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CL conceived and designed the study, identified plant species; FL conducted data collection and wrote the manuscript; FL, BL, ZC, and PL integrated the inventory and its analysis

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ORIGINAL RESEARCH PAPER in ETHNOBOTANY

# Ethnobotanical Study on *Garcinia* (Clusiaceae) in China

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## Abstract

The genus *Garcinia* L. (Clusiaceae) is gaining increasing scientific attention worldwide owing to its ethnobotanical and pharmacological significance. In China, even though *Garcinia* plants have long been used for food, ethnomedicine, building materials, and other purposes, a comprehensive ethnobotanical study of the genus is notably limited. In the current study, the ethnobotanical importance of *Garcinia* plants has been extensively investigated through field surveys and literature reviews. Our studies revealed that *Garcinia* plants have been used in folk medicine since ancient times in China, including the Northern Song Dynasty, 960–1127 AD. Through their extensive interactions with genus, the Chinese people have gained various traditional knowledge, which is reflected in the following six aspects: food, traditional medicines, ornamental trees, construction and technology, cultural and spiritual significance, and miscellaneous uses. In particular, the four species: *Garcinia hanburyi*, *G. paucinervis*, *G. xanthochymus*, and *G. oblongifolia*, have cultural or spiritual values, among which *G. paucinervis* could be considered a cultural keystone species in the local communities, considering its crucial contribution to people's cultures, spirits, and community identity. However, in general, some concerns originating from swift socio-economic changes have also been identified in the knowledge and *Garcinia* species. Strategies are needed to conserve traditional botanical knowledge, as well as plants.

## Keywords

*Garcinia*; ethnobotany; traditional botanical knowledge; traditional uses; cultural keystone species; sacred tree; ethnomedicine

## 1. Introduction

*Garcinia* Linnaeus, the second largest genus in the family Clusiaceae, consists of more than 400 species worldwide, which naturally occurs mainly in tropical and subtropical regions, such as South Africa, Madagascar, and tropical regions of Asia and America (X. W. Li et al., 2007). In China, 22 species of *Garcinia* plants have been recorded, of which 13 species are endemic and three are introduced species. They are mainly distributed in southern parts of China, such as Yunnan, Guangxi, Guangdong, and Hainan Provincial Regions (Editorial Committee of Flora of China, 1990; X. L. Li et al., 2016). Plants of this genus are evergreen trees or shrubs, usually characterized by monopodial branches and they produce yellow or white latex in different plant parts, such as pericarps, twigs, and leaves (Nazre et al., 2018). They are usually functionally dioecious, with opposite leaves, berry-like fruits, and large seeds (Crepet & Nixon, 1998; X. W. Li et al., 2007).

*Garcinia* species have been extensively recognized as ethnobotanically significant plants worldwide, for food, medicinal, and ornamental purposes (Hemshekhar et al., 2011; Sarma & Devi, 2015; Semwal et al., 2015; Yapwattanaphun et al., 2000). Many species of the genus produce edible juicy fruits that are consumed and sold in

local areas (Murthy et al., 2018). For example, *G. mangostana* is well known for its fruits, which are praised as the queen of fruits, and cultivated throughout Southeast Asia and other tropical countries (Pedraza-Chaverri et al., 2008). In addition, many *Garcinia* plants have long been used as ethnomedicines for treating various human ailments (Rameshkumar, 2016). For instance, the pericarps, seeds, and leaves of *G. indica* have been used to treat inflammatory disorders and rheumatism in traditional Indian Ayurvedic medicines (Kadam et al., 2012). Furthermore, *Garcinia* plants have also been used as timber and for ornamental purposes. In addition, cultural uses have also been reported by researchers who conducted ethnobotanical surveys (Liu et al., 2016; Zhang et al., 2015). For example, *G. hanburyi* plays an important role in cloth dyeing and painting culture in Thailand because of the production of exploitable yellow resin from the bark, which indicates the biocultural interactions between the species and local people (Hutchings, 1996).

Due to the multitraditional uses of *Garcinia* species, the genus is of great interest to researchers. Extensive phytochemical and pharmacological studies have been carried out to understand the traditional uses and explore their potential for drug development. Some *Garcinia* species such as *G. kola* and *G. benthamiana*, traditionally used as antimalarial agents, have been further demonstrated to possess antiplasmodial activities (Lyles et al., 2014; Subeki, 2012; Tona et al., 2004). Another example is the anticancer activities of *Garcinia* taxa such as *G. kola* and *G. hanburyi*, which are ethnomedicinally used for anticancer purposes, have been further evaluated by modern pharmacological evidence (Hemshekhar et al., 2011; Popoola et al., 2016). These ethnopharmacologically-guided investigations revealed a positive relationship between ethnomedicinal knowledge and state-of-the-art pharmacological research, emphasizing the importance of recording associated traditional botanical knowledge to facilitate related studies on human health.

In recent years, a rapid decline in the traditional knowledge of important plants has been recognized by researchers worldwide for various reasons, such as massive industrialization and tourism (Ahmad et al., 2019; Bussmann et al., 2018; Kala et al., 2006; Paniagua-Zambrana et al., 2016). The conservation and sustainability of ethnobotanical knowledge have become a global concern, which indicates the importance of ethnobotanical records of knowledge before its disappearance (Signorini et al., 2009; X. L. Zheng & Xing, 2009). After a long history of interaction with *Garcinia* plants, diverse related traditional botanical knowledge has been gained by Chinese people. For example, the medicinal uses of several *Garcinia* species, including *G. xanthochymus* and *G. multiflora*, have been recorded in the Chinese medicinal book *Zhong Hua Ben Cao* [Chinese materia medica] (Editorial Committee of the Administration Bureau of Traditional Chinese Medicine, 1999). However, such knowledge is usually scattered in published literature or unpublished sources, which hinders the convenient accessibility for researchers to obtain a comprehensive picture of the value of *Garcinia* plants. In addition, according to our preliminary ethnobotanical surveys in several areas of Yunnan and Guangxi regions of southern China (Liu et al., 2016), the traditional knowledge about the genus is threatened in the course of swift socio-economic changes, highlighting the urgency of complemented investigations to document the ethnobotanical significance of *Garcinia* plants.

