Plant leaves for wrapping *zongzi* in China: an ethnobotanical study

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**Abstract**

**Background:** *Zongzi*, a common Chinese rice-pudding and one of the most symbolic foods in traditional Chinese festivals, is integral to both Chinese traditional culture and daily meals. Traditionally, the leaves of different plant species have been used to wrap *zongzi*. The variety of *zongzi* leaves (ZLs) can contribute to the *zongzi*-based cultural diversity. Given the cultural and dietary significance of *zongzi*, the ethnobotanical surveys were carried out, aiming to investigate the diversity of plant species and associated traditional botanical knowledge of ZLs, which could attract particular attention for their further studies.

**Method:** Both literature studies and field surveys were conducted in the study. The field investigations were carried out from May 2006 to June 2018 throughout China. Ethnobotanical information about ZLs was obtained by direct observation, semi-structured interviews, and key informant interviews.

**Results:** In total, ZLs from 57 plant species were identified and recorded, belonging to 38 genera and 18 families. Several folk legends have been formed to explain the origin of using plant leaves to pack *zongzi*. Over time, Chinese people have developed diverse traditional botanical knowledge surrounding ZLs, especially regarding the *zongzi* flavor, antiseptic functions, and medicinal values. Based on the literature review, some species of ZLs such as the leaves of *Corchorus capsularis* and *Vernicia fordii* may even pose a potential threat to human health. Presently, in some regions of China, the traditional ZLs, such as *Cocos nucifera*, *Tilia tuan*, and *Zizania latifolia*, are being substituted by commercialized ZLs such as *Phragmites australis* and *Indocalamus tessellatus*.

**Conclusion:** A variety of traditional ZLs have been discovered in China. Although diverse traditional knowledge exists in China surrounding the usage of ZLs, some species may have the potential of threatening human health. Therefore, further explorations are necessary to comprehensively evaluate traditional ZLs, the results of which could help to conserve the cultural diversity of *zongzi*, to guarantee food safety, and to encourage the uses of plant leaves in food, medicine, and environmental management, for our human health.

**Keywords:** Plant leaves, *zongzi*, Dragon Boat Festival, Traditional botanical knowledge, Chinese symbolic food

**Background**

The Dragon Boat Festival, one of the most significant traditional festivals in China, has been celebrated for over 2000 years, occurring on the fifth day of the fifth month in the Chinese lunar calendar [1]. It is also named the *Zongzi* Festival, since eating *zongzi* is a widespread custom to celebrate this festival all over China [2]. *Zongzi*, also named *Jiao Shu* and *Tong Zong*, is a traditional Chinese rice-pudding, which is made of glutinous rice stuffed with different fillings, and then wrapped in plant leaves that are used only for wrapping purposes instead of consumption. Additionally, *zongzi* also plays an indispensable role in daily meals in China [2]. Even though *zongzi* has a distinct cultural significance for Chinese people, *zongzi*-like food is prevalent and carries cultural significance in many other countries and regions, such as Japan, Korea, the Philippines, and Latin America. In Japan, the *zongzi*-like food called *Chimaki* is made of rice flour and is also essential to the Dragon Boat Festival, while in Mexico, *tamales* is made of maize-based dough to celebrate Day of the Dead [3, ...
In Southeast and East Europe, *sarma* or *dolma*, usually made of rice, bulgur, or minced meat and wrapped in plant leaves, are very common. In Turkey and Caucasus, these foods could be served as festivity meals to celebrate some festivals, such as Easter and Christmas Eve [5].

In present-day China, a great variety of *zongzi* has been developed, with different colors, shapes, fillings, and tastes, thus contributing to the diversification of the *zongzi* culture [6]. There are two most common shapes of *zongzi*: triangular-pyramidal and rectangular. According to the flavor, *zongzi* can be roughly divided into three categories: original, salty, and sweet. The original *zongzi* are only made of white glutinous rice without any other salty or sweet ingredients, while the salty and sweet *zongzi* are made of glutinous rice with the addition of other salty or sweet ingredients. The ingredients added to *zongzi* vary from region to region [7]. In addition to meat like pork and chicken, different parts of plants have been developed to be used as seasonings, such as the flowers of *Nelumbo nucifera*, the fruits of *Ziziphus jujuba*, the seeds of *Castanea mollissima*, and the leaves of *Clausena lansium* and *Perilla frutescens* [6].

Regardless of the category of *zongzi*, after all the fillings are completely prepared, *zongzi* is traditionally wrapped by plant leaves of different species called *zongzi* leaves (ZLs) before they are steamed or boiled. The species of ZLs used depends on regional traditions and geographical locations [6, 8]. The ideal ZLs should meet the requirements of non-contamination, integrity, proper size, pleasant fragrance, preferable flexibility, and tolerance to steaming or boiling [8, 9]. These leaves can be collected from the wild and sold on the market immediately. However, commercially, they are usually air-dried for dehydration in long-term storage in order to eliminate the limitation of regionalism and seasonality [10].

In recent years, the development of biodegradable packaging materials for food has received increased attention since petroleum-based plastics have caused serious environmental contamination because of the resistance to degradation [11]. Renewable natural resources can be effective for the development of biodegradable packing materials [12]. Thus, ZLs with packaging functions may provide a new opportunity for the development and utilization of environmentally friendly packaging materials. In addition to the importance of their packaging properties, ZLs can contribute to the flavor and storage time of *zongzi*. It was reported by Maite et al. [4] that the flavor of *tamales*, the *zongzi*-like food from Mexico, was affected by the plant leaves used to wrap them.

Ethnobotanical surveys focusing on the plant leaves used as wrapping materials for food have been reported in some countries and regions [4, 5, 13]. For example, 21 species of plant leaves have been reported to wrap *tamales* in the Mexican state of Veracruz [4], and the leaves from 87 botanical taxa were used to wrap *sarma* in Turkey and the Balkans [5]. In addition, plant leaves used to wrap food were discovered from time to time when researchers conducted ethnobotanical investigations [14–18]. For instance, nine species of plant leaves were used to wrap food like *tamales* which were cooked in earth ovens located in Maya Lowlands [18]. Although a few species of ZLs have been sporadically reported in publications, most of them were published in Chinese [6, 9, 10, 19]. No studies, to the best of our knowledge, have been carried out to investigate the ethnobotanical importance of ZLs in China. In view of the cultural and dietary significance of *zongzi*, the ethnobotanical surveys of ZLs were conducted from May 2006 to June 2018. The aim of the present study was to investigate the plant species and associated traditional knowledge of ZLs, which could help with the conservation of the cultural diversity of *zongzi*, and be of interest to scientific researchers studying the traditional uses of ZLs. If the associated traditional knowledge can be recorded and understood, it would make contributions to food safety and to the further development and utilization of ZLs in the fields of food, medicine, environmental sanitation, and more broadly, for the sake of our human and environmental health.

