang Mai, Thailand, 2011.
[80] C. Trisonthi, P. Trisonthi, Ethnobotanical study in Thailand, a case study in Khum Yuam district, Mae Hong Son province, Thai J. Bot. 1 (2009) 1–23.
[81] K. Udompanid, Ethnobotany of Tai Yai in Naisoi village. Mueng District, Mae Hong Son Province. Special Project, Chiang Mai University, Chiang Mai, Thailand, 2012.
[82] K. Panta, Ethnobotany of Lisu in Khun Chae village, Phrao district, Chiang Mai province. Special Project, Chiang Mai University, Chiang Mai, Thailand, 2015.
[83] R. Kantasrila, Ethnobotany of Karen at Ban Wa Do Kro, Mae Song Sub-district, Tha Song Yang District, Tak Province, Chiang Mai University, Chiang Mai, Thailand, 2016. Master's Thesis.
[84] A. Junsongduang, Roles and Importance of Sacred Forest in Biodiversity Conservation in Mae Chaem District, Chiang Mai Province, Chiang Mai University, Chiang Mai, Thailand, 2014. Doctoral Dissertation.
[85] P. Wangpakapattanawong, N. Kavinchan, C. Vaidhayakarn, D. Schmidt-Vogt, S. Elliott, Fallow to forest: applying indigenous and scientific knowledge of swidden cultivation to tropical forest restoration, For. Ecol. Manage. 260 (2010) 1399–1406, https://doi.org/10.1016/j.foreco.2010.07.042.
[86] J. Tovaranonte, Ethnobotany in Surroundings Area of Mae Fah Luang University, School of Science, Mae Fah Luang University: Chiang Rai, Thailand, 2001.

[87] D. Krueasan, Plant diversity and utilization by local people in Ban Toon subdistrict, Mueang district, Phayao province. Special Project, Chiang Mai University, Chiang Mai, Thailand, 1998.
[88] K. Tangjitman, Ethnobotany of the Karen at Huay Nam Nak village, Tanaosri subdistrict, Suanpheng district, Ratchaburi province, Thai J. Bot. 9 (2017) 253–272.
[89] N. Chaisoung, P. Panyadee, C. Long, C. Ngernsaengsaruay, T. Chaowasku, A. Inta, Ethnobotanical study in the underexplored species of Genus Litsea (Lauraceae) in Northern Thailand, Biodiversitas 24 (2023) 3977–4000.