In the current study, a comprehensive ethnobotanical study was conducted in combination with ethnobotanical surveys and literature review, to provide detailed data on traditional uses within *Garcinia* species in China, especially in the aspects of culture and spirit. The results of our study could contribute to the conservation of associated traditional knowledge as well as to the potential utilization of *Garcinia* plants.

## 2. Material and Methods

### 2.1. Literature Review

To collect the sporadically distributed ethnobotanical information of *Garcinia* species in China, a literature review was conducted. Records from the National

Library of China such as the Databases of China's Basic Ancient Books, along with various traditional medicinal books, ancient to recent, have been extensively consulted. Furthermore, the information of each Chinese *Garcinia* species in the literature databases, including Google Scholar, Science Direct, Web of Science, SciFinder, PubMed, and Chinese databases such as China National Knowledge Infrastructure (CNKI), Wanfang, and China Science and Technology Journal Database (WP) were comprehensively examined. In addition, to acquire botanical and distribution information, the data from *Flora of China* (English version, http://www.iplant.cn/foc/), *Flora Reipublicae Popularis Sinicae* (Chinese version, http://www.iplant.cn/frps/), and the Chinese Virtual Herbarium (CVH; http://www.cvh.ac.cn/) were exhaustively investigated and examined.

## 2.2. Field Investigations

Field surveys were conducted in 2013 (June and July), 2014 (July, August, October, and December), 2015 (June, November, and December), 2019 (May, July, August, and December), and 2020 (August and September) in areas with abundance of *Garcinia* species in China, including Yunnan, Guangxi, Guangdong, and Hainan provinces. In total, 31 areas (county or county-level city/district) were investigated (Figure 1). In each region, 20–35 people were selected using snowball sampling (Handcock & Gile, 2011). A total of 787 informants, including 352 males and 435 females with ages ranging from 17 to 88 years, were interviewed. The interviewees belonged to the following 14 socio-linguistic groups: Dai, Yao, Lisu, Miao, She, Hani, Jinuo, Drung (also called Dulong), Bai, Zhuang, Li, Pumi, Nu, and Han.

Different approaches were used for data collection, including semistructured interviews, key informant interviews, and participatory rural appraisals (Alexiades & Sheldon, 1996; Chambers, 1994; Long & Wang, 1996). When we conducted surveys in the local areas, the ethical guidelines published by the American Anthropological Association (https://www.americananthro.org/) and the International Society of Ethnobiology (https://www.ethnobiology.net/) were rigorously followed. After obtaining informed consent, one to two local people in each investigated area were asked to serve as assistants for language communication and translation during the surveys.

At the beginning of the interviews, color pictures of different plant parts of *Garcinia* species from the Plant Photo Bank of China (PPBC) (http://ppbc.iplant.cn/) were shown to the local people to help them recognize the plant to facilitate the efficacy of

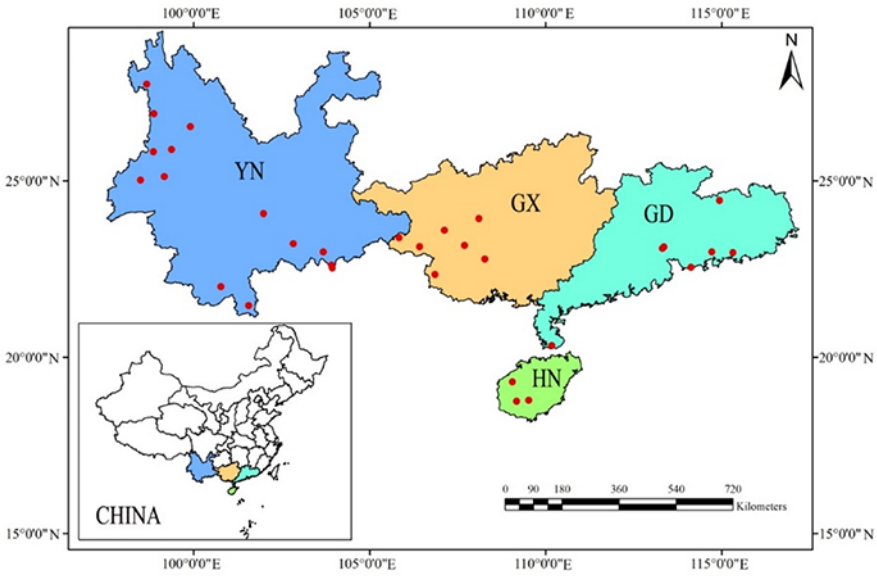


**Figure 1** Investigation areas (county-level administrative units) at the provincial level. YN, GX, GD, and HN represent Yunnan, Guangxi, Guangdong, and Hainan regions, respectively.

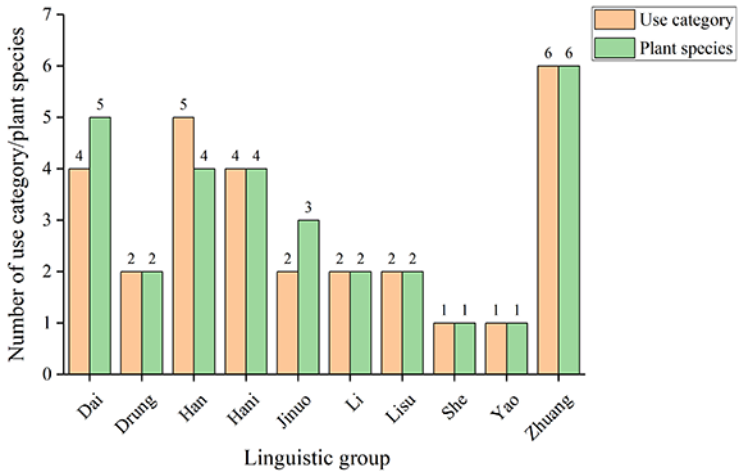


**Figure 2** Number of use categories or *Garcinia* species with traditional values characterized by different linguistic groups.

communication with the locals. The people who were knowledgeable about *Garcinia* plants were characterized as key informants and further subjected to key informant interviews. The main questions on *Garcinia* species that were asked in the interviews for ethnobotanical data collection are shown in Table S1. In the interviews, information such as the local name, traditional uses, used parts, and used modes were recorded in detail. Additionally, if the *Garcinia* species were not easily accessible, the distribution information such as location and resources were mapped and evaluated by the key informants using the participatory rural appraisal (PRA) method to improve the efficiency of specimen collections. All voucher specimens were examined and identified by the authors according to the *Flora of China* (http://www.iplant.cn/foc/) and were deposited in the Herbarium of the Minzu University of China.