**Materials and methods**

**Literature studies**

A large quantity of records about *zongzi* has been discovered in ancient literatures. Collections from the National Library of China, together with books from ancient to recent times were investigated and examined. Information on the plant species recorded in *Flora of China* (English version) has been intensively studied. In addition, information from databases including Web of Science (WoS), Science Direct, Google Scholar, PubMed, and the Chinese databases such as WP (China Science and Technology Journal Database), Wanfang and CNKI (China National Knowledge Infrastructure) were used in the study.

**Field surveys**

Our research group has focused on the ZLs for a long time. Here, we recorded and summarized all the ethnobotanical surveys concerning the ZLs by our group. The surveys were mainly conducted close to the Dragon Boat Festival because the *zongzi* were prevalent during this festival, which was beneficial for us to identify the species of ZLs and to investigate the associated traditional knowledge. The ethnobotanical investigations of ZLs were conducted on 31 separate occasions throughout China from May 2006 to June 2018, including 23 provinces, 5 autonomous regions, 4 municipalities, and 2...
special administrative regions. Two to nine areas (county or county-level city/district) were investigated in each province. In total, 143 areas throughout China were studied (Fig. 1). In each area, 2 to 5 villages were surveyed and 5–10 people in each village who had traditional knowledge of ZLs were chosen to interview. A total of 3603 informants including 1701 males and 1902 females between 18 and 87 years of age were interviewed. Informants could be characterized as belonging to the following ethnic groups: Mongolian, Tibetan, Uyghur, Hui, Miao, Yi, Zhuang, Buyi, Man, Korean, Dong, Bai, Yao, Hani, Tujia, Dai, Li, She, Shui, Qiang, Maonan, Lisu, Jinuo, and Gaoshan ethnic groups, as well as the Han people, who represent the major linguistic group in China.

Several different ethnobotanical methods, including direct observation, semi-structured interviews, and key informant interviews [20] were employed to collect the ethnobotanical data. When conducting surveys, we strictly followed the ethical guidelines issued by the American Anthropological Association (www.aaanet.org) and the International Society of Ethnobiology (http://www.ethnobiology.net). During our surveys, the scientific name, family name, Chinese name, life form, medicinal value, and main distribution of ZLs were recorded. Voucher specimens collected from the various regions were determined and identified by the authors based on Flora of China (http://flora.huh.harvard.edu/china), and the nomenclature standards of plant species were referred to The Plant List (http://www.theplantlist.org/). The voucher specimens were deposited in the Herbarium of the Minzu University of China.

