Diversity, knowledge, and valuation of plants used as fermentation starters for traditional glutinous rice wine by Dong communities in Southeast Guizhou, China

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Abstract

Background: Beverages prepared by fermenting plants have a long history of use for medicinal, social, and ritualistic purposes around the world. Socio-linguistic groups throughout China have traditionally used plants as fermentation starters (or koji) for brewing traditional rice wine. The objective of this study was to evaluate traditional knowledge, diversity, and values regarding plants used as starters for brewing glutinous rice wine in the Dong communities in the Guizhou Province of China, an area of rich biological and cultural diversity.

Methods: Semi-structured interviews were administered for collecting ethnobotanical data on plants used as starters for brewing glutinous rice wine in Dong communities. Field work was carried out in three communities in Guizhou Province from September 2017 to July 2018. A total of 217 informants were interviewed from the villages.

Results: A total of 60 plant species were identified to be used as starters for brewing glutinous rice wine, belonging to 58 genera in 36 families. Asteraceae and Rosaceae are the most represented botanical families for use as a fermentation starter for rice wine with 6 species respectively, followed by Lamiaceae (4 species); Asparagaceae, Menispermaceae, and Polygonaceae (3 species respectively); and Lardizabalaceae, Leguminosae, Moraceae, Poaceae, and Rubiaceae (2 species, respectively). The other botanical families were represented by one species each. The species used for fermentation starters consist of herbs (60.0%), shrubs (23.3%), climbers (10.0%), and trees (6.7%). The parts used include the root (21.7%), leaf (20.0%), and the whole plant (16.7%). Findings indicate a significant relationship between knowledge of plants used as fermentation starters with age (P value < 0.001) and educational status (P value = 0.004) but not with gender (P value = 0.179) and occupation (P value = 0.059). The species that are most used by informants include Pueraria lobata var. montana (Lour.) van der Maesen (UV = 1.74; Leguminosae), Actinidia eriantha Benth. (UV = 1.51; Actinidiaceae), Oryza sativa L. var. glutinosa Matsum (UV = 1.5; Poaceae).

Conclusion: This study highlights that while most of the Dong informants continue to use a diverse range of plants as a fermentation starter for brewing glutinous rice wine, knowledge of these plants is being lost by the younger generations. Documentation of traditional ethnobotanical knowledge and outreach is thus needed to conserve biocultural diversity in the rural Dong communities in southern China.

Keywords: Ethnobotany, Traditional ecological knowledge, Rice wine, Fermented beverage, Fermentation starters

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Background
Fermented beverages have a long history of preparation and use globally for medicinal, social, and ritualistic purposes [1–4]. In China, different socio-linguistic groups in regions throughout the country have developed their own characteristic fermented beverages that are associated with cultural identity and social aspects of communities [3, 4]. For example, Guyuelongshan is a rice wine from Shaoxing in Zhejiang Province, Hejiu is a rice wine from Shanghai, and koumiss is a Mongolian liquor [5]. In addition, Tibetan communities prepare barley wine and there are many types of sweet rice wine from southwestern China including “nuomi” that are consumed during weddings, hospitality, funerals, ancestor worship, and other ceremonies [5].

Rice wine is among the most common and oldest fermented beverages in China. It is fermented using a fermentation starter, also known as koji (or jiuqu in Mandarin) [6]. Koji can be made with staple crops such as wheat, rice, millet, and maize that consist of microorganisms that support the fermentation process [7]. For example, communities in Shaoxing prepare koji as a raw material for rice wine from wheat that harbors many microorganisms including Absidia, Acetobacteria, Aspergillus, Bacillus, Mucor, Lactobacillus, and Rhizopus [8]. Some of these microorganisms are also used as single strains for the industrial manufacture of rice wine. Zhang et al. [9] highlighted that Aspergillus oryzae SU16, as a single strain, could be used in the production of koji.

