Research paper

An ethnobotanical study of forage plants in Zhuxi County in the Qinba mountainous area of central China

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A B S T R A C T

In the Qinba mountainous area of Central China, pig farming has a significant impact on the growth of the rural economy and has substantially increased farmer incomes. Traditional knowledge plays an important role in the selection of forage plant species for pig feeding by local people. This study aimed to identify the forage plants used for pig feeding and to catalog indigenous knowledge regarding their use. During 2016 and 2017, ethnobotanical surveys and inventories were conducted in Zhuxi County, Hubei Province, China. Data were collected using semi-structured interviews, key informant reports, free listings, guided field walks, and participatory observations with 77 households in 16 villages in 13 towns/townships. The obtained data were analyzed using a relative frequency citation (RFC) index. Overall, 145 wild forage plants from 91 genera and 31 families were recorded. The most cited families were Asteraceae, Polygonaceae, Urticaceae, Amaranthaceae, Fabaceae, Cruciferae, Caryophyllaceae, and Lamiaceae. Whole plants (75.9%) and tender leaves (12.4%) were the most frequently used parts of the plants. Most of the forage plants were herbaceous (88.9%). Almost all forage plants could be collected throughout the year (62.7%). Raw and cooked were the two main preparation methods. The most frequently cited species were Taraxacum mongolicum, Bidens pilosa, Sonchus oleraceus, Pilea verrucosa, and Pilea pemula var. obtusifolia. A total of 14 species were identified as the top forage plants in Zhuxi County based on their RFC values (RFC value greater than 0.5). Local people possess rich traditional knowledge about the utilization and management of forage plants for pig feeding. However, the maintenance of this traditional knowledge may be seriously threatened by changes in pig feeding modes and the lack of successors. Appropriate strategies and action plans have been suggested for the conservation of traditional knowledge associated with biodiversity and the sustainable use of forage species resources. These include 1) taking targeted measures to protect forage resources and associated traditional knowledge; 2) strengthening research on the forage plants with the highest RFC values for nutritional value, digestibility, other functions, and ecological status; and 3) enhancing the identification of poisonous forage plants.

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1. Introduction

China’s small-scale pig farmers are the largest community of pork producers in the world (Riedel et al., 2012). China’s consumption of meat, particularly pork, has increased tremendously as its economy has grown. Fifty to eighty percent of all pigs produced in China originate from smallholder farms (Neo and Chen, 2009; Geng et al., 2017). In rural areas, pig breeding plays a vital role in the
local economy, especially in the vast mountainous areas of China. In these areas, arable land is limited, vehicle travel is inconvenient, and local people still maintain traditional farming and animal husbandry practices to meet their daily food supply needs. Smallholder farmers rely on their observations and experience in feeding and managing their livestock. The sustainable production of livestock usually involves the efficient utilization of locally available resources, particularly feed resources (Geng et al., 2017).

The Qinba mountainous area is located in central mainland China, which is the transitional zone between the northern and southern climate regions in China. It is an important ecological barrier in the upper reaches of the Yangtze River and includes 76 counties (districts) in six provinces. In this area, the zonal climate spans two climatic zones: the northern subtropical zone and the warm temperate zone. The elevation is very variable, the ecological conditions are diverse, and the plants show an obvious vertical distribution. Many plants thrive in the complex and diverse climatic conditions in the Qinba Mountains. The Qinba Mountains are one of two key areas of biodiversity conservation (the Qinling Mountains and the Shennongjia Forest region) in China (Xu et al., 1997; Gong, 2006). Zhuxi County is located at the southern end of the eastern section of the Qinling Mountains. Zhuxi has a great natural environment with a high level of biodiversity, where the local community has kept traditional pig farming with a long history.

Zhuxi County, which is a typical mountainous area that is difficult to access and has a limited connection to the outside world, has been designated a national poverty-stricken county. A semi-self-sufficient model dominates the rural economy in this area. According to official reports, animal husbandry in Zhuxi County accounts for approximately 30% of the total agricultural output, of which pig farming accounts for more than 80% of the total output value of animal husbandry. Small-scale household farming is dominant, accounting for approximately 50% of pig farming (Compilation Committee of Local Chronicles of Zhuxi County, 2014). Indigenous people have accumulated abundant ethnobotanical knowledge about describing and applying local natural resources from long-term practice.