Results and discussion
Diversity of plant leaves used for zongzi-wrapping
China harbors great plant biodiversity, with about 34,000 species of higher plants discovered and recorded [21]. With such diverse plant resources, people in different regions of China have generated different traditions to use local plant species to wrap zongzi. On the basis of investigations in China, a total of 57 plant species were documented and identified, falling into 38 genera and 18 families (Table 1). Some examples of zongzi with different shapes wrapped by plant leaves are shown in Figs. 2 and 3. There was only one species, namely, Podocarpus nagi, that belonged to gymnosperm, while others were all categorized into angiosperm (Table 1). Among the
| No. | Scientific name                          | Family name | Chinese name | Life form | Medicinal value                                           | Main distribution                  | Voucher number |
|-----|-----------------------------------------|-------------|--------------|-----------|----------------------------------------------------------|------------------------------------|----------------|
| 1   | *Alpinia abundiflora* Burtt and R. M. Sm. | Zingiberaceae | 草豆蔻       | Herb      | Treating rheumatism, invigorating spleen and alleviating emesis | Hainan                             | MUCH-ZLS-057 |
| 2   | *Alpinia pricei* Hayata                 | Zingiberaceae | 短穗山姜     | Herb      | ——                                                        | Taiwan                             | MUCH-ZLS-046 |
| 3   | *Alpinia zerumbet* (Pers.) B. L. Burtt and R. M. Sm. | Zingiberaceae | 艳山姜       | Herb      | Treating rheumatism                                       | Taiwan and Fujian                  | MUCH-ZLS-039 |
| 4   | *Amomum villosum* Lour.                 | Zingiberaceae | 砂仁         | Herb      | Treating rheumatism                                       | Guangdong, Guangxi, Yunnan         | MUCH-ZLS-010 |
| 5   | *Arundo donax* L.                       | Gramineae    | 芦竹          | Bamboo    | Clearing heat and diuresis                               | Yunnan, Guangxi, and Guizhou       | MUCH-ZLS-007 |
| 6   | *Aspidistra elatior* Blume              | Liliaceae    | 蜘蛛抱蛋     | Herb      | Diminishing inflammation, hemostasis, treating rheumatism and analgesia | Yunnan and Guizhou                  | MUCH-ZLS-008 |
| 7   | *Aspidistra oblongifolia* F. T. Wang et K. Y. Lang | Liliaceae | 棕叶草       | Herb      | ——                                                        | Yunnan and Guizhou                  | MUCH-ZLS-044 |
| 8   | *Aspidistra sichuansis* K. Y. Lang et Z. Y. Zhu | Liliaceae | 四川蜘蛛抱蛋 | Herb      | ——                                                        | Sichuan, Yunnan, and Guizhou       | MUCH-ZLS-043 |
| 9   | *Aspidistra zongbaya* K. Y. Lang et Z. Y. Zhu | Liliaceae | 棕粑叶       | Herb      | Clearing heat, detoxification, hemostasis, and diuresis   | Yunnan and Guizhou                  | MUCH-ZLS-009 |
| 10  | *Cocos nucifera* L.                     | Palmae       | 椰子          | Tree      | Clearing heat                                            | Hainan                             | MUCH-ZLS-031 |
| 11  | *Corchorus capsularis* L.               | Tiliaceae    | 黄麻          | Herb      | Diminishing inflammation, detoxification, hemostasis, and analgesia | Guangxi                           | MUCH-ZLS-034 |
| 12  | *Dendrocalamus giganteus* Munro         | Gramineae    | 龙竹          | Bamboo    | Clearing heat                                            | Yunnan                             | MUCH-ZLS-011 |
| 13  | *Dendrocalamus latiflorus* Munro        | Gramineae    | 麻竹          | Bamboo    | Clearing heat and detoxification                          | Southern China                     | MUCH-ZLS-056 |
| 14  | *Evodia glabrifolia* (Champ.) N. P. Balakr. | Rutaceae | 梆叶吴萸     | Tree      | Diminishing inflammation and analgesia                    | Guangxi, Hainan and Fujian         | MUCH-ZLS-032 |
| 15  | *Fargesia fractiflexa* T.P. Yi          | Gramineae    | 扫把竹        | Bamboo    | ——                                                        | Yunnan                             | MUCH-ZLS-012 |
| 16  | *Firmiana platanifolia* (L.f.) Marsili   | Labiatae     | 梧桐          | Tree      | Clearing heat and detoxification                          | Guangdong and Hunan                | MUCH-ZLS-041 |
| 17  | *Hedychium coronarium* J. Koenig        | Zingiberaceae | 姜花          | Herb      | Treating rheumatism, analgesia and insomnia               | Taiwan                             | MUCH-ZLS-049 |
| 18  | *Indocalamus guangdongensis* H. R. Zhao and Y. L. Yang | Gramineae | 广东箬竹     | Bamboo    | Clearing heat and detoxification                          | Guangdong, Guangxi, and Guizhou    | MUCH-ZLS-020 |
| 19  | *Indocalamus henkii* McClure            | Gramineae    | 粽巴箬竹      | Bamboo    | Clearing heat and detoxification                          | Guangdong, Guangxi, and Hunan      | MUCH-ZLS-037 |
| 20  | *Indocalamus latifolius* (Keng) McClure | Gramineae    | 闽叶箬竹      | Bamboo    | Clearing heat and detoxification                          | Southern China                     | MUCH-ZLS-013 |
| 21  | *Indocalamus tessellatus* (Munro) Keng f. | Gramineae | 箸竹          | Bamboo    | Clearing heat, detoxification, hemostasis, and diminishing inflammation | Southern China                     | MUCH-ZLS-006 |
| 22  | *Livistona chinensis* (Jacq.) R.Br. ex Mart. | Palmae | 蒲葵          | Tree      | Diminishing inflammation and hemostasis                   | Yunnan and Hainan                  | MUCH-ZLS-014 |
| 23  | *Magnolia officinalis* Rehder and E.H.Wilson | Magnoliaceae | 四叶厚朴     | Tree      | Treating rheumatism, diminishing inflammation and analgesia | Guangxi                            | MUCH-ZLS-033 |
| 24  | *Miscanthus floridulus* (Labill.) Warb. ex K. Schum. and Lautererb. | Gramineae | 五节芒        | Herb      | Clearing heat, detoxification, and diuresis               | Fujian and Zhejiang                | MUCH-ZLS-028 |
| 25  | *Monocladus amplexicaulis* Chia et al.   | Gramineae    | 萌香竹        | Bamboo    | Clearing heat and treating rheumatism                     | Guangxi                            | MUCH-ZLS-045 |
| No. | Scientific name                  | Family name       | Chinese name | Life form | Medicinal value                                      | Main distribution                | Voucher number |
|-----|----------------------------------|-------------------|--------------|-----------|-----------------------------------------------------|----------------------------------|----------------|
| 26  | Musa acuminata Colla             | Musaceae          | 小果野蕉     | Herb      | Clearing heat                                       | Yunnan and Guangxi               | MUCH-ZLs-015  |
| 27  | Musa balbisiana Colla            | Musaceae          | 野蕉         | Herb      | ——                                                  | Yunnan and Guangxi               | MUCH-ZLs-055  |
| 28  | Musa basjoo Siebold and Zucc. ex Iljuma | Musaceae | 芭蕉     | Herb      | Clearing heat and diuresis                          | Southern China                   | MUCH-ZLs-001  |
| 29  | Musa nana Lour.                  | Musaceae          | 香蕉         | Herb      | Clearing heat, detoxification, and diuresis         | Yunnan, Guangdong, Guangxi and Fujian | MUCH-ZLs-003  |
| 30  | Musa sapientum L.                | Musaceae          | 大蕉         | Herb      | Clearing heat and diminishing inflammation         | Yunnan, Guangdong, and Guangxi   | MUCH-ZLs-016  |
| 31  | Musa itineras Tutcher            | Musaceae          | 野芭蕉       | Herb      | Clearing heat and antimalarial effect               | Yunnan, Guizhou, and Guangxi     | MUCH-ZLs-002  |
| 32  | Nelumbo nucifera Gaertn.         | Nymphaeaceae      | 莲           | Herb      | Clearing heat, detoxification, and hemostasis       | Jiangsu, Zhejiang, Guangdong, and Hainan | MUCH-ZLs-021  |
| 33  | Pandanus australinensis T. L.Wu   | Pandanaceae       | 露兜草       | Herb      | Clearing heat, detoxification, and diminishing inflammation | Guangdong and Hainan            | MUCH-ZLs-022  |
| 34  | Pandanus tectorius Parkinson ex Du Roi | Pandanaceae | 露兜树     | Tree      | Clearing heat and diuresis                          | Guangdong and Hainan             | MUCH-ZLs-023  |
| 35  | Perilla frutescens (L.) Britton  | Labiatae          | 紫苏         | Herb      | Treating common cold, alleviating emesis, invigorating spleen and stomach | Liaoning                       | MUCH-ZLs-052  |
| 36  | Phegmites australis (Cav.) Trin. ex Steud. | Gramineae | 芦苇     | Herb      | Clearing heat and detoxification                     | Northern China                   | MUCH-ZLs-029  |
| 37  | Phylllostachys bambusoides Siebold and Zucc. | Gramineae | 桂竹     | Bamboo    | Clearing heat, detoxification, hemostasis, relieving sore throat, diminishing inflammation and anti-alcoholism | Guangdong, Guangxi, Hainan, and Yunnan | MUCH-ZLs-004  |
| 38  | Phylllostachys heterocycla (Carrière) Matsum. | Gramineae | 尖苞柊叶   | Herb      | Clearing heat                                        | Hainan                           | MUCH-ZLs-047  |
| 39  | Phylllostachys heteroepalata (Lour.) Merr. | Gramineae | 尖苞柊叶   | Herb      | Clearing heat, detoxification, hemostasis, and diuresis | Guangdong, Guangxi, and Yunnan | MUCH-ZLs-017  |
| 40  | Piper sarmentosum Roxb.           | Piperaceae        | 假蒟         | Herb      | Diminishing inflammation, treating rheumatism, analgesia, and antimarial effect | Guangdong and Guangxi            | MUCH-ZLs-025  |
| 41  | Pleioblastus amarus (Keng) Keng f. | Gramineae | 苦竹       | Bamboo    | Clearing heat, detoxification, and removing the phlegm | Yunnan and Guizhou               | MUCH-ZLs-042  |
| 42  | Podocarpus nagi (Thunb.) Pilg.    | Podocarpaceae     | 竹柏         | Tree      | Hemostasis and treating common cold                  | Guangdong and Guangxi            | MUCH-ZLs-035  |
| 43  | Quercus dentata Thunb.           | Fagaceae          | 槲          | Tree      | Clearing heat, hemostasis, diuresis, and treating hemorhoid | Shanxi, Henan, and Shandong       | MUCH-ZLs-053  |
| 44  | Raphis excelsa (Thunb.) Henry     | Palmae            | 棕竹         | Shrub     | Treating rheumatism, hemostasis, and alleviating emesis | Guangxi and Yunnan               | MUCH-ZLs-019  |
| 45  | Saccharum officinarum L.          | Gramineae         | 甘蔗         | Herb      | Clearing heat, detoxification, and hypoglycemic effect | Fujian and Guangdong             | MUCH-ZLs-040  |
| 46  | Sorghum bicolor (L.)             | Gramineae         | 高粱         | Herb      | Diminishing inflammation and treating                | Hunan, Hubei,                    | MUCH-
Table 1 Plant leaves used to wrap zongzi in China based on our field work (Continued)