In addition to common staple grains such as wheat, rice, millet, and maize for the preparation of fermentation starters, indigenous groups in mountainous regions of China have a long history of using a wide diversity of local plants for making koji. We previously documented a total of 103 species in 57 botanical families of wild plants that are traditionally used as starters for preparing fermented beverages by Shui communities in southwestern China [4]. The Dong are a socio-linguistic group (also known as the Kam) of southeast Guizhou that also have a long history of using koji for producing glutinous wine as a source of livelihood. Our previous studies demonstrate that the Dong people cultivate many varieties of glutinous rice [10, 11] which they use as their staple food. However, there remains a lack of documentation regarding the plants used as fermentation starters by Dong communities. This study seeks to address this knowledge gap by identifying the diversity of plants used as fermentation starters (koji) by Dong communities and associated knowledge and values. Findings have the potential to inform the conservation of natural resources associated with a culturally-relevant beverage of Dong communities while preserving traditional ecological knowledge.

Methods
Study area
Research was carried out in three Dong villages in Qiandongnan Miao and Dong Autonomous Prefecture in the southeastern part of Guizhou Province (longitude 108°50.3′ E–109°58.5′ E, latitude 25°53.7′ N–26°24.2′ N), located near Hunan and Guangxi provinces. These villages are in the core zone of Dong socio-linguistic group and include Xiaohuang of Congjiang County, Huanggang of Liping County, and Nongwu of Rongjiang County (Fig. 1, Table 1). The three villages have a combined area of 51.22 km² and are located between 630 and 780 m above sea level. The climate is characterized as subtropical monsoon humid with an annual average temperature of 18.4°C, an average precipitation of 1200 mm, average sunlight time of 1300 h, and a frost-free period of 310 days per year.

The three study site villages are dominated by members of the Dong and Miao socio-linguistic groups. Traditional rice-fish co-culture system predominates in these villages and integrates with animal husbandry, forestry management, and medicinal plant collection and trade [10, 11]. In this study, we selected to focus on interviewing Dong households because of their longer history of cultivating glutinous rice (Oryza sativa var. glutinosa) compared to the Miao as well as their subsistence lifestyle for procuring food. Glutinous rice wine is a very popular fermented beverage in local communities. The Dong, as many indigenous communities, rely on their environment for a range of wild and cultivated crops for preparing food, beverages, and medicine [12, 13]. The above information indicates that these villages are ideal areas for studying the traditional knowledge of plants used as fermentation starters for traditional glutinous rice wine.

Ethnobotanical data collection
Ethnobotanical surveys were carried out from September 2017 to July 2018. A total of 217 informants (including 126 male and 91 female) were interviewed from the three study sites (Table 2). Semi-structured interviews were carried out using a snowballing approach of meeting Dong community members including in fields, around fish ponds, in canteens, in artisanal workshops, in farmhouses, and in village squares. The semi-structured interviews involved open-ended questions and conversations with informants in the above scenes. The major questions are as follows:

1. Do you know about “jiuqu” (fermentation starters for brewing traditional glutinous rice wine)?
2. Do you know the technology of koji-making?
3. If yes, which plants did you choose, and which parts of the plants to make the fermentation starters?

Ethnobotanical data collection
4. Where do you usually collect these plants?
5. Can you take us to collect these plants? (Field identification or local plant flora).
6. Do you know these plant names?
7. Can you read these names in Dong language?
8. Why do not you choose a commercial "jiqu" for brewing traditional glutinous rice wine?
9. Would you consider passing this knowledge to your children or other people?
10. What other interesting things can you share with us?

Interviews were carried out in either the Dong language with the assistance of a local Dong translator (Fig. 2) or in simplified Mandarin.

In the local area, people with primary and higher education tend to go out to work as migrant workers in non-agriculture times, and those with higher education have the opportunity to find permanent jobs in the provincial and prefectural capital cities, or county towns nearby. Interviews in Mandarin were primarily with individuals with primary education or above including migrant workers and local government officials. All interview procedures involved in this study were in accordance with the International Society of Ethnobiology Code of Ethics including procuring prior informed consent before interviews [14]. The demographic characteristics (age, educational status, and occupation) were identified and recorded in all face-to-face interviews (Fig. 2).

In addition to interviews, we carried out participatory observation in the study site communities. Specifically, we focused on observing the process of collecting plants and preparing koji. These observations were supplemented by key informant interviews on the type of plant species. All of the plants mentioned by key informants have the opportunity to find permanent jobs in the provincial and prefectural capital cities, or county towns nearby.