Forage plants refer to the plants that can be eaten by livestock, poultry, and wild animals (Kahasbagan and Pei, 2000). Because wild forage plants are nutritious, safe, and important for environmental conservation and do not generate medicinal residues, more attention is being paid by scientists to the sustainable use and integrated management of wild forage plants. Indigenous knowledge (or traditional knowledge) is the tool with which local people interact with the environment to meet their needs and goals, which range from survival to personal achievement and self-esteem (Yemataw et al., 2016). Indigenous communities that have been involved in livestock handling possess significant knowledge about potential forage resources (Sadat-Hosseini et al., 2017). Ethnobotanical investigations of fodder plants for ruminant animals have been performed in some countries, such as Ethiopia, Nigeria, Uganda, India, Mexico, Brazil, and Pakistan (Bahru et al., 2014; Nunes et al., 2015; Vogel et al., 2016; Geng et al., 2017, 2020; Harun et al., 2017; Shaheen et al., 2020). In China, there is no overall documentation about the relative importance of these feeds to farmers, especially for pig feeding, although some researchers have reported on the fodders browsed by ruminant animals (Jia, 1987; Geng et al., 2017; Ma et al., 2019). This study aimed to (i) investigate and document traditional knowledge about the forage plants utilized for pig feeding through a case study of Zhuxi County, (ii) assess the traditional knowledge regarding the use of forage plants, (iii) identify the top-priority fodder plants for pig feeding, and (iv) provide appropriate suggestions for the conservation of biodiversity and the sustainable use of forage species resources.

2. Materials and methods

2.1. Study area

This study was carried out in 16 villages located in the rural zone around Zhuxi County (109°29′–109°08′E, 31°31′–32°32′N), Hubei Province, China (Fig. 1). All mountains in Zhuxi County are within the Daba Mountains. The county has 15 townships, and the whole county is approximately 51 km from east to the west and approximately 104 km from north to south. The area of the county is 3310 km². The highest elevation in the county is at Congping (2740 m) in the southwest, and the lowest elevation in the county is at Langningwang (276 m) in the northeast; there is a relative elevation difference of 2464 m between these locations (Gan, 2005). The population living in Zhuxi is 99.8% ethnically Han Chinese. Zhuxi County is one of the key floral distribution areas in Central China, and it is also an area where flora and vegetation resources are well preserved in the northern subtropical region of China (Gan, 2005). Zhuxi has a great natural environment with a high level of biodiversity, where the local community has kept traditional pig farming for a long time.

The economy of Zhuxi consists of traditional agriculture, forestry, animal husbandry, and fishery, as well as industry. The local economy is dominated by traditional agriculture and forestry. Pig farming is often integrated with other agricultural activities; pig manure is used to fertilize crops, and crop residues are in turn used as pig feed (An et al., 2004). According to local surveys (Compilation Committee of Local Chronicles of Zhuxi County, 2014), there are three main modes of pig production: traditional small-scale household farming (70% of all production), professional farming (25%), and large-scale farming (5%). Traditional small-scale household farming is dominant in the countryside, where pigs are usually fed kitchen waste, agricultural byproducts, and wild forage plants.