## 3. Results

### 3.1. Overview of Traditional Uses

According to our field surveys and literature review, the traditional uses of 17 out of 22 recorded *Garcinia* species (77.3%) in China have been documented, which can be divided into six different use categories: food, ethnomedicine, construction and technology, ornamentals, spiritual and cultural aspects, and miscellaneous uses. The most commonly used category was food with 13 species, followed by ethnomedicines (10 spp.), as ornamental trees (seven spp.), in construction and technology (five spp.), and for cultural and spiritual uses (four spp.). The use categories of each *Garcinia* species recognized by different linguistic groups are shown in Table 1. A total of 10 linguistic groups have developed traditional knowledge of *Garcinia* plants, among which the Zhuang people recognized the highest number of use categories (six), followed by the Han (five) and Hani (four) linguistic groups (Figure 2). At the species level, six *Garcinia* species were believed by the Zhuang people to possess traditional values, while the Dai and Han communities recognized the uses of five and four *Garcinia* taxa, respectively (Figure 2).

### 3.2. Food Purposes

The earliest record of food uses of *Garcinia* plants can be traced back to the Southern Song dynasty (1127–1279 AD), which was documented in *Gui Hai Yu Heng Zhi* [Local records in Guihai area], the ancient book to document the customs and cultures of the time, authored by Chengda Fan (1126–1193 AD), who was a litterateur and politician at that time. The fruits of *G. multiflora*, vividly described by the author as a giant fruit of *Eriobotrya japonica*, could be harvested between fall and

**Table 1** Use category of each *Garcinia* taxon recognized by different linguistic groups.

| Species name | Use category | | | | | | Number of categories |
|---|---|---|---|---|---|---|---|
| | Food | Ethnomedicine | Ornamental | Construction and technology | Cultural and spiritual | Miscellaneous | |
| **Garcinia oblongifolia* | Zhuang, Dai, Li | Zhuang | Zhuang | Zhuang | Zhuang | Zhuang | 6 |
| *G. multiflora* | Zhuang | Zhuang, Lisu, Hani, She | Zhuang | Zhuang | - | Zhuang | 5 |
| **G. paucinervis* | Hani | Zhuang, Yao | Zhuang | Zhuang | Zhuang | - | 5 |
| *G. xanthochymus* | Zhuang, Hani, Dai, Jinuo | Dai, Hani, Zhuang | Zhuang | - | Zhuang | Zhuang, Dai | 5 |
| **G. yunnanensis* | Hani | Hani | Hani | Hani | - | - | 4 |
| *G. bracteata* | Zhuang | - | - | Zhuang | - | Zhuang | 3 |
| *G. cowa* | Dai, Jinuo | Dai, Jinuo | - | - | - | - | 2 |
| **G. esculenta* | Drung | Drung | - | - | - | - | 2 |
| *+G. hanburyi* | - | Han | - | - | Han | - | 2 |
| *G. subelliptica* | - | - | Han | | | Han | 2 |
| **G. xipshuanbannaensis* | Dai | - | Dai | - | - | - | 2 |
| *+G. mangostana* | Jinuo, Han | - | - | - | - | - | 1 |
| **G. nujiangensis* | Drung, Lisu | - | - | - | - | - | 1 |
| *G. oligantha* | - | Li | - | - | - | - | 1 |
| *G. pedunculata* | Dai | - | - | - | - | - | 1 |
| *+G. schefferi* | - | Han | - | - | - | - | 1 |
| **G. subfalcata* | Zhuang | - | - | - | - | - | 1 |

Note: * and + represent the endemic and introduced species, respectively.

**Table 2** Edible uses of *Garcinia* species recognized by different linguistic groups based on field surveys.

| Species | Edible part | Traditional use | Fruit taste (aril part) | Linguistic group |
|---|---|---|---|---|
| *Garcinia bracteata* | Aril, pericarp, seed | Arils of ripe fruits eaten directly; pericarps for making spice, pickle and soup; young seeds eaten directly | Sour and sweet | Zhuang |
| *G. cowa* | Aril | Arils of ripe fruits eaten directly | Sour and sweet | Dai, Jinuo |
| *G. esculenta* | Whole fruit, aril | Arils of ripe fruits eaten directly; whole fruits immersed in water for making beverages | Sour | Drung |
| *G. mangostana* | Aril | Arils of ripe fruits eaten directly | Sour and sweet | Jinuo, Han |
| *G. multiflora* | Aril | Arils of ripe fruits eaten directly | Sour and sweet | Zhuang |
| *G. nujiangensis* | Aril | Arils of ripe fruits eaten directly | Sour and sweet | Drung, Lisu |
| *G. oblongifolia* | Aril, pericarp, leaf | Arils of ripe fruits eaten directly; pericarps for making jam, spice and pickle; dried pericarps eaten directly; leaves eaten as vegetable and used as condiments for pickles | Sour and sweet | Zhuang, Dai, Li |
| *G. paucinervis* | Leaf | Young leaves chewed as snacks | - | Hani |
| *G. pedunculata* | Aril | Arils of ripe fruits eaten directly | Sour | Dai |
| *G. subfalcata* | Aril | Arils of ripe fruits eaten directly | Sour and sweet | Zhuang |
| *G. xanthochymus* | Whole fruit, aril, fruit juice, leaf | Arils of ripe fruits eaten directly; fruit juice used as fish sauce; young leaves cooked as vegetable; whole fruits immersed in water for making beverages | Sour | Zhuang, Hani, Dai, Jinuo |
| *G. xipshuanbannaensis* | Aril | Arils of ripe fruits eaten directly | Sour | Dai |
| *G. yunnanensis* | Whole fruit, aril | Arils of ripe fruits eaten directly; whole fruits for making wine and beverages | Sour and sweet | Hani |

winter for edible fruit purposes (Editorial Committee of the Administration Bureau of Traditional Chinese Medicine, 1999).