Table 1: Study area (three Dong villages in Qiandongnan Miao and Dong Autonomous Prefecture)

| Village name       | No. of family | Population | Area (km²) | Altitude (m) | Geographic location          |
|--------------------|---------------|------------|------------|--------------|------------------------------|
| Xiaohuang (Congjiang) | 740          | 3800       | 16.53      | 630          | 25°53.7' N, 109°58.5' E     |
| Huanggang (Liping)  | 325           | 1629       | 29.70      | 780          | 26°24.2' N, 109°14.6' E     |
| Nongwu (Rongjiang)  | 135           | 550        | 4.99       | 740          | 25°94.1' N, 108°50.3' E     |

Fig. 1 Geographic location of the study area: Xiaohuang, Huanggang, and Nongwu in three counties of Congjiang, Liping, and Rongjiang, respectively (Qiandongnan Miao and Dong Autonomous Prefecture, China)
Table 2 Demographic details of interviewed informants

| Category                  | Subcategory      | Number of informants | % of informants |
|---------------------------|------------------|----------------------|-----------------|
| Gender                    | Male             | 126                  | 58.06           |
|                           | Female           | 91                   | 41.94           |
| Age                       | 20–40            | 22                   | 10.14           |
|                           | 40–60            | 117                  | 53.92           |
|                           | 60 and older     | 78                   | 35.94           |
| Education status          | Illiterate       | 152                  | 70.05           |
|                           | Primary          | 44                   | 20.28           |
|                           | Secondary        | 16                   | 7.37            |
|                           | Higher           | 5                    | 2.30            |
| Occupation                | Farmer           | 133                  | 61.29           |
|                           | Migrant workers  | 71                   | 32.72           |
|                           | Local officials  | 13                   | 5.99            |
| Knowledge about koji-making plants | Yes    | 193                  | 88.94           |
|                           | No               | 24                   | 11.06           |

Results

Socio-demographic characteristics of respondents

Table 2 describes the demographic characteristics of the 217 study informants. Informants comprised of 58.06% (N = 126) males and 41.94% (N = 91) females. In addition, informants were between the ages of 20 and 96 years (the

Data analysis

Classical ethnobotanical descriptive statistics were used to summarize ethnobotanical data in Excel 2013. The association between indigenous knowledge of koji-making with participant's demographic factors including gender, age, educational status, and occupation was tested with Chi-square analysis. Statistical analysis was carried out using SPSS version 20 (SPSS, Chicago) at 5% level of significance (P < 0.05). Use Value (UV) index [16] was calculated to evaluate the botanical species with the greatest use across the study site communities. The UV of each plant mentioned was calculated using the following formula:

$$UV = \frac{\sum UP}{n}$$

where UP is the number of uses mentioned by each informant for a given plant use and n is the total number of informants.

Fig. 2 Indigenous knowledge of traditional glutinous rice wine koji-making plants: a A local guide to helping identification of glutinous rice wine koji-making plants. b One of face-to-face interview. c The koji for brewing glutinous rice liquor/wine. d Glutinous rice wine made from koji.
majority were between 40 and 60 years old). Most of the surveyed respondents (70.05%) are illiterate, and only five (2.30%) of the interviewed respondents had completed higher education (Table 2). The majority of the respondents were farmers (61.29%, N = 133) and migrant workers (32.72%, N = 71), except for a few local government officials (5.99%, N = 13). Most respondents (N = 193; 88.94%) demonstrated average knowledge about koji plants in general (Tables 2 and 3).

Diversity of plants used for koji
A total of 60 plant species were documented for preparing koji, belonging to 58 genera and 36 families (Table 4). The most prevalent botanical families were Asteraceae and Rosaceae (N = 6, respectively), followed by Lamiaceae, Menispermacaeae, and Polygonaceae (N = 3, respectively); Lardizabalaceae, Leguminosae, Moraceae, Poaceae, and Rubiaceae (N = 2, respectively); and the other botanical families represented in our collections each consisted of a single species (Table 4).

Analysis of the life forms of koji-making plants showed that 60.0% of the reported species are herbaceous plants (N = 36), 23.3% are shrubs (N = 14), 10.0% are lianas (10.0%), and 6.7% are trees (5.0%) (Table 4). The root was the most commonly used plant part (21.7% of N = 13 citations), followed by the leaf (20.0%, N = 12), whole plant (16.7%, N = 10), fruit (13.3%, N = 8), aerial part (11.7%, N = 7), branch (10.0%, N = 6), stem (3.3%, N = 2), bark, and flower (1.7%, N = 1, both) (Table 4, Fig. 3).