2.2. Data collection

In October 2016 and May 2017, ethnobotanical studies were carried out in 16 villages in 13 towns/townships (Fig. 1). All investigated communities were located in Zhuxi County, where the main method of raising pigs is small-scale family farming. Informed consent for the investigation of traditional knowledge was obtained from the local government and participants based on the “Intangible Cultural Heritage Law of the People’s Republic of China (2018)” and access and benefit-sharing (ABS)-related rules (Zheng, 2019). Informants were selected randomly during house-to-house questioning. Semi-structured interviews, key informant reports, free listings, guided field walks, and participatory observations were used in the surveys. A total of 77 households were selected. The ages of the informants ranged from 20 to 73, and the mean age was 45 years old. The questions were designed to collect data on the (i) local names of the plants, (ii) function (forage, veterinary, or other uses), (iii) parts used, (iv) methods for preparation and the feeding mode (cooked or raw), and (v) condition of the plant material (dried or fresh). Other factors, such as the availability of the plant in the area (scarce, sufficient, or abundant), the harvesting season, and the extent of the palatability to pigs (highly palatable, fairly palatable, or weakly palatable), were also recorded. All interviews were carried out in spoken Mandarin and were performed by visiting each respondent individually; we recorded the local names for the plants using Chinese characters and Pinyin.
The plant specimens were collected with the assistance of the key informants during guided field trips, and specimens were identified by referencing the *Flora of China*. The taxonomic circumscription of plant families and species followed the APG IV system (APG, 2016), and the information found in *The Plant List* (2020) was used to provide a uniform nomenclature. All voucher specimens were deposited in the Key Laboratory of Economic Plants and Biotechnology, Kunming Institute of Botany, Chinese Academy of Sciences.

### 2.3. Data analysis and quantitative index

#### 2.3.1. Data analysis

An inventory of the forage plant species cited by each informant was established in a spreadsheet using Microsoft Excel (Microsoft Corporation, http://www.microsoft.com/). Along with the list of plant taxa, the compiled table (see Table S2) also contains the local and scientific names, family name, palatability, parts consumed, life form, and feeding mode.

#### 2.3.2. Relative frequency of citation (RFC)

The relative frequency of citation (RFC) index helped us establish the priority order of the listed forage plants (Tardío and Pardede-Santayana, 2008; Sujarwo and Caneva, 2016; Harun et al., 2017). The following formula was used:

$$\text{RFC} = \frac{\text{FC}}{\text{N}} \quad (0 < \text{RFC} < 1)$$

where FC is the number of informants that mentioned the use of the species as fodder, and N is the total number of informants included in the study.

### 3. Results

#### 3.1. The transition of local pig production and feeding modes

Two pig feeding modes, traditional pig feeding and modern pig feeding, are recorded in our study. Traditional pig feeding involves feeding cooked food that consists of cooked wild forage plants mixed with corn cobs and bran, distiller grains, wheat bran, maize bran, or cornmeal, occasionally with some raw wild forage plants. Modern pig feeding primarily uses concentrate supplemented with raw green forage plants, which are usually the leaves of other readily available cultivated plants, such as sweet potato, cabbage, mustard, and turnip.

The distribution of traditional knowledge about forage plants and feeding modes among local populations varies by gender and age.
Among 77 households interviewed in this survey, there were 33 males and 44 females, accounting for 42.9% and 57.1% of the total, respectively (Table S1). Males and females reported the same number of forage plant species. Informants over 60 years old preferred the traditional pig feeding mode, while the younger adults preferred the modern pig feeding mode. In addition, we found there has been a dramatic change in the pig production modes. Specifically, previous reports indicated that from 1980 to 2005 the major mode of pig production was traditional small-scale household farming (70% of all production), followed by professional farming (25%), and large-scale farming (5%) [Compilation Committee of Local Chronicles of Zhuxi County, 2014]. Currently, however, the proportion of traditional small-scale household farming is declining. According to the local farmers, the proportion of traditional small-scale household farming has shrunk to approximately 40–50%, a reduction that was accelerated by conservation policy in 2016 that banned pig feeding in some special areas. This shift in pig production modes from traditional small-scale household farming to professional farming and larger-scale farming has led to dramatic changes in feeding modes. We found that almost 78% of farmers are currently using modern feeding methods, whereas only 22% of farmers still use traditional feeding methods.

### 3.2. Diversity of forage plants, parts consumed, and life forms

A total of 145 forage plants used for pig feeding were documented (Table S2). These species belong to 91 genera and 31 families. The most cited families of the forage plants were Asteraceae (species 27), Polygonaceae (19), Urticaceae (17), Amaranthaceae (11), Fabaceae (9), Cruciferae (6), Caryophyllaceae (5), and Lamiaceae (5) (Fig. 2). Of all species, 68.3% were in these families. Twenty families (13.8% of the total) were represented by only one species each. The remaining ten families contributed between 2 and 4 species each (17.2%).