According to our field investigations, 414 informants (52.6%) reported the edible uses of *Garcinia* species. The local people (over 85%) could easily recognize the species with edible properties when we showed the photos to them. At least eight linguistic groups have a tradition of consuming *Garcinia* plants. The food uses from 13 species reported are listed in Table 2, some of which have also been reported in previous literature (Editorial Committee of Flora of China, 1990; Hu, 2005; Liu et al., 2016; Xu & Li, 2016; Zhang et al., 2015). In addition to *G. paucinervis*, the aril part of ripe fruits from documented species could be eaten directly with a sour or sour and sweet taste. In addition, other parts of the fruit such as pericarps and seeds were also reported to possess edible values (Table 2). For instance, according to our interviews, the dried pericarps of *G. oblongifolia* and young seeds of *G. bracteata* could be consumed directly as snacks, as mentioned by the Zhuang people in Guangxi. Apart from the edible fruit part, the consumption of young leaves from *G. paucinervis*, *G. xanthochymus*, and *G. oblongifolia* has also been reported (Table 2). For example, in Mengla County, Yunnan Province, the young leaves of *G. xanthochymus*, as reported by eight people aged over 60 years old, could be consumed as wild vegetables, whereas in Jinping County of Yunnan, the young leaves of *G. paucinervis* could be chewed directly as snacks with a slightly sour and bitter taste as reported by five informants over 50 years old. Nevertheless, in addition to the fruits and leaves, the edible purposes of other plant parts of *Garcinia* spp. have not been determined in China.

### 3.3. Ethnomedicines

*Garcinia* plants have been used as traditional medicines for a long time in China and can be found in various ancient medicinal books. In general, the earliest ethnomedicinal documentation of the genus was presented in a famous medicinal

magnum opus, *Compendium of Materia Medica*, written by Shizhen Li of the Ming Dynasty (1368–1644 AD), where it recorded that *Teng huang*, the latex of *G. hanburyi*, could be used to treat dental caries (Editorial Committee of the Administration Bureau of Traditional Chinese Medicine, 1999; S. Z. Li, 1979). Since then, the medicinal records of *Teng huang* have been reported in various traditional therapeutic books from ancient to recent times (Editorial Committee of the Administration Bureau of Traditional Chinese Medicine, 1999). For example, as recorded in the *Supplement to the Compendium of Materia Medica* published by Xuemin Zhao in 1765 of the Qing Dynasty, *Teng huang* could be used to cure many ailments, such as ulcers, tumors, and taeniasis (Zhao, 1998). In addition to *G. hanburyi*, the medicinal practices of other *Garcinia* plants were also found in ancient Chinese pharmacopeias. It was recorded by *Shi Wu Ben Cao* [Food herbs], published at the end of the Ming Dynasty by Kecheng Yao, that the fruits from either *G. oblongifolia* or *G. multiflora* were effective in fighting a wide range of human disorders, such as emesis, heatstroke, and spleen deficiency (Yao, 1994).

Based on our field surveys, diverse ethnomedicinal practices have also been mentioned by 83 interviewees (10.5%) from different linguistic people, such as the Zhuang, Hani, and Dai communities. Among the reporters, 65.2% were male, and over 85% were more than 50 years old, which indicated that men knew more about traditional medicinal uses of *Garcinia* plants than women, and ethnomedicinal knowledge was mainly conserved among the elderly. In addition, most interviewees (18) provided medicinal information about *G. xanthochymus*, followed by *G. yunnanensis* (13); however, the reported number of other species was lower than 10 people.

Combined with our field surveys and literature overview (Editorial Committee of National Compilation of Chinese Herbal Medicine, 1996; Editorial Committee of the Administration Bureau of Traditional Chinese Medicine, 1999; Liu et al., 2016), the ethnomedicinal knowledge on *Garcinia* plants is summarized in Table 3. In total, 10 species (*G. cowa*, *G. esculenta*, *G. hanburyi*, *G. multiflora*, *G. oblongifolia*, *G. oligantha*, *G. paucinervis*, *G. schefferi*, *G. xanthochymus*, and *G. yunnanensis*) were used as traditional medicines to treat 41 types of human diseases and disorders, ranging from simple ailments such as cough and emesis to complicated disorders, including deficiency of spleen and kidney (Table 3). Some traditional medicinal uses were similar to those recorded in ancient books. For example, it was reported by seven Zhuang people over 55 years old in Longzhou County, Guangxi Region, that *G. oblongifolia* fruits were useful for the treatment of emesis and heatstroke, which were also documented in the ancient literature *Shi Wu Ben Cao* [Food herbs]. Some medicinal uses have not been documented in previous medicinal books or literature. For instance, for the first time, we reported that *G. esculenta* fruits have medicinal effects on detoxication, rheumatism, and periodontitis. However, only 20.4% of the investigated Drung people in Yunnan Province knew these traditional uses.