Traditional knowledge on koji-making plants
Results of the Chi-square test showed that there was no significant association between knowledge of the koji-making plants and gender (X² = 1.807, df = 1, P value = 0.179) and occupation (X² = 5.664, df = 2, P value = 0.059). However, there was a significant association between knowledge of koji plants with age (X² = 58.668, df = 2, P value < 0.001) and educational status (X² = 13.443, df = 3, P value = 0.004) (Table 3). Informants older than 40 years and those with lower educational status were the most knowledgeable regarding plants for making koji (Table 3).

Frequently utilized species
The use values (UV) calculated for this study range from 0.27 to 1.74, with a higher UV indicating the plant was more frequently reported to be used by informants. The plant species most frequently utilized by informants for making koji are Pueraria lobata var. montana (Lour.) van der Maesen (1.74), Actinidia eriantha Benth. (1.51), and Oryza sativa L. var. glutinosa Matsum (1.5). There were 23 other species with a UV value greater than 1 including Kadsura longipedunculata Finet et Gagnep, Houttuynia cordata Thunb., Mentha canadensis L., Rosa roxburghii Tratt, Polygonum pubescens (Meissn.) Steward, Rubus pluribracteatus L.T. Lu & Boufford, Rosa laevigata Michx, Uncaria rhynchophylla (Miq.) Miq. ex Havil, Solanum americanum Mill., Cayratia trifolia (L.) Domin, Gaultheria leucocarpa Bl. var. crenulata (Kurz) T. Z. Hsu, Cunninghamia lanceolata (Lamb.) Hook, Frangula crenata (Siebold & Zucc.) Miq., Gentiana

| Characteristics | Total number of respondents | Knowledge about koji-making plants | X² | P value |
|-----------------|----------------------------|-----------------------------------|----|---------|
| Gender          |                            | Yes                               | No |         |
| Male            | 126                        | 109                               | 17 |         |
| Female          | 91                         | 84                                | 7  |         |
| Age             |                            |                                   |    |         |
| 20–40           | 22                         | 9                                 | 13 |         |
| 40–60           | 117                        | 108                               | 9  |         |
| 60 and older    | 78                         | 76                                | 2  |         |
| Education status|                            |                                   |    |         |
| None            | 152                        | 141                               | 11 |         |
| Primary         | 44                         | 38                                | 6  |         |
| Secondary       | 16                         | 11                                | 5  |         |
| Higher          | 5                          | 3                                 | 2  |         |
| Occupation      |                            |                                   |    |         |
| Farmers         | 133                        | 119                               | 14 |         |
| Migrant workers | 71                         | 65                                | 6  |         |
| Local officials | 13                         | 9                                 | 4  |         |
Table 4: Inventory of plants traditionally used for koji-making in the study area (species are listed alphabetically)