Most of the forage plants consumed were used as whole plants (75.9% of the total), followed by the use of tender leaves (12.4%), aerial parts (8.3%), and tender leaves and branches (3.5%) (Fig. 3). In terms of the plant life form (Fig. 4), the forage plants included mostly herbs (88.9% of the total), followed by shrubs (3.5%), trees (3.5%), vines (2.1%), herbs or shrubs (1.4%), and trees or shrubs (0.7%).

### 3.3. Gathering season administration and preparation

The gathering of wild forage plants for pig feed showed no obvious seasonality in Zhuxi County. Generally, the local people collect the tender parts of the plant as pig forage; therefore, the gathering activities always follow the cycle of plant growth. Forage plants for pigs are available throughout most of the year. Most forage plants can be collected throughout the year (62.7% of the total) (Fig. 5); others can be collected from May to August (20.7%), March to August (4.8%), and March to June (3.5%). The collection months overlap with each other.

The analysis of the preparation methods in the study area revealed that there were two main preparation methods: raw and cooked. Raw is usually either direct feeding or chopping and mixing with other starchy foods, such as cornmeal, soybean meal, and bran. Cooked involves chopping the plant and cooking it with other starchy foods or drying and powdering the plant, before cooking it.

### 3.4. Availability and prioritization of recorded forage plants based on RFC

The relative frequencies of citation (RFC) of the 145 cited species are shown in Table S2. The RFC values vary from 0.01 to 0.97, with 45 species having RFC values higher than 0.19 (the average RFC value). There were 100 species with lower-than-average RFC values. The most frequently cited species were Taraxacum mongolicum Hand.-Mazz. (RFC value: 0.97), Bidens pilosa L. (0.95), Sonchus oleraceus L. (0.95), Pilea verrucosa Hand.-Mazz. (0.90), and Pilea pumila (L.). A. Gray var. obtusifolia C. J. Chen (0.90). In addition to these species, another nine plant species had RFC values greater than 0.5, namely, Crassocephalum crepidioides (Benth.) S. Moore (0.84), Sisymbrium pubescens (Makino) Makino (0.84), Chrysanthemum indicum L. (0.82), Boehmeria nivea (L.) Gaudich. (0.64), Bidens bipinnata L. (0.64), Bidens bibernata (Lour.) Merr. et Sherff (0.64), and Lamium amplexicaule L. (0.56). These plants had good palatability and were preferred feed types for pigs. The least-cited species were Cayratia albiloba C. L. Li, Cayratia oligocarpa (H. Lév. & Vaniot) Gagnep., Orychophagus violaceus (L.) O.E. Schulz, Fallopia dentata (F. Schmidt) Holub, Actinidia callosa var. henryi Maxim., and Veronica laxa Benth. (RFC values of 0.01 each).

### 4. Discussion

#### 4.1. Current situation for traditional knowledge of forage plants

In this study, we found that wild forage plant resources are abundant in Zhuxi County. The local people have accumulated rich traditional knowledge about forage plant utilization and management. However, our study showed that only a small group of older smallholding farmers occasionally use wild forage plants to feed pigs. Traditional knowledge about the utilization and management of wild forage plants may be at risk of disappearing because the number of smallholding pig farmers is dwindling, and the use of traditional feeding methods is being abandoned by the younger generation. In recent years, the younger generation has received a better education. Increasing numbers of young people have abandoned traditional farming to seek higher incomes in big cities. We also found a dramatic change in feeding modes. In the past, especially in times of food scarcity, wild forage plants were considered...
an essential component of pig food in all production environments (Kambashi et al., 2014a). In addition to being a substitute for food crops, these plants can also improve the overall health of pigs (Aubé et al., 2019). In developing countries, the high cost and low availability of conventional livestock feedstuffs drive rural pig-keeping smallholders to use fiber-rich ingredients and forage species (Kambashi et al., 2014b). In the past twenty years, rearing pigs in this region has mostly depended on local vegetation, agricultural byproducts, and household and kitchen waste. However, farmers have changed their attitude and management approach to pig keeping in response to increased regulations and socioeconomic development. Professional smallholders that operate on a larger scale have increased, and since 2011 have represented half of all smallholders (Hu et al., 2017). The change in the production mode has been accompanied by a dramatic shift in feeding mode. The traditional feeding mode has been replaced by the modern feeding mode. The modern feeding mode utilizes less green forage. Wild forage plants have been replaced by concentrates and the leaves of other readily available cultivated plants, such as sweet potato, cabbage, mustard, and turnip. The collection of wild forage plants has become unnecessary, resulting in the gradual disappearance of traditional knowledge about the utilization and management of forage plants.