At least 10 indigenous groups have a history of using *Garcinia* species as ethnomedicines, especially among the Zhuang, Hani, and Dai people. Some differences in the ethnomedicinal uses of the same species can be discovered among or within linguistic communities. For instance, according to our surveys, the Dai people used the stems and leaves of *G. xanthochymus* as traditional medicines to fight against worm and leech infection, while the Hani and Zhuang people only used the bark and fruit, respectively, for medicinal purposes. Another example is that the medicinal value of *G. oblongifolia*, a heat-clearing and detoxifying drug, has been recognized by the Zhuang people in Longzhou County, Guangxi Region; however, the medicinal uses of this species were not identified among the Zhuang people in Napo County, Guangxi. Additionally, the medicinal effects of the same plant parts from different species were characterized. For example, the bark from both *G. multiflora* and *G. oligantha* can be used for several ailments, such as eczema and gastric and duodenal ulcers (Table 3).

Regarding the medicinal part, a total of nine specific plant parts were used to fight human diseases, and these included fruits, bark, leaves, pericarps, seeds, twigs, stems, root, and latex. The most commonly used plant part was the fruit (seven

species), followed by the bark (six species), and leaves (five species). However, the ethnomedicinal uses of plant parts such as flowers have not been reported (Figure 3). The most common preparation method used by local people is decoction. Other preparation methods, such as water and alcoholic extraction were also found (Table 3).

**Table 3** Medicinal uses of *Garcinia* species by different linguistic groups in China.

| Species | Medicinal part | Preparation | Traditional use | Linguistic group |
|---|---|---|---|---|
| *Garcinia cowa* | Stem, leaf | Decoction, poultice, sap | Aphtha, burns and scalding, carbuncle, clearing heat, detoxication, eczema, expelling leech out of nose, gum pain, periodontitis, stomatitis | Dai, Jinuo |
| | Fruit | Decoction | Analgesia, antiphlogosis | Dai |
| *G. esculenta* | Fruit | Water extraction | Clearing heat, detoxication, periodontitis, rheumatism | Drung |
| *G. hanburyi* | Latex | Decoction, poultice | Burns and scalding, carbuncle, detoxication, dental caries, detumescence, eczema, hemostasis, skin cancer, skin tinea, taeniasis, tumor, traumatic injury, ulcer | Han |
| *G. multiflora* | Bark | Decoction, poultice | Analgesia, antialcoholism, aphtha, asthma, burns and scalding, clearing heat, detoxication, diarrhea, duodenal ulcer, ecthyma, eczema, enteritis, epigastric pain, gastric ulcer, gum pain, hemostasis, infantile dyspepsia, lower limb ulcer, periodontitis, stomachache, tissue generation, toothache, stomatitis | Zhuang, Lisu |
| | Fruit | Decoction | Antialcoholism, anorexia, clearing heat, cough, diarrhea, emesis, heatstroke, rectocele, spleen deficiency | Hani |
| | Seed | Distillation | Analgesia, burns and scalding, eczema, hematocele, periodontitis, stomatitis | Zhuang |
| | Pericarp | Decoction | Cough | Hani, She |
| *G. oblongifolia* | Bark | Decoction, poultice | Analgesia, antiphlogosis, asthma, burns and scalding, clearing heat, detoxification, duodenal ulcer, eczema, enteritis, gastric ulcer, gastroenteritis, hemostasis, infantile dyspepsia, leucorrhoea, lower limb ulcer, periodontitis, stomatitis, traumatic injury, tissue generation | Zhuang |
| | Fruit | Decoction | Abdominal distension, anorexia, antialcoholism, clearing heat, cough, dyspepsia, emesis, heatstroke, spleen deficiency | Zhuang |
| | Seed | Distillation | Analgesia, burns and scalding, clearing heat, detoxification, eczema, hematocele, periodontitis, stomatitis | Zhuang |
| | Pericarp | Direct consumption after air drying | Clearing heat, detoxification | Zhuang |
| | Leaf | Decoction | Abdominal distension; dyspepsia, thenar ulcer | Zhuang |
| *G. oligantha* | Bark | Decoction, poultice | Analgesia, antiphlogosis, aphtha, burns and scalding, clearing heat, detoxification, duodenal ulcer, ecthyma, eczema, enteritis, epigastric pain, gastric ulcer, gastroenteritis, gum pain, infantile dyspepsia, lower limb ulcer, periodontitis, stomatitis, tissue generation | Li |
| | Fruit | Decoction | Anorexia, antialcoholism, detoxication, diarrhea, emesis, rectocele, thenar ulcer | Li |

*Continued on next page*

**Table 3** *Continued.*

| Species | Medicinal part | Preparation | Traditional use | Linguistic group |
|---|---|---|---|---|
| *G. paucinervis* | Root | Aqueous alcohol extraction | Epigastric pain, stomachache | Zhuang, Yao |
| | Bark, twig, leaf | Decoction, poultice | Analgesia, antiphlogosis, burns and scalding, clearing heat, detoxication, detumescence, ecthyma | Zhuang |
| *G. schefferi* | Bark | Decoction, poultice | Analgesia, burns and scalding, clearing heat, detoxification, detumescence | Han |
| *G. xanthochymus* | Stem | Decoction, sap | Expelling leech out of nose, expelling worm, | Dai |
| | Leaf | Decoction, sap | Expelling leech out of nose, expelling worm, stomachache | Dai |
| | Bark | Decoction | Dysentery, stomachache | Hani |
| | Fruit | Water extraction | Clearing heat, detoxication, gastrointestinal discomfort | Zhuang |
| *G. yunnanensis* | Twig, leaf | Decoction | Bronchitis, cough | Hani |
| | Fruit | Alcoholic extraction | Kidney deficiency, rheumatism | Hani |