| Scientific name                  | Voucher number | Family name         | Dong name         | Chinese name          | Habit      | Part used | UV   |
|----------------------------------|----------------|---------------------|-------------------|-----------------------|------------|-----------|------|
| *Actinidia eriantha* Benth.      | KJBT0040       | Actinidiaceae       | Sangp buc dongl   | Mao Hua Mi Hou Tao    | Shrub      | Branch    | 1.51 |
| *Adiantum flabellulatum* L.     | KJBT0052       | Pteridaceae         | Kaok naeml       | Shan Ye Tie Xian Jue  | Herb       | Leaf      | 0.79 |
| *Agrimonia pilosa* Ledeb.       | KJBT0029       | Rosaceae            | Demh Meix Sais    | Lu Bian Huang         | Herb       | Root      | 0.47 |
| *Akebia quinata* (Houtt.) Decne. | KJBT0064       | Lardizabalaceae     | Gueel ryani bds   | Ba Yue Gua            | Shrub      | Fruit     | 0.67 |
| *Arctium lappa* L.             | KJBT0027       | Asteraceae          | Mal kap gueec     | Niu Bang              | Herb       | Aerial part | 0.45 |
| *Artemisia annua* L.           | KJBT0019       | Asteraceae          | Mal yaems sul     | He Hao                | Herb       | Root      | 1.19 |
| *Asarum forbesii* Maxim.        | KJBT0033       | Aristolochiaceae    | Naos max tic      | Ma Ti Xiang           | Herb       | Leaf      | 0.77 |
| *Asparagus cochinchenensis* (Lour.) Merr. | KJBT0050 | Asparagaceae        | Sangp pegs sangp laox | Tian Men Dong          | Herb       | Root      | 0.56 |
| *Bauhinia brachyarpa* Wall. ex Benth. | KJBT0059 | Leguminosae         | Joal bav          | Ye Guan Men           | Shrub      | Root      | 0.47 |
| *Cayratia trifolia* (L.) Domin  | KJBT0023       | Vitaceae            | Joal meixguv      | San Ye Wu Lian Mei    | Shrub      | Fruit     | 1.25 |
| *Cirsium japonicum* DC.         | KJBT0044       | Asteraceae          | Mal sax bav laox  | Da Ji                  | Herb       | Root      | 0.31 |
| *Clerodendrum cytophyllum* Turcz. | KJBT0009      | Lamiaceae           | Bav sup geel kuenp | Da Qing Ye            | Shrub      | Aerial part | 0.44 |
| *Codonopsis pilosula*          | KJBT0011       | Campanulaceae       | DemhGaams Yous    | Dang Shen             | Climer     | Root      | 0.40 |
| *Cunninghamia lanceolata* (Lamb.) Hook. | KJBT0047     | Taxodiaceae         | Meix beens        | Sha Mu Ye             | Tree       | Leaf      | 1.24 |
| *Cyclea racemosa* Oliv.         | KJBT0002       | Menispermaceae      | Joal enl sup dangl | Lun Huan Teng          | Herb       | Branch    | 0.79 |
| *Diospyros cathayensis* Steward | KJBT0048       | Ebenaceae           | Meix bav minc     | Shi Zi Ye             | Tree       | Leaf      | 0.86 |
| *Elaeagnus pungens* Thunb.      | KJBT0051       | Elaeagnaceae        | Demh nyox senc    | Hu Tui Zi             | Shrub      | Aerial part | 0.78 |
| *Fallopia multiflora* (Thunb.) Harald. | KJBT0018 | Polygonaceae        | Joal maenc yeex   | He Shou Wu            | Climer     | Root      | 0.28 |
| *Ficus pumila* L.              | KJBT0006       | Moraceae            | Joal liangc fenx  | Cheng Tuo Guo         | Tree       | Leaf      | 0.27 |
| *Ficus tikoua* Bur.            | KJBT0013       | Moraceae            | Joal demh xexens  | Di Gua Teng           | Climer     | Whole plant | 0.47 |
| *Gardenia jasminoides* Ellis   | KJBT0022       | Rubiaceae           | Wap lagx ngoc     | Huang Zhi Zi          | Shrub      | Flower    | 1.03 |
| *Gaultheria leuccaspa* Bl. var. crenulata (Kurz) T. Z. Hsu | KJBT0053 | Ericaceae           | Melx demh mius    | Bai Zhu Shu           | Herb       | Leaf      | 1.25 |
| *Gentiana rhodantha* Franch. ex Hemsl. | KJBT0028 | Gentianaceae        | Nyangt boy liongc | Long Dan Cao          | Herb       | Whole plant | 1.21 |
| *Gerbera piloselloides* (L.) Cass. | KJBT0034   | Asteraceae          | Sangp mal kap gav | Mao Da Ding Cao       | Herb       | Whole plant | 1.00 |
| *Geum macrophyllum* Willd.     | KJBT0030       | Rosaceae            | Yangh muic naemx  | Lu Biao Qiang          | Herb       | Aerial part | 0.92 |
| *Glochidion puberum* (Linn.) Hutch. | KJBT0049   | Phyllanthaceae      | Meix sonp ponc    | Suan Pan Zi           | Tree       | Fruit     | 1.07 |
| *Ganostegia hirta* (BL) Miq.    | KJBT0038       | Urticaceae          | Mal kgoux lail    | Nuo Mi Tuan           | Herb       | Whole plant | 0.92 |
| *Hedera nepalensis* var. sinensis (Toibl.) Rehhd. | KJBT0005   | Araliaceae          | Joal ba yaoq      | Chang Chun Teng       | Shrub      | Aerial part | 0.40 |
| *Houttuynia cordata* Thunb.     | KJBT0063       | Saururaceae         | Sangp wadc        | Zhe Er Gen            | Herb       | Root      | 1.46 |
| *Imperata cylindrica* (L.) Beauv. | KJBT0003     | Poaceae             | Sangp nyangt bagx | Bai Mao Gen           | Herb       | Root      | 1.12 |
| *Kadsura longipedunculata* Finet et Gagnep. | KJBT0046 | Schisandraceae      | Joal dangl borgl padt | Shan Wu Wei ZI        | Shrub      | Bark      | 1.47 |
| *Kalimeris indica* (L.) Sch.-Bip. | KJBT0032   | Asteraceae          | Mal langx         | Ni Qiu Chuan          | Herb       | Aerial part | 0.76 |
| *Leunonas japonicus* Houtt.    | KJBT0060       | Lamiaceae           | Mal semp beengc   | Yi Mu Cao             | Herb       | Whole plant | 0.96 |
| *Ligularia fischera* (Ledeb.) Turcz. | KJBT0042 | Asteraceae          | Bav dini max      | Ti Ye Tuo Wu          | Herb       | Branch    | 0.46 |
| *Melastoma dodecandrum* Lour.  | KJBT0014       | Melastomataceae     | Mal demh xexens   | Di Shen               | Shrub      | Leaf      | 0.79 |
| *Mentha canadensis*             | KJBT0043       | Lamiaceae           | Naos suc yeex     | Bo He                  | Herb       | Leaf      | 1.46 |
| *Oryza sativa* var. glutinosa* Matsum. | KJBT0037 | Poaceae             | Ouc                | Nu He                  | Herb       | Stern     | 1.50 |
| *Paris polyphylla* Smith        | KJBT0039       | Melanthiaceae       | Wap bar Yeal      | Qi Ye Yi Zhi Hua      | Herb       | Whole plant | 0.55 |
| *Polygonal sibirica* L.        | KJBT0017       | Polygalaceae        | Sangp jeml meec angh | Gua Zi Jin           | Herb       | Aerial part | 0.82 |
Table 4 Inventory of plants traditionally used for koji-making in the study area (species are listed alphabetically) (Continued)