| No. | Scientific name          | Family name | Chinese name | Life form | Medicinal value                              | Main distribution          | Voucher number |
|-----|-------------------------|-------------|--------------|-----------|---------------------------------------------|-----------------------------|----------------|
| 50  | Vernicia fordii (Hemsl.) | Euphorbiaceae| 油桐          | Tree      | Removing the phlegm and promoting digestion and assimilation | Hunan and Sichuan           | MUCH-ZLs-036  |
| 51  | Terminalia catappa L.    | Myrtiflorae | 檀仁树        | Tree      | Treating rheumatism, detoxification, relieving cough and hypoglycemic effect | Guangdong, Guangxi, Guizhou, and Yunnan | MUCH-ZLs-048  |
| 52  | Thysanolaena maxima (Roxb.) Kuntze | Gramineae | 棕叶芦 | Herb | Detoxification, treating bronchitis, hepatitis, and diarrhea | Guangdong, Guangxi, Guizhou, and Yunnan | MUCH-ZLs-005  |
| 53  | Tilia tsien Szyssyl.     | Tiliaceae   | 桂树          | Tree      | Treating rheumatism and astalgia             | Beijing                    | MUCH-ZLs-050  |
| 54  | Trachycarpus fortunei (Hook.) H. Wendl. | Palmae | 棕榈          | Tree      | Hemostasis and diuresis                     | Hunan, Jiangxi, and Sichuan | MUCH-ZLs-036  |
| 55  | Vernicia fordii (Hemsl.) | Euphorbiaceae| 油桐          | Tree      | Removing the phlegm and promoting digestion and assimilation | Hunan and Sichuan           | MUCH-ZLs-038  |
| 56  | Zea mays L.              | Gramineae   | 玉米          | Herb      | Clearing heat, hypoglycemic effect          | Shandong and Northwestern China | MUCH-ZLs-051  |
| 57  | Zizania latifolia (Griseb.) Turcz. ex Stapf | Gramineae | 稻 | Herb | ——                                       | Jiangsu                    | MUCH-ZLs-054  |

The species of ZLs employed in each province of China are listed in Table 3. Some similarities and differences between the species of ZLs in different regions have been observed, which partly reflected the cultural diversity of zongzi. The species of ZLs used by the people in the south of China were much more numerous than that in the north of China (Table 3), which may due to the differences between plant resources, people’s experience and observation towards ZLs and traditional culture. The number of ZLs used in Guangxi Province was the maximum with 28 species, followed by Yunnan, Guangdong, Hainan, and Guizhou provinces with 24, 21, 15, and 15 species, respectively. However, the traditional ZLs had not been found in Biru and Leiwuqi counties, and Chengguan District in Tibet because the local people did not have the traditional custom of eating zongzi, or they bought the commercialized ZLs such as the leaves of Indocalamus herklotsii from adjacent Sichuan Province due to the local limitations of plant resources. Among these ZLs, the leaves of Indocalamus spp. were the most common ZLs in Southern China; however, the leaves of Phragmites australis were found to be the most dominant in Northern China. Additionally, the husk leaves or leaves of Z. mays were regarded as traditional ZLs in 13 provinces located in both the south and north of China, which may partly be because of the widespread cultivation and people’s similar traditional knowledge related to Z. mays.

According to our surveys, some similarities and differences of ZLs among or within ethnic groups were discovered. The ZLs of Phrynium capitatum were widely

plant families, the most dominant family was Gramineae with 20 species (35.1%), followed by Musaceae (10.5%) Zingiberaceae (8.8%), Liliaceae (7.0%), and Palmae (7.0%), with 6, 5, 4, and 4 species, respectively. As for the plant genera, Musa, Aspidistra, and Indocalamus were the three most common genera, with 6, 4, and 4 species, respectively, followed by Alpinia, Phrynium, Phyllostachys, Dendrocalamus, and Pandanus. By contrast, other genera contained one species only (Tables 1 and 2). Within these 57 plant species, 30 plant species were herbaceous (52.6%), while 13 were trees or bamboos (22.8%) (Fig. 4). However, only one species, Raphis excelsa, was liana and no shrubs were discovered. When compared with previous investigations [4, 5, 13], the species of plant leaves were quite different from our findings. In Veracruz of Mexico, Marantaceae, Heliconiaceae, and Araliaceae were the three most dominant families whose leaves were used to wrap tamales, and only one common species was found, namely, Zea mays whose leaves could be used as ZLs by Chinese people [4]. The species of plant leaves as food wrappers for sarma in Turkey and the Balkans are all different from ZLs we investigated mostly because the sarma leaves could be eaten while the ZLs were only used for wrapping purposes [5, 13]. Our surveys together with the previous studies highlight the significance of ethnobotanical investigations regarding the plant leaves for food wrapping. Extensive investigations are still worthwhile to be conducted in some places, especially in Latin America and Southeast Asia where people consume zongzi-like food [6].
used by the Han people in the west and south of Guangdong Province. However, it was hardly found among the Han people in the east, mainly due to the distribution area of *P. capitatum*. It was commonly believed by the Han people in Shanghai that the usage of the traditional ZLs of *Indocalamus* spp. was originated from the Han communities in Anhui Province because of the cultural communication in the course of economic exchange. Even though *Piper sarmentosum* is widely distributed in Guangxi Province, it was told that *P. sarmentosum* leaves were mainly used by the Zhuang people in East Guangxi. It was rarely used by the same ethnic group in other parts of Guangxi because, for the Zhuang people in the east part, the knowledge that *P. sarmentosum* leaves could be used as ZLs was inherited from their ancestors for a long time. Therefore, the similarities and differences of the species of ZLs among and within ethnic groups could be considered the results of plant distribution, the heritage of traditional knowledge, and cultural exchange.

The leaves of *Zizania latifolia* represent the earliest ZLs, which have been used since the Spring and Autumn period of China (770–476 BC) [22]. Even though using the ZLs of *Z. latifolia* was prevalent in ancient times, it has now greatly lost its popularity based on our field investigations. According to the areas we investigated, only people in Suzhou City of Jiangsu Province in China still used this species as one of the traditional ZLs. The leaf of *Melia azedarach* was another ancient ZL, which was recorded in the Chinese ancient book, *Xu Qi Xie Zhi*, written by Wu Jing of Southern Dynasties of China (420–589 AD) [23]. However, it had not been discovered
Fig. 3 Some shapes of zongzi with different species of ZLs (a. Cocos nucifera; b. Phrynium hainanense; c. Nelumbo nucifera; d. Thysanolaena maxima; e. Phrynium capitatum; f. Pandanus tectorius; g. Indocalamus tessellatus; h. Aspidistra sichuanensis; i. Phragmites australis)

Table 2 Taxonomic diversity of plant species in China

| Family          | Number of genera | Percentage | Number of species | Percentage |
|-----------------|------------------|------------|------------------|------------|
| Gramineae       | 14               | 36.8       | 20               | 35.1       |
| Palmae          | 4                | 10.5       | 4                | 7.0        |
| Zingiberaceae   | 3                | 7.9        | 5                | 8.8        |
| Labiatae        | 2                | 5.3        | 2                | 3.5        |
| Tiliaceae       | 2                | 5.3        | 2                | 3.5        |
| Lilaceae        | 1                | 2.6        | 4                | 7.0        |
| Marantaceae     | 1                | 2.6        | 3                | 5.3        |
| Musaceae        | 1                | 2.6        | 6                | 10.5       |
| Pandanaceae     | 1                | 2.6        | 2                | 3.5        |
| Other families  | 9                | 23.7       | 9                | 15.8       |
| Total           | 38               | 100        | 57               | 100        |
as being used by people to wrap zongzi. Studying the inheritance and change of traditional ZLs in each area could prove significant to the conservation of biodiversity of ZLs.