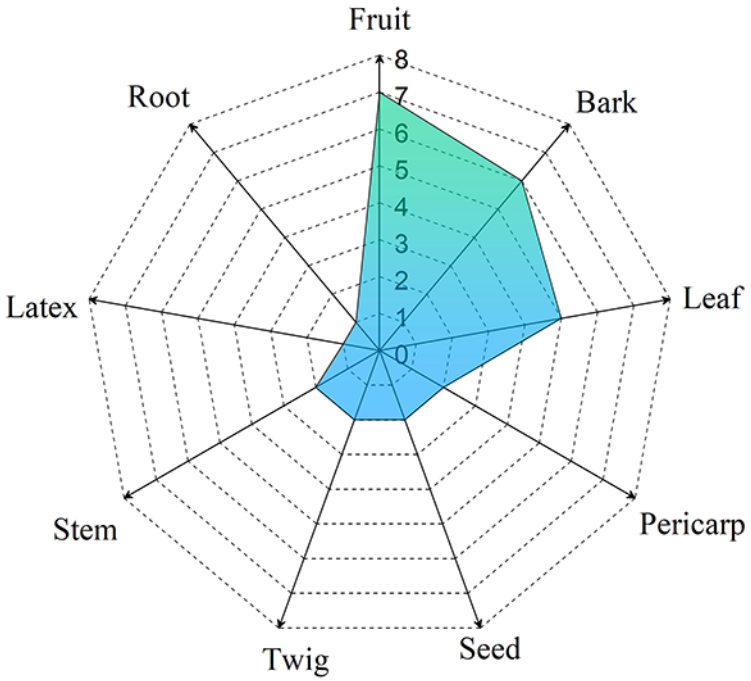


**Figure 3** Number of species of medicinal part used.

### 3.4. Ornamental Purposes

The ornamental values of some *Garcinia* plants were reported by 55 people (7.0%) in the ethnobotanical surveys. Seven species were ornamentally appreciated, including *G. multiflora*, *G. oblongifolia*, *G. paucinervis*, *G. xanthochymus*, *G. yunnanensis*, *G. subelliptica*, and *G. xipshuanbannaensis*, owing to their unique morphological characteristics, such as attractive architecture, which meets the aesthetic standards of the local people. For example, based on our surveys, *G. xanthochymus* (Figure 4A) was appreciated ornamentally by more than 50% of the investigated Zhuang people in Baise City, Guangxi, because of its pyramidal shape and evergreen glabrous


**Figure 4** Photos of *Garcinia xanthochymus* (**A**) and *G. subelliptica* (**B**), with ornamental values.

foliage, and *G. subelliptica* (Figure 4B) has long been cultivated in streets, parks, and universities for aesthetic and greening purposes in Guangzhou City, Guangdong Province.

### 3.5. Construction and Technology

The wood (trunks and thick branches) of five species, including *G. paucinervis*, *G. bracteata*, *G. multiflora*, *G. oblongifolia*, and *G. yunnanensis*, can be used as materials for buildings, boats, and bridges. In Guangxi, *G. paucinervis*, along with *Excentrodendron tonkinense*, *Erythrophleum fordii*, and *Madhuca pasquieri*, are regarded as the four ironwood trees due to their high hardness, abrasion, and corrosion resistance (S. Y. Li & Fu, 1997). According to our field investigations, 11 local people who had traditional knowledge in using *Garcinia* material as building wood from Jingxi City, Guangxi, reported that *G. paucinervis* wood has been used as a building material for hundreds of years, and wooden houses constructed using *G. paucinervis* branches could last for more than 50 years. In Jinping County, Yunnan Province, the cabins built by *G. yunnanensis* trunks could last for nearly 30 years, as mentioned by the seven local carpenters with ages ranging from 49 to 56 years. In addition, the timber from *G. paucinervis*, *G. multiflora*, and *G. oblongifolia* was traditionally used as furniture and carving materials, and *G. paucinervis* wood can also be used as raw materials for traditional musical instruments.

### 3.6. Cultural and Spiritual Significance

The cultural or spiritual importance of *Garcinia* species, including *G. hanburyi*, *G. paucinervis*, *G. xanthochymus*, and *G. oblongifolia*, are available in the literature (Editorial Committee of the Administration Bureau of Traditional Chinese Medicine, 1999; Song et al., 2020) or the local communities we investigated. In addition to the medicinal uses of the latex of *G. hanburyi*, this plant material has long been used to generate pigments for traditional Chinese paintings, woodcut paintings, and frescos. This record can be found in various ancient books in different dynasties, such as *Ying Zao Fa Shi* [Technology for building construction] published by Jie Li in 1100 AD of the Northern Song Dynasty, *Nan Cun Chuo Geng Lu* [Fallow period in South Village] initiated by Zongyi Tao in 1366 AD of the Yuan Dynasty, and *Pei Wen Zhai Shu Hua Pu* [Paintings on jades and books], edited by Yueban Sun


**Figure 5** The sacred tree: *Garcinia paucinervis*. (**A**) whole tree; (**B**) leaf part; (**C**) stem part; (**D**) stone stele with character introductions to the tree.

in 1708 AD of the Qing Dynasty. This information indicates an indispensable contribution of *G. hanburyi* resin in Chinese traditional painting cultures (Editorial Committee of the Administration Bureau of Traditional Chinese Medicine, 1999; Song et al., 2020).

According to our surveys, other valuable data regarding the cultural and spiritual information from *Garcinia* species were also uncovered in Guangxi. In Zanzi village (Duan County, Guangxi), over 95% of the local people highly appreciated the cultural and spiritual values of *G. paucinervis*, which were handed down from generation to generation. The oldest tree of *G. paucinervis* with a stone stele beside (Figure 5) is estimated to be more than 550 years old by the local communities and has been enshrined as the only sacred tree since their ancestors settled in the village (about 1530 AD, the Ming Dynasty). More than 80% of the investigated people maintain the faith that a big old tree can protect the villagers and bless them with a healthy and happy life. If the tree grows well, the locals believe that the auspiciousness will arrive and be maintained; however, ominous things will follow if the tree is damaged by thunder and strong winds. Therefore, people carefully protect the sacred trees from disruption by the outside world. The conservation statements have also been carved in the stone stele in which everyone, regardless of whether he/she is an emperor, soldier, or civilian, has no power to destroy the sacred tree. The other trees of this species, mature or young, are considered as the brothers and sisters or children of the sacred tree and are also taken care of. Interestingly, for some children who easily get sick, the sacred tree is respected as their Gandie, the nominated "father" of the children, to bless them to grow healthily and happily after a solemn ceremony. In return, the children, along with their family members, are responsible for safeguarding and protecting trees. Due to the sacred status, people have developed customs and cultures to offer sacrifice to the god tree and pray for blessings on the first or fifteenth day of each month or during traditional festivals.