4.2. Relationships among palatability, gathering season, and preparation

The diversity of traditional forage plant resources used by indigenous people is related to the life forms, quantity, and parts of wild plant species, and traditional knowledge about feeding forms, gathering season, and preparation (Vogl et al., 2016; Harun et al., 2017; Ouachinou et al., 2018; Ma et al., 2019; Shaheen et al., 2020). Pigs are omnivorous animals; their demand for forage plants is different from that of other ruminants. Green forage plants are only

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**Fig. 3.** Wild forage plant parts consumed by pigs in Zhuxi County.

**Fig. 4.** Wild forage plant life forms in Zhuxi County.
used as additional nutritional supplements to provide fiber, protein, amino acids, and minerals (Kambashi et al., 2014a). In our investigation, we found that local people improve the palatability of forage plants through seasonal management and preparation to improve the utilization rate of forage plants. On the surface, there was no obvious seasonality in the collection of wild forage plants by the local people in Zhuxi County. However, they always collect forage plants according to the growth cycle of the plants. To improve plant palatability, they usually collect the tender parts of a plant in the season when the plant is flourishing. For example, in *Oenothera biennis* L., *Polygonum lapathifolium* L., *Rumex patientia* L., and *Sigesbeckia pubescens* (Willd.) MB., palatability will decrease after flowering, so the local people usually collect these plants before blooming. There are spines on plants such as *Humulus scandens* (Lour.) Merr., *Cirsium setosum* (Wild.) MB., *Urtica littoralis* E. Pritz., and *Polygonum perfoliatum* L.; the local people commonly cook these plants to improve their palatability. Some forage plants have strong smells, such as *Premna puberula* Pamp., *Bidens tripartita* L., and *Perilla frutescens* (L.) Britt., others have poor palatability when fed raw, such as *Annarea cordifolia* (Ten.), *Rumex acetosa* L. Steenis, and *Rumex japonicus* Houtt. These plants are also cooked and mixed with corn cobs and bran, distiller grains, or cornmeal to improve their palatability.

### 4.3. The fodder value of the top forage plants in Zhuxi County based on their RFC values

The swine industry in China has grown rapidly over the last two decades (Li and Chen, 2005). To improve household economies and reduce breeding costs, as well as to reduce morbidity and mortality, feed additives such as antibiotics fed at subtherapeutic levels have been widely utilized in the swine and poultry industries for the past 50 years (Cromwell, 2002). However, the use of feed additives has brought a series of environmental pollution and food safety problems. For example, many countries have restricted or even banned the use of antibiotics as feed additives due to increased concerns regarding the transmission and proliferation of resistant bacteria via the food chain (Zeng et al., 2015). To reduce the harm caused by the abuse of antibiotics and to maintain animal-derived food safety and public health safety, the Ministry of Agriculture and Rural Affairs of the People’s Republic of China issued notice No. 194. Starting on January 1, 2020, all growth-promoting antibiotic additives were withdrawn except for those used in traditional Chinese medicine (MARA, 2019). In response, alternatives to these additives are being widely considered, including environmentally friendly and sustainable agriculture. Replacing chemical additives with organic additives may be an essential method for environmentally friendly agriculture. Phytopgenic feed additives would expand the number of nonantibiotic growth promoters, such as organic acids and probiotics, that are already well established in animal nutrition (Windisch et al., 2008).