| Scientific name | Voucher number | Family name | Dong name | Chinese name | Habit | Part used | UV |
|-----------------|----------------|-------------|-----------|--------------|-------|-----------|----|
| Polygonatum cyrtonema Hua | KJBT0021 | Asparagaceae | Xingp mant jenc | Huang Jing | Herb | Root | 1.00 |
| Polygonum hydropiper L. | KJBT0026 | Polygonaceae | Meix bav | La Liao | Herb | Leaf | 1.42 |
| Portulaca oleracea L. | KJBT0016 | Portulacaceae | Mal Nguedc | Gua Zi Cai | Herb | Whole plant | 1.00 |
| Sargentodoxa cuneata (Oliv.) Rehd. et Wils. | KJBT0062 | Lardizabalaceae | Kaok | Jue Cai | Herb | Stem | 0.92 |
| Pueraria lobata var. montana (Lour.) van der Maesen | KJBT0015 | Leguminosae | Sangp nieengv | Ge Teng | Climber | Branch | 1.74 |
| Frangula crenata (Siebold & Zucc.) Miq. | KJBT0024 | Rhamnaceae | Meix liuuclic | Ku Li Ye | Shrub | Leaf | 1.22 |
| Rohdea japonica (Thunb.) Roth | KJBT0054 | Asparagaceae | Mal nyinc sup | Wan Nian Qing | Herb | Root | 1.12 |
| Rosa laevigata Michx | KJBT0065 | Rosaceae | Ongv kuaoit | Jin Ying Zi | Shrub | Fruit | 1.38 |
| Rosa roxburghii Tratt. | KJBT0007 | Rosaceae | Sunl ongy kuaoit | Ci Lis | Herb | Fruit | 1.44 |
| Portulaca oleracea (L.) (Table 4). | | | | | | | |