For example, on Tomb Sweeping Day, the traditional Chinese festival to memorize their ancestors, the local people also perform ceremonies to show respect and gratitude to the sacred tree.

In addition, the cultural and spiritual importance of *Garcinia* spp. has also been mentioned in other areas of Guangxi. In Jingxi City, *G. xanthochymus* and *G. oblongifolia* play roles in the local culture of Feng Shui (Chinese geomancy). Approximately 21% of the investigated Zhuang people were inclined to place their ancestor's cemetery beside the old trees of *G. xanthochymus* or *G. oblongifolia*, because they believed that the evergreen and longevous tree could protect their ancestors better and their ancestors could better bless them in return. Furthermore, about 15.1% of the local communities built a tiny house near or under the old trees of *G. xanthochymus* for Tudigonggong, a local god, to safeguard the villagers.

### 3.7. Miscellaneous Usages

Despite the multiple values mentioned above, some other uses of *Garcinia* species have been identified based on our surveys or literature review. *G. subelliptica* acts as a windbreak against strong winds or typhoons in coastal areas of China, such as the Taiwan region (Zhang et al., 2015). In addition, the seed oils from *G. oblongifolia*, *G. xanthochymus*, *G. bracteata*, and *G. multiflora* were used for multiple purposes. In Jingxi City, Guangxi, six elderly people over 65 years old reported that the seed oil of *G. bracteata* was used as a fuel oil for lighting in the past. The seed oils from *G. oblongifolia*, *G. xanthochymus*, and *G. multiflora* can be used as lubricants or for making soaps (Liu et al., 2016).

## 4. Discussion

With diverse climate types and intricate geographic conditions, China is renowned as one of the most significant biodiversity hotspots worldwide, harboring over 34,000 higher plant species (Long, 2015). Interacting with surrounding plants for thousands of years, Chinese people have obtained a rich trove of traditional botanical knowledge based on their own experiences and observations of the plant species (Hong et al., 2015; Lee et al., 2008; Long et al., 2017). Our findings demonstrate that with long-term use of *Garcinia* plants, a variety of traditional botanical knowledge originating from 17 species has been developed by 10 linguistic groups in China, divided into six use categories, such as food, ethnomedicines, and cultural and spiritual applications, indicating the close interactions between the people and *Garcinia* plants. Among the 10 linguistic groups, the Zhuang people recognized the highest number of use categories (six) and *Garcinia* species (six) with traditional values, while the She and Yao communities knew the traditional uses of only one *Garcinia* species. The differences in traditional uses of *Garcinia* species among different linguistic groups could be related to the distribution of plant resources and the difference in people's observations and practices from the natural world.

*Garcinia* species are well known for their edible purposes. Based on our field surveys, 13 taxa can be used as food. Hu (2005) reported that five species, including *G. cowa*, *G. multiflora*, *G. oblongifolia*, *G. xanthochymus*, and *G. paucinervis*, could be consumed for their edible fruits. However, according to our field investigations, the edibility of *G. paucinervis* fruits has not been discovered, which might be due to the differences in the investigated locations. Seven endemic species were found to have traditional values, especially *G. oblongifolia*, which could be used as food, medicine, or ornamental trees. As endemic species are restricted to narrow geographical ranges with low population sizes (Kruckeberg & Rabinowitz, 1985), the records of traditional uses within the endemic species in China could display some specificity and directly enrich the inventory of related traditional botanical knowledge from *Garcinia* plants. For those that are not endemic species, some uniformity and divergence of *Garcinia* utilizations were discovered compared to those in other countries. For example, similar to the Chinese, the Thais and Indians also appreciate the edibility of fruit arils of *G. cowa*, *G. pedunculata*, and *G. xanthochymus* (Gogoi et al., 2016; Yapwattanaphun et al., 2000). In Thailand, the young leaves and shoots of *G. cowa* can also be used to produce soup. Another example is that although the

medicinal uses of *G. cowa* are recognized by both the Chinese and the people in Indonesia, the bark and latex of *G. cowa* are used as medicinal parts to cure several human diseases, such as fever (Jabit et al., 2009). However, the Chinese people used different plant parts as ethnomedicines, such as stems, leaves, and fruits (Table 2). These traditional utilizations of the same *Garcinia* species among the people in different countries might result from the similarities and differences between local cultures and people's experiences and observations of *Garcinia* plants.

In addition, several species are excellent examples of the significance of knowledge communication and sharing. Attracted by the fruit edibility of *G. mangostana*, this species has been introduced and cultivated in many countries, including China, where the plant does not natively occur (Pedraza-Chaverri et al., 2008). Recent phytochemical and pharmacological studies have revealed that the extracts or biochemical constituents such as xanthones and benzophenones possess various pharmacological activities, including anticancer and antidiabetic effects, indicating the therapeutic potential of *G. mangostana* fruits as food supplements for human health (Aizat et al., 2019; Palakawong & Delaquis, 2018; Tousian Shandiz et al., 2017). Therefore, the knowledge accessibility of *G. mangostana* fruits contributes to the intake of both nutrients and pharmaceutically active ingredients. *G. hanburyi* and *G. schefferi* have been introduced in China recently; however, they are traditionally used as medicinal plants to treat human diseases in China (Editorial Committee of the Administration Bureau of Traditional Chinese Medicine, 1999). These uses result from the exchange and sharing of traditional medicinal practices with people in Southeast Asia. Altogether, the effective communication of indigenous botanical knowledge can help people better understand the potential uses of the trees and complement their own experiences and practices for their health.