In addition to plant leaves, the shells of bamboo shoots, according to our interviews, can also be traditionally used to wrap zongzi in some regions such as Sichuan, Hunan, and Zhejiang provinces. Some species of plant leaves with correct length and good flexibility are good resources to bind zongzi apart from their wrapping abilities, such as the leaves of Phragmites australis, Cocos nucifera, and Livistona chinensis. Traditionally, the leaves or stems of Imperata cylindrica, Iris tectorum, Oryza sativa, Trachycarpus fortunei, Typha angustifolia, and Cyperus malaccensis can be used as binding materials as well. However, it has become more and more common to use strings made of cotton or flax to bind zongzi at present because of their convenience and low prices.

The folk legends of ZLs

According to our surveys, some folk legends of ZLs had been widely spread. It is generally believed that both the Dragon Boat Festival and the traditional custom of eating zongzi are to commemorate the great Chinese patriotic poet, Qu Yuan (339–278 BC), who drowned himself to death for his country in the Miluo River (Yueyang City, Hunan Province, at present). At that time, when people heard the news of his suicide, they fell into a deep sadness. Then, it was agreed that scattering the cooked glutinous rice into the river as a sacrifice for Qu Yuan was beneficial to express these feelings. However, the food thrown into the river was mainly robbed and eaten by Jiaolong, the mythical dragon-like creature at the time. Fortunately, Jiaolong could be effectively deterred by the plant leaves of Melia azedarach. Using this knowledge, the people started using plant leaves to wrap glutinous rice before it was thrown into the river so as to protect the food for Qu Yuan from being eaten by Jiaolong. This folk legend was widely spread and passed down from generation to generation throughout China. Over time, different ZLs from various plant species are gradually adopted on the Dragon Boat Festival in China. Our investigations were consistent with those recorded in the ancient books, Xu Qi Xie Zhi and Jing Chu Sai Shi Ji [23], which, to some extent, indicated the stability of cultural inheritance of ZLs in China.

Interestingly, a particular folk legend concerning the leaves of Miscanthus floridulus was well known by the She people in Chibi Village of Fujian Province in Southern China. This legend is related to the revenge and atrocity of Zhu Yuanzhang (1328–1398 AD), who was the first emperor of the Ming Dynasty (1368–1644 AD) [24]. When Zhu Yuanzhang was a cowboy in his childhood, he did not take care of his cow. As a result, his cow usually audaciously trampled and ate the vegetables cultivated by the She people. One time, when an old She woman found that the cow was eating her vegetables, she was so angry that she expelled it with a whip. After knowing that his cow was seriously lashed, Zhu Yuanzhang became furious and made a promise to revenge one day. When he became the emperor of the Ming Dynasty, he still remembered the humiliation that he experienced in his childhood and he commanded his army to kill the She people. Therefore, the She people had to leave their hometowns, those of whom in Guangdong Province escaped to the remote mountains distributed in the east of Fujian Province. They were so afraid of being killed that they could not collect the bamboo leaves that grew down the hill at lower altitudes, which they originally used to wrap zongzi during the Dragon Boat Festival. One patriarch came up with a good idea that the leaves of M. floridulus could also be used as ZLs. This novel way to wrap zongzi was widely spread and accepted by the She people. From then on, the tradition of using the ZLs of M. floridulus had been gradually formed. While the origin and authenticity of this legend remain to be determined and validated, it is possible that these legends about ZLs could be partly responsible for the diversity of the traditional culture of the Dragon Boat Festival.