Fig. 3 Percentage of koji-making plant parts used

Discussion

The technique of using plants as fermentation starters is a prevalent traditional method for preparing many well-known fermented foods and beverages in China [17, 18]. This study highlights the diversity of plants used by Dong communities as fermentation starters for making rice wine as well as associated knowledge and use value based on the most frequently reported plants used for koji. We documented a total of 60 plant species and associated plant parts used by informants in the Dong study site communities as fermentation starters for making glutinous rice wine. Our results further
showed that 88.94% of respondents had knowledge about plants used as fermentation starters. This finding indicates the rich indigenous ecological knowledge regarding plants in Dong communities which contributes to sustaining livelihoods and well-being along with biodiversity.

Many informants claimed “People who cannot make glutinous rice wine are not a real Dong people, because drinking and singing become a part of our daily life.” This naive view clearly emphasized the importance of fermented beverages in Dong communities and partially suggested that the koji for brewing glutinous rice wine was widely used in the area. Our results further showed that there was no significant difference in knowledge of koji plants between gender or social occupation. These results suggest that koji plants are generally known by local people irrespective of their gender or job.

An older informant (the old woman in red shirt in Fig. 2b) said “Glutinous rice wine is easy to brew, but making koji is a profound knowledge that young people won’t understand.” This statement has been cross-validated among several other informants. Interestingly, the results of this survey showed a significant association between knowledge of koji plants and the respondent’s age, indicating that elder people have more knowledge about koji plants than young people.

Although our results showed there was a significant negative correlation between the education level of respondents and the traditional knowledge on koji plants they possess, findings from this study are in line with another study that shows that educational status does not contribute to the mastery of traditional ecological knowledge [19]. But we cannot conclude that the education status decreased this traditional knowledge. Because the ratio of educated informants was too small, while education is more or less related to age (the younger people are more educated than older ones). It is worth mentioning that, in the study area, many young community members intend to go to distant cities for higher education from an early age. Thus, their communication with elders about traditional glutinous rice wine koji plants is limited.

The 60 species documented in this study represent a diverse range of botanical genera; specifically, the koji plants belong to 58 genera and 36 families with the dominant families including Asteraceae, Rosaceae, Lamiaceae, Asparagaceae, Menispermaceae, and Polygonaceae. A comparison of findings from this study with other regional surveys on plants used as fermentation highlights how species composition and diversity notably varies on the basis of cultural group. A survey by Hong et al. [4] with the Shui socio-linguistic group, also in Guizhou Province, documented that respondents harvested 103 wild plant species in 88 genera and 57 families used as starters for preparing fermented beverages. The majority of plants belonged to the families Asteraceae, Rosaceae, Fabaceae, Melastomaceae, Moraceae, and Rutaceae. For example, Shui communities have been shown to use 9 species in the Rosaceae as fermentation starters (Agrimonia pilosa Ledeb., Geum aleppicum Jaq., Rosa roxburghii Tratt., Rosa laevigata Michx., Rubus alceafolius Poir., Rubus coronifolius L., Rubus ellipticus Sm., Rubus xanthocarpus Bureau & Franch., and Rubus niveus Thunb.) while Dong communities use 6 species in the family for koji (Agrimonia pilosa Ledeb., Geum macrophyllum, Rosa laevigata Michx., Rosa roxburghii Tratt., Rubus pluribracteatus L., and Sanguisorba officinalis L.). This comparison demonstrates the distinctiveness in species composition among different socio-linguistic groups within the same region (Guizhou Province) of China. Through our interviews, we got a general understanding of traditional technology of local starter-making. They roughly mashed the cleaned plants and plant parts with a wooden hammer, then stirred the powder of the glutinous rice shell into the mixture until mixing, and then rubbed or rolled the mixture into a bolus between hands. After wetting the surface of the bolus with water from mountain springs, they put the mixture in a barrel and let it ferment naturally, and then place it in indoors for air drying after the surface of bolus has grown white mold.

At the same time, a comparison of findings from this study with other regional surveys on plants highlights how species composition and diversity may also show convergence between cultural groups. Specifically, the species composition found in this study has notable congruence to the general floristic profile of Miao community reported by Liu et al., which revealed that the Rosaceae, Asteraeaceae, Poaceae, and Liliaceae were dominant botanical families in Puding, Guizhou Province [20]. The analysis of the community structure of local plants in the study area confirms the rationality of the versatility hypothesis of Gaoue et al. [21]. The traditional practice of plant uses, along with the enhancement of the brewing technology, contributes to the diversity and complexity in the use of koji plants by the Dong.