As many more traditional uses have been discovered worldwide, the relevance between traditional knowledge and modern scientific studies using state-of-the-art scientific approaches has been well reported by researchers. Many traditional practices, especially ethnomedicinal uses, have been supported by current scientific evidence (Carvalho et al., 2018; Houghton, 1995; Taylor et al., 2001). In recent decades, considerable phytochemical and biological investigations of Chinese *Garcinia* species have verified their traditional uses from a scientific perspective (Hassan et al., 2018; Ritthiwigrom et al., 2015). For instance, the anti-inflammatory properties of the pure compounds or extracts from the stems and fruits of *G. cowa* (Jabit et al., 2009, Panthong et al., 2009), fruits of *G. multiflora* (Tsai et al., 2018), and bark of *G. oblongifolia* (Z. W. Zheng & Lin, 1994) have been reported, supporting their corresponding ethnomedicinal uses to treat various human inflammatory diseases, such as stomatitis and asthma (Table 3). However, the validity of the medicinal uses of some *Garcinia* species still needs to be explored, such as the antiphlogistic effects of *G. esculenta* fruits and *G. oligantha* bark. Our ethnobotanical inventories could serve as valuable clues for further phytochemical and pharmacological studies.

In recent years, erosion of traditional knowledge has been reported through ethnobotanical surveys (Long et al., 2017; Srithi et al., 2009). Based on our survey, we also found some erosion phenomena related to the traditional knowledge of *Garcinia* species. Commonly, the older informants mentioned much more traditional uses of *Garcinia* species than the younger ones in the investigated areas, indicating the inheritance crisis of traditional knowledge. For example, in Jinping County, Yunnan Province, people aged over 50 years, in total, reported 11 traditional medicinal uses of *Garcinia* species; however, people with ages between 30 and 50 and less than 30 could only provide four and one medicinal uses, respectively. Additionally, some traditional medicinal uses recorded in traditional medicinal books were not identified during our surveys. For instance, it was recorded in Chinese classic medicinal books that, in traditional Dai medicine, the sap of stems and leaves from *G. cowa* and *G. xanthochymus* could expel leech out of the nose (Editorial Committee of Chinese Ethnomedicines, 2005). Nevertheless, according to our extensive investigations in Dai communities, the local people, even experienced healers, did not know the uses. Due to the knowledge erosion within *Garcinia* plants, effective investigations are crucial for knowledge conservation before it disappears,

emphasizing the importance and necessity of our research. Protection actions such as the identification of knowledge inheritors and the organization of workshops in the community for young and old people to share related botanical knowledge should be put forward by the local governments to compromise the decline of traditional knowledge.

Conservation of valuable plants in the wild is vital for the development and sustainability of associated traditional botanical knowledge, especially for trees, such as *Garcinia* taxa, usually with recalcitrant seeds (Malik et al., 2005; Noor et al., 2016; Uprety et al., 2012). To date, six endemic species, including *G. lancilimba*, *G. erythrosepala*, *G. tetralata* and *G. xipshuanbannaensis*, *G. paucinervis*, and *G. kwangsiensis*, have been characterized as vulnerable species in the Threatened Species List of China's Higher Plants, based on the International Union for Conservation of Nature (IUCN) Red List criteria, and *G. paucinervis* and *G. tetralata*, in particular, have also been identified as Class II endangered species in China due to its decreasing population (National Forestry and Grassland Administration, 2021; Qin et al., 2017). Thus, preservation strategies remain critical before we better understand the biology and anatomy of *Garcinia* seeds. Our surveys revealed that the cultural importance of *Garcinia* species contributed to their conservation in the local regions, which is consistent with the theory that cultural significance could result in the maintenance and development of biodiversity (Gavin et al., 2015; Pungetti et al., 2012). Plant species that play fundamental roles in diet, material production, medicine, and/or spiritual practices can be considered cultural keystone species, contributing to biodiversity conservation and ecological restoration (Garibaldi & Turner, 2004; Uprety et al., 2013). *Garcinia paucinervis*, the only sacred tree species in Zanzi village, is irreplaceable for maintaining people's stable spirits and cultures, which directly influences people's social life and practice as well as the persistence of community identity; we argue that the species is a cultural keystone species for the Zhuang people in the village. We first reported that *Garcinia* species could be considered as a sacred tree in China, which was similar to a previous study in which *G. subelliptica* was discovered in sacred forests in Okinawa Prefecture, Japan, with cultural significance (Chen & Akamine, 2021). Although other species such as *G. oblongifolia* and *G. multiflora* can be used as food, medicines, or building materials, their roles in the local region could hardly be considered fundamental because of the low percentage of interviewees who provided the use information, substitutability, and limited cultural salience. Therefore, they may not be identified as a cultural keystone species.

Even though our studies noticed that cultural and spiritual applications play an essential role in plant preservation, protection policies for the genus remain scarce. Based on our field surveys, several key threats to *Garcinia* species have been identified, including land expansion, road construction, agricultural land extension for economic crops, and wood for construction and technology. For example, in Chongzuo City, Guangxi Region, over 90% of informants regarded land expansion as the most serious threat to *Garcinia* plants, followed by road construction (75.1%). Therefore, strategies are needed to better balance rural development and the conservation of *Garcinia* taxa, which is integral to preserving related traditional botanical knowledge.

## 5. Conclusions

In combination with literature review and field surveys, our findings consolidate the long-term use of *Garcinia* plants in China, which has been recorded in various books from ancient to modern times. With a long history of use, a variety of traditional botanical knowledge originating from 17 species has been developed by different linguistic groups in China, which were divided into six usage categories: food, ethnomedicines, ornamental trees, construction and technology, cultural and spiritual applications, and miscellaneous uses. In particular, the cultural significance of several species, especially *G. paucinervis*, the sacred tree in the local area, contributes to their preservation and sustainability. However, *Garcinia* species without cultural or spiritual applications are easily threatened by rural urbanization and development, and erosion of traditional knowledge has been discovered from

time to time during our surveys. Consequently, effective policies are required to preserve the associated traditional knowledge under the rapid urbanization of rural areas and to protect the plants, especially endangered species, including *G. paucinervis* and *G. tetralata*.

## 6. Supplementary Material

The following supplementary material is available for this article:

Table S1: The main questions on *Garcinia* plants for ethnobotanical data collection.

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