Collection and processing of ZLs

According to our interviews, despite a diversity of plant leaves used, the people across different regions had almost the same processes to collect and process ZLs. In general, the fresh healthy ZLs are collected during the Dragon Boat Festival in the mountains or home gardens and then washed with fresh water to remove dirt and dust. After the leaves are cleaned up, they are immersed in boiling water until they become soft and flexible enough to wrap the prepared glutinous rice. The
| Province      | Investigated area (county or county-level zone) | Linguistic group | Species of ZLs (No.) | Number |
|--------------|-----------------------------------------------|------------------|----------------------|--------|
| East China   |                                               |                  |                      |        |
| Shandong     | Zhuchengshi, Dongchangfu, Pingyi, Decheng     | Han              | 36, 46, 49, 56       | 4      |
| Jiangsu      | Gaoyou, Peixian, Shihong, Wuzhong             | Han              | 32, 36, 57           | 3      |
| Anhui        | Tongqiao, Lujiang, Huaining, Linx             | Han              | 20, 36               | 2      |
| Zhejiang     | Taishun, Rui'an, Jinging, Putuo, Xi'an        | Han, She         | 21, 24, 32, 36, 42   | 5      |
| Fujian       | Xiapu, Hanjiang, Shangcheng, Cangshan         | Han, She         | 3, 13, 14, 20, 21, 24, 28, 40, 48 | 9      |
| Shanghai     | Hongkou, Pudong, Fengxian                      | Han              | 20, 21, 32           | 3      |
| South China  |                                               |                  |                      | 36     |
| Guangdong    | Sanxiang, Qingcheng, Haifeng, Huidong, Deqing, Leizhou, Haizhu | Han, Yao | 4, 13, 16, 18, 19, 20, 21, 28, 29, 30, 32, 33, 34, 37, 39, 40, 43, 45, 48, 50, 52 | 21     |
| Guangxi      | Yongfu, Jingxi, Leye, Huanjing, Lingshan, Pingshang, Pingle | Han, Zhuang, Yao | 4, 5, 9, 11, 13, 14, 18, 19, 20, 21, 23, 25, 26, 27, 28, 29, 30, 31, 34, 37, 39, 40, 41, 43, 45, 47, 50, 52 | 28     |
| Hainan       | Ledong, Wenchang, Meilan, Lingshi, Wanning   | Han, Li, Miao    | 1, 10, 14, 20, 21, 22, 27, 28, 29, 32, 33, 34, 37, 38, 40 | 15     |
| Central China|                                               |                  |                      | 17     |
| Hubei        | Xiangyang, Hongan, Hongshan, Xiaoting         | Han              | 28, 36, 49, 54, 56   | 5      |
| Hunan        | Guiyang, Lixian, Qiandong, Xinshao, Jianghua, Tongdao | Han, Dong, Yao | 6, 13, 16, 19, 20, 21, 28, 29, 37, 40, 49, 54, 55 | 13     |
| Henan        | Lushi, Xiping, Taikang, Minquan               | Han              | 20, 21, 36, 42, 46, 56 | 6      |
| Jiangxi      | Huichang, Ningdu, Shangli, Dean               | Han              | 13, 20, 21, 28, 36, 54 | 6      |
| North China  |                                               |                  |                      | 6      |
| Beijing      | Yanqing, Haidian, Shunyi                      | Han, Man         | 36, 53               | 2      |
| Tianjin      | Baodi, Hedong, Hexi                           | Han              | 36                   | 1      |
| Hebei        | Cixian, Xianghe, Lixian, Suning               | Han              | 36                   | 1      |
| Shanxi       | Laocheng, Ruicheng, Xiaoyi, Yanggao          | Han              | 36, 46               | 2      |
| Inner Mongolia| Keerqin, Alashanzuqi, Zhalantun, Etuokeqianqi | Han, Mongolian   | 36, 56               | 2      |
| Northwest China|                                             |                  |                      | 6      |
| Ningxia      | Jingyuan, Dawukou, Xingqing, Shapotou         | Han, Hui         | 36                   | 1      |
| Xinjiang     | Akesu, Tianshan, Cabuchaenibo, Kuche, Bohu    | Han, Uighur      | 36, 56               | 2      |
| Qinghai      | Chengxi, Huangzhong, Geermu                   | Han, Tibetan     | 36, 56               | 2      |
| Shanxi       | Luonan, Baqiao, Baishui, Shenmu               | Han              | 32, 36, 46, 56       | 4      |
| Gansu        | Anning, Zhenyuan, Huining                     | Han              | 28, 32, 36, 56       | 4      |
| Southwest China|                                           |                  |                      | 30     |
| Sichuan      | Nanxi, Pengxi, Hanyuan, Fucheng, Miaoping, Chongzhou | Han, Yi, Qiang | 6, 8, 13, 20, 21, 28, 36, 40, 42, 45, 54, 55, 56 | 12     |
| Yunnan       | Panlong, Ludian, Eshan, Mengla, Maguan, Shuangjiang, Jinping, Xiangyuan, Yongsheng | Han, Dai, Han, Jinuo, Yi, Yao, Lizhu, Tuji, Maonan | 4, 5, 6, 7, 8, 9, 12, 13, 15, 20, 21, 22, 26, 27, 28, 29, 30, 37, 39, 40, 41, 44, 47, 52, 56 | 24     |
| Guizhou      | Yuxing, Suyang, Tongzi, Xingren, Sandu, Taijiang | Han, Miao, Dong, Buyi, Shui | 5, 6, 7, 8, 9, 13, 18, 20, 21, 28, 31, 32, 40, 44, 52 | 15     |
| Tibet        | Chengguan, Leiwuqi, Biru                      | Tibetan          | ——                   | 0      |
| Chongqing    | Nanchuan, Jilongpo, Kaizhou                   | Han              | 20, 21, 28, 56       | 4      |
| Northeast China|                                         |                  |                      | 3      |
necessity of preliminary heat treatment was also reported by Dogan and colleagues [5] when the leaves were used to wrap sarma in Turkey or the Balkans. The leaves used for sarma are eaten afterward, but ZLS are just for the package. Once packed with ZLS and bound tightly, zongzi as a whole is then boiled or steamed until they were suitable to eat. The similarity in the collection and processing of ZLS exemplifies the unity of culture surrounding the zongzi or the Dragon Boat Festival in China.

**Contribution to zongzi flavor**

The zongzi flavor can be affected by both the inside fillings and the ZLS [9]. It was reported that some species of plant leaves such as *Oreopanax flaccidus* leaves could add a unique flavor to *tamales* [4]. According to our surveys, in general, over 80% of people preferred to use the ZLS which they believed were more fragrant. It was commonly believed that ZLS could vastly contribute to the zongzi flavor. For example, people in some regions of Southern China have found that zongzi wrapped by the leaves of *Nelumbo nucifera*, *Piper sarmentosum*, *Indocalamus* spp., and *Musa* spp. have a special fragrance, and it was believed by the Li ethnic group in Hainan Province that zongzi with *Cocos nucifera* leaves had coconut-like flavor that came from the leaves. The areas where people are familiar with the flavor contributions of ZLS were provided in Additional file 1: Table S1.

The flavor compounds from *Alpinia zerumbet* [25], *Hedychium coronarium* [26], *Indocalamus latifolius* [27], *I. tessellatus* [28], *Musa acuminate* [29], *Nelumbo nucifera* [30], *Perilla frutescens* [31], *Quercus dentata* [32], and *Terminalia catappa* [33] have been previously characterized and identified. For instance, nine critical flavor components have been identified by GC-MS from the leaves of *I. tessellatus* including *p*-vinylphenol, *p*-vinylguaiacol, diphenylmethanone, 2, 2′-diethylbiphenyl, 2, 6-diisopropynaphthalene, (Z)-phytol, eicosanenitrile, 2-phenyltridecane, and (E)-phytol [28]. These results therefore supported the traditional knowledge that these species of ZLS could contribute the zongzi flavor.

However, as far as we know, there have been no reports on the flavor compounds of other ZLS yet. Consequently, further studies are greatly needed to fully characterize the aroma-active constituents, which will encourage them to be developed as naturally refreshing agents for our environmental sanitary or natural flavor substances with health-promoting properties for food.

**Antiseptic functions of ZLS**

According to our interviews, apart from the contribution to the zongzi flavor, some species of ZLS are believed to have antiseptic properties, which results in relatively long-term storage time of zongzi under natural conditions. The Dragon Boat Festival is celebrated at the end of the spring and the beginning of the summer when the food is easily attacked by spoilage organisms because of the suitable temperature and humidity [34]. Thus, ZLS with antiseptic functions are more favorable. According to our surveys in the local areas, 26 species of ZLS were considered to be responsible for the shelf life of zongzi, including the leaves of *Aspidistra* spp., *Cocos nucifera*, *Evodia glabrifolia*, *Fargesia fractiflexa*, *Indocalamus* spp., *Magnolia officinalis*, *Micanthus floridulus*, *Monocaldus amplexicaulis*, *Musa* spp., *Pandanus tectorius*, *Phragmites australis*, *Phrynium capitatum*, *Piper sarmentosum*, *Quercus dentata*, and *Thysanolaena maxima*. For instance, according to the interviews, the sweet zongzi with ZLS of *I. latifolius*, *P. australis*, or *Q. dentata* would not be spoiled during 10 days of storage in summer, and the salty-meat zongzi with ZLS of *P. tectorius*, *M. basjoo*, or *C. nucifera* could still stay fresh within five days under natural ventilation condition. The areas where people are familiar with the antiseptic functions of ZLS were listed in Additional file 1: Table S1.