As species and family level alone are not enough to comprehensively understand the keystone ethnobotanical species of koji plants, a quantitative evaluation method of calculating use values (UV) was applied in this study. UV is a commonly used indicator in the fields of ethnobotany and ethnoecology [15]. The evaluation of UV has the potential to reveal the utilization value of plant species and identify culturally-important plant resources [18]. Findings on UV in Dong communities showed that some parts of plant species had very restricted uses. For example, stems of Pueraria lobata var. montana, Actinidia eriantha, and glutinous rice were not reported in any published ethnobotanical studies as food or food raw materials. Alternatively, we found some
kōji plants widely reported in the literature as edible wild vegetables or fruits while having limited commercial use in the study area. Examples of these plants include Artemisia annua [22], Elaeagnus pungens [23], Houttuynia cordata [24], Portulaca oleracea [25], Peridium aquilinum var. latusculum (bracken fern) [26], Rosa laevigata, and Rosa roxburghii [27]. Additionally, we identified multiple other plants not used by study informants for kōji that have not been reported for this use in other geographical and sociocultural contexts, including “Naos suic yeex” (Mentha canadensis) and “Sangp siul yanl” (Zanthoxylum bungeanum). Mentha canadensis is a widely used plant to extract essential oil [28] and is also consumed in China for medicinal purposes in treating human diseases and to enhance appetite. The fruit of Zanthoxylum bungeanum is popular as a seasoning and traditional Chinese herbal medicine, and widely distributed in China and some Southeast Asian countries [29].

Conclusion
This study highlights that the majority of Dong informants in the study site communities continue to use a wide diversity of plants as fermentation starters for brewing glutinous rice wine, a tradition that is over a thousand years old. In addition, this study highlights that elders in study site communities continue to have richer traditional ecological knowledge regarding plants used as fermentation starters and that this knowledge is not being transmitted to the younger generation. The most prevalent kōji plants reported in this study include Pueraria lobata var. montana (Lour.) van der Maesen stem, Actinidia eriantha Benth., and Oryza sativa var. glutinosa Matsum. stem. Findings of this study can be used to inform programs focused on the preservation of botanical resources used for preparing traditional glutinous rice wine wine. Similar to our findings of dye plants in the Dong area [30], we suggest supporting educational workshops and training focused on transmitting the traditional ecological knowledge of community elders to the younger generation. It is expected that such efforts will not only support the cultural identity of communities through the preservation of knowledge and practices, but will also help conserve surrounding biodiversity that is embedded in traditional ecological knowledge.

Acknowledgements
The authors acknowledge the local people in the study area. We also thank Professor Daoying Lan, Jishou University, China, for his critical reading and extensive comments on this manuscript.

Funding
This study was financed by the National Natural Science Foundation of China (31761143001, 31870316 & 31560088), Key Laboratory of Ethnomedicine (Minzu University of China) of Ministry of Education of China (KLEM-ZZ201806), Minzu University of China (Collaborative Innovation Center for Ethnic Minority Development, YLDXXK201819), Ministry of Education of China and State Administration of Foreign Experts Affairs of China (B08044), the Special Funds Project for Central Government Guides Local Science and Technology Development (2018CT5012), Open Programme of Center of Tuja Medical Research in Hunan Province, China (2017-6), and the Research Platform Foundation of Jishou University (JD201605, NLE201708).

Availability of data and materials
The data for this study may be availed upon request.

Authors’ contributions
CLL conceived and designed the study. JWH and RFZ collected the data. QYL performed the statistical analysis. JWH, RFZ, GXC, KGL, and QYL participated in discussions. SA and CLL finalized the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate
We followed ethical guidelines adopted by the International Society of Ethnobiology (2008). Permissions were verbally informed by all participants in this study. All people appeared in Fig. 2 agreed to publish the photos.

Consent for publication
Not applicable

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

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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Received: 1 January 2019 Accepted: 5 April 2019
Published online: 27 April 2019

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