At present, antimicrobial properties of packaging materials have attracted public concerns and have been included in the next generation of food packaging [35]. Based on previous studies, the polar extracts or the essential oils from the leaves of *A. elatior* [36], *C. nucifera* [37], *I. latifolius* [38], *I. tessellatus* [39], *M. officinalis*...
M. acuminata [41], M. sapientum [42], P. tectorius [43], P. australis [44], P. capitatum [19], P. sarmentosum [45, 46], Q. dentata [47], and T. maxima [19] showed good antimicrobial activities. For instance, the essential oils of the leaves of P. capitatum and T. maxima presented considerable activity against spoilage organisms such as Aspergillus fumigatus and Candida albicans, with MIC (minimum inhibitory concentration) ranging from 64 to 1024 mg/mL [19], and the acetone extracts from the leaves of M. acuminata showed significant antifungal activities against Aspergillus terreus and Penicillium solitum after 5 days, with the inhibition rate of mycelial growth of 81.1 and 45.6%, respectively [41]. These results are in accordance with the traditional knowledge that these traditional ZLs have antiseptic functions, suggesting the potential utility of associated traditional botanical knowledge surrounding ZLs.

Previous research showed that the fruits extracts containing flavonoids from M. balbisiana exhibited antibacterial activity against Shigella dysenteriae ATCC 13313, with MIC value ranging from 5 to 10% w/v [48], and the extracts from rhizomes and flowers of M. basjoo showed antimicrobial activity against Staphylococcus aureus and methicillin-resistant Staphylococcus aureus [49]. However, to the best of our knowledge, the antibacterial activities of the leaves of both M. balbisiana and M. basjoo have not been reported yet. Furthermore, no studies have been yet reported regarding the antimicrobial properties of ZLs of A. ob lanceifolia, A. sichuanensis, A. zongbayi, E. glabrifolia, F. fractiflexa, I. guangdongensis, I. herklotsii, M. amplexicaulis, M. floridulus, M. nana, Musa itineras, P. hainanense, and P. placentarium, even though people believe that they can increase the storage time of zongzi. Therefore, further studies on the antimicrobial bioactivity of ZLs are worthwhile to be conducted. The ZLs with antiseptic functions are expected to be further developed as biodegradable packaging materials for food, and the bioactive compounds have great potential to be applied in food preservation and drug development.

**Medicinal value of ZLs**

According to our survey, among the 57 species of ZLs, 51 were known to have medicinal values, accounting for 89.5%, some of which had multiple medicinal effects, such as the leaves of Alpinia abundiflora, Aspidistra zongbayi, Indocalamus tessellatus Phrynium capitatum, and Piper sarmentosum (Table 1). In total, 23 types of medicinal values were found (Fig. 5). Heat-clearing, detoxification, and rheumatism treatment were the three most dominant medicinal functions, with 31 (54.4%), 22 (38.6%), and 13 (22.8%) species of ZLs, respectively, followed by inflammation-diminishing, hemostasis, and diuresis, with 12, 12, and 9 species of ZLs, respectively. Heat-clearing is a concept in traditional Chinese medicine (TCM). In TCM, heat is one of the main pathogenic factors which could cause disturbance in human body, such as oral ulcer and urethritis [50, 51]. Besides, there were 6, 4, and 3 species of ZLs used to relieve pain, alleviate emesis and reduce hyperglycemia, respectively. The areas where people characterized the medicinal values of ZLs were listed in Additional file 1: Table S1.

Based on our analysis, 28 of 31 species of ZLs with heat-clearing function, 20 of 22 with detoxifying effect, and 10 of 13 with rheumatism-treating value are widely used as traditional ZLs in regions located in Southern

![Fig. 5 Medicinal values of ZLs](image-url)
have been emerged in Africa \[62, 63\]. Hence, continuing malaria globally, parasites with artemisinin resistance with Artemisinin-based drugs are effective to remedy
eases in the world \[61\]. Although combination therapies
agents which have certain side effects are still the main
endocrine disorder, has posed a great threat to human
possessed a medicinal value of clearing
ing function; within 22 with detoxifying function, 19
still greatly needed \[55\]. It is worthwhile to mention that
for natural and effective compounds to treat diabetes is
constructions for TCM \[34\].

Importantly, among the nine species of ZLs which
were useful for diuresis, all species also had a heat-clearing
function; within 22 with detoxifying function, 19
possessed a medicinal value of clearing heat. In addition,
five species were also involved in the inflammation-diminishing effect among six species with analgesia value. Further studies should be conducted to clarify the relationship, which will be beneficial to the theoretical
constructions for TCM \[34\].

Nowadays, diabetes mellitus, a common metabolic and
dermatological disorder, has posed a great threat to human health globally \[53\]. Insulin and some synthetic diabetic
agents which have certain side effects are still the main
drugs used for diabetic therapy clinically \[54\]. Searching
for natural and effective compounds to treat diabetes is
still greatly needed \[55\]. It is worthwhile to mention that
people believe the leaves of Saccharum officinarum, Termi-
\[305\]nalia catappa, and Zea mays have hypoglycemic e
ffects. It was reported that the polysaccharides from the
leaves of \[305\]S. officinarum and aqueous extracts of \[305\]T. cat-
\[305\]appa leaves had significant hypoglycemic activities on
mice \[56, 57\], which supported the medicinal value of
traditional knowledge. Even though the polysaccharides
from corn silk and the phenolic extract of corn seeds
were found to have bioactivity for hypoglycemia man-
germent \[58–60\], the hypoglycemic effects of corn leaves
have not been reported yet. Thus, further studies should
be conducted to evaluate the hypoglycemic properties of
corn leaves.

Malaria caused by Plasmodium parasites, such as \[305\]P. falciparum and \[305\]P. vivax, is one of the most serious dis-
ees in the world \[61\]. Although combination therapies
with Artemisinin-based drugs are effective to remedy malaria globally, parasites with artemisinin resistance
have been emerged in Africa \[62, 63\]. Hence, continuing
investments in the development of new medicines re-
main urgent \[64\]. According to our surveys, the ZLs of
\[305\]Musa wilsonii and \[305\]Piper sarmentosum possessed anti-
malarial activities. It is reported by Rahman et al. \[65\]
that methanol and chloroform extracts from \[305\]P. sarmen-
tosum showed significant antimalarial effects, supporting
our investigated plant knowledge. However, to date, the
antimalarial activity as well as the chemical constituents
of the leaves of \[305\]M. wilsonii have not been clarified.

Future research deserves to be conducted to determine
its potential ability against malaria.

Other functions of ZLs
In addition to the functions of flavor contribution, anti-
septic activity and medicinal effects, some species of ZLs
also have other functions. On the basis of our surveys,
the edible value of the leaves of \[305\]Piper sarmentosum has
been recognized by local people in Southern China, es-
pecially in Guangdong and Guangxi provinces. The
leaves from this species could serve as delicious season-
ings that could be added into dishes, such as soup, river-
snail cuisine, and beef patty. In Thailand, the leaves of \[305\]P. sarmentosum are traditionally used as food as well \[66\].
In Lingshui Li Autonomous County of Hainan Province,
the leaves of Pandanus austrosinensis not only could be
used to wrap \[305\]zongzi, but also could be used for the
weaving of straw mats, hats and baskets, the construc-
tions of house barriers, and even the mythical functions
of frightening and expelling the evils. Interestingly, it
was told by the local people in Shagang Village that the
leaves of \[305\]P. austrosinensis could be used as fences to pre-
vent intruders because of its spiny leaves. Consequently,
the leaves of \[305\]P. austrosinensis provide convenience for
people both materially and mentally. People in Cimu-
chuan Village (Dazhuangge Township, Yanqing County,
Beijing) had found that the leaves of \[305\]Tilia tuan could
make more contribution to both the sweet taste and
spongy texture of \[305\]zongzi when compared with the leaves
of Phragmites australis.

Effects of ZLs on food safety
According to our interviews, people generally believe that
traditional ZLs are environmental-friendly, non-toxic, and
good for human health. However, based on the literature
studies \[67–70\], the ZLs of Corchorus capsularis and Ver-
nicia fordii may have potential health risks.

The ZLs of \[305\]C. capsularis are prevalent in the northern
part of Guangxi Province such as Yongfu County. Al-
though the current research showed that the plant spe-
cies of \[305\]C. capsularis possessed various pharmacological
effects such as antioxidant, anti-inflammatory and anti-
pyretic activities, it is considered a toxic plant due to the
presence of cardioactive constituents contained, such as
Corchoroside A and B in the leaves and seeds \[67\]. It
was reported that Corchoroside A and B from leaf ex-
tracts exhibited toxicity to cats with a lethal dose of
0.053–0.0768 and 0.059–0.1413 mg/kg, respectively \[68\].
In addition, after dietary exposure to \[305\]C. capsularis
leaves, cattle can suffer from the functional depression
of respiratory and vasomotor center, and even death \[69\]. We should be cautious when using the leaves of \[305\]C.
capsularis as packaging materials, and the accessible fre-
frequency of \[305\]zongzi with \[305\]C. capsularis leaves should be
limited until we better understand its potential toxicity to humankind.

It is prevalent to use the leaves of *V. fordii* to wrap *zongzi* in Hunan and Sichuan provinces in China. Even though the roots, leaves, and fruits of *V. fordii* have been traditionally used to remedy ailments including sore throats, respiratory illnesses, constipation, and diuresis in East Asian folk medicine [71, 72], it was reported that the whole plant of *V. fordii* had some toxicity especially its seeds [70]. Consequently, the potential effects of the leaves of *V. fordii* on our human health should not be ignored.

Despite the fact that these two species of ZLs we found may have a potential threat to people’s health, no acute poisoning events have been reported in folk history. Herein, we speculate that the toxic constituents may be destroyed or transferred to non-toxic components by steaming or boiling with high temperature, or the contents of poison-active compounds are not enough to cause acute intoxication. Nevertheless, despite the long history usage of traditional ZLs, studies concerning their effects on human health are greatly lacking. Further studies are urgently necessary in order to guarantee food security for the sake of our human health. The future investigations can focus on toxicological assessments of ZLs, such as acute and subacute tests, and the possibility of detoxification under *zongzi*-making processes.

### Potential impact of commercialization on traditional ZLs

Nowadays, 12 species of ZLs have been commercialized and are easily accessed via online shopping stores: the leaves of *Alpinia zerumbet*, *Indocalamus tessellatus*, *Musa basjoo*, *Musa nana*, *Nelumbo nucifera*, *Phragmites australis*, *Phrynium capitatum*, *Piper sarmentosum*, *Quercus dentata*, *Sterculia nobilis*, *Vernicia fordii*, and *Zea mays*. According to our interviews, some species of traditional ZLs including *Cocos nucifera* used in Wenchang City of Hainan Province, *Tilia tuyen* used in Yangqing County of Beijing, and *Zizania latifolia* used in Suzhou City of Jiangsu Province, had been threatened by commercialized ZLs such as the leaves of *I. tessellatus* and *P. australis*, because of their low price, good quality, and easily accessible advantages. The indivisible interconnections have been recognized between biological and cultural diversity, and the destruction of biodiversity can lead to the loss of associated culture [73]. Thus, once the traditional ZLs used in extremely limited regions, such as the threatened ZLs of *T. tuyen* and *Z. latifolia*, which, according to our surveys, are only utilized by people in Beijing and Suzhou City, respectively, have been substituted by other common leaves, they are likely to be lost irreversibly, along with related culture including associated traditional knowledge. The effects of e-commerce and commercialized ZLs on traditional ZLs should not be neglected. The variety of traditional ZLs in China may decrease, which could threaten the cultural diversity of *zongzi* or the Dragon Boat Festival to some extent. However, the specific influence of commercialized ZLs still needs to be further determined.

### Conclusion

The plant species used for wrapping *zongzi*, the traditional food for celebrating the Dragon Boat Festival in China, depending on regional traditions and local plant species. Using various species of ZLs reflects the fact that Chinese people make good use of the local materials in their regions. A total of 57 plant species (38 genera and 18 families) were documented and identified, among which the leaves of *Indocalamus* spp. and *Phragmites australis* are the most dominant in Southern and Northern China, respectively. There are some widespread folk legends about ZLs, which culturally reveal the origins of using plant leaves to wrap *zongzi*. With the traditional uses of ZLs, Chinese people have achieved a wealth of traditional botanical knowledge, particularly in flavor contribution, antiseptic functions, and medicinal effects, some of which are supported by current scientific research. However, some species of traditional ZLs such as the leaves of *C. capsularis* and *V. fordii* may pose a potential threat to human health. Further studies remain to be conducted to comprehensively evaluate these traditional uses. At present, in some areas, there is a potential possibility that some traditional ZLs, including the ZLs of *Cocos nucifera* and *Tilia tuyen*, as well as the most ancient ZLs of *Zizania latifolia*, are threatened and could be replaced by the commercialized ZLs, such as the leaves of *Indocalamus tessellatus* and *Phragmites australis*. However, the potential impact of commercialization on traditional ZLs still needs to be studied. Our study highlights the ethnomedical knowledge surrounding ZLs, and could provide important clues for their further studies.

### Supplementary information

Supplementary information accompanies this paper at [https://doi.org/10.1186/s13002-019-0339-7](https://doi.org/10.1186/s13002-019-0339-7).

**Additional file 1: Table S1.** The investigation areas (county level) where people are familiar with the functions of ZLs.

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### Authors’ contributions

LCL and LB conceived and designed the study. LFK conducted the data collection. LFK, LBS, and LB integrated the inventory and its analysis. LCL and LB identified the plant species. LFK wrote the draft manuscript. All authors read and approved the final manuscript.
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Availability of data and materials
All data generated or analyzed during this study are included in this published article and its supplementary information files.

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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Objectives
The objective of this study is to identify and analyze the flavoroids and volatile components of Indocalamus leaves in order to understand their chemical composition and potential applications in food science. The study also aims to contribute to the ethnobotanical knowledge of these plants in the region of interest. Through this research, we hope to provide insights into the cultural significance of Indocalamus leaves as traditional food components, and to support the sustainable utilization of these plants in local communities.
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