In this study, we used RFC values to identify the 14 top forage species (RFC values greater than 0.5) that are prioritized in the choice of forage species. The relevant research on forage values, forage situations, functions, and other multifunctional studies are summarized in Table S3. These species should be investigated as rich sources of food, medicine, and feed additives for humans and animals in the future. For example, *Taraxacum mongolicum* is the forage plant species that was most frequently cited by the local people. It not only can be gathered year-around but also has both edible and medicinal uses. It is a type of Chinese medicine that is commonly used in medical practices and has multiple functions, including heat reduction, detoxification, swelling reduction, and tumor therapy (Ma et al., 2015). In addition, this species has been associated with antimicrobial (Li et al., 2014; Sun et al., 2018), anti-inflammatory (Ma et al., 2015; Yang et al., 2016), and anticancer activities (Li et al., 2017). It can also be used as a compound feed additive that can promote lactation in sows after birth to help piglets grow healthily (Liu, 2012).

*Sonchus oleraceus* is a multifunctional species; as a forage plant, it has both edible and medicinal uses (Vilela et al., 2010; Dolina and Luczaj, 2014). It contains rich nutrient matter as a wild vegetable (Jimoh et al., 2011), and it is high in vitamin C for a forage plant (Cheng and Jia, 2002; Tian et al., 2014). Previous studies showed that it could improve the immunity of pigs as a feed composition additive (Shi et al., 2020). In addition, it shows some potential pharmacological properties, such as antioxidant (Yin et al., 2008), antidepressant-like (Vilela et al., 2010), antibacterial (Xia et al., 2011), anti-inflammatory (Vilela et al., 2010), and antidiabetic (Chen et al., 2019) properties.

*Bidens pilosa* was also one of the most frequently cited species, and it grows abundantly in Zhuxi County. It is an easy-to-grow herb that is widely distributed globally and has been traditionally used in foods and medicines without obvious adverse effects (Bartolome et al., 2013). It has high nutritional value both as food and forage (Cheng and Jia, 2002; Bartolome et al., 2013). According to previous studies, this species has no adverse effects in mice or chickens when given as 5% or less of the total food intake (Liang et al., 2020). *B. pilosa* has a beneficial impact on growth performance and protozoan infection in chickens, probably via modulation of gut bacteria (Chang et al., 2016). In addition, previous studies have claimed that it can be used as a feed composition additive for pigs to enhance immunity and reduce the incidence of common diseases (Hu, 2016). In our study, we found that several plants from this same genus, which had RFC values greater than 0.5, were used as forage plants, including *B. bipinnata* Li, *B. biennia* L., *B. pilosa* (Salisb.), *B. flabellina* L., and *B. tripartita* (see Table S3).

*Boehmeria nivea* (Ranmie) is a multipurpose crop. It has been used as a raw textile material for a long time in China. It is also used as a source of feed for livestock because it is an excellent source of crude protein, lysine, methionine, carotenoids, riboflavin, and calcium, and it has a low level of crude fiber (Miranda et al., 2012; Behman et al., 2019). It can improve the quality of mutton and increase milk
fat percentage, milk solids, and dry matter digestibility (Zhang et al., 2019; Gao et al., 2020). At the same time, there were no adverse effects in Sprague–Dawley rats from the intragastric administration of ramie leaf, and it can be an animal feed supplement in China (Mu et al., 2020).

Several plants have been widely used as forage plants in Zhuxi. Nevertheless, few studies have examined the nutritive composition, forage function, or other functions of plants such as Pilea verrucosa, P. pumila var. obtusifolia, Sigesbeckia pubescens, Chrysanthemum indicum, and Lamium amplexicaule. These species should be the primary focus of related research in the future.

4.4. Notable uses of forage plants

Wild plant resources with medicinal and veterinary effects can provide a basic reference for improving animal health and treating related diseases in the future (Khan et al., 2019; Mertenat et al., 2020; Miara et al., 2019; Shaheen et al., 2020). In this study, there were some species that are used as veterinary medicine by local people. For example, Ficus tikousa Bur. was cited as having a lactation-promoting effect. R. japonicus, Rumex nepalensis Spreng., and Rumex obtusifolius L. were cited as having internal heat-reducing and laxative effects.

At the same time, our study found that a kind of poisonous plant has been used as a forage plant. Coriaria nepalensis Wall. is a plant used in Chinese medicine that has toxic properties. It is used in the treatment of numbness, toothache, traumatic injury, and acute conjunctivitis in traditional Chinese medicine (Jiangsu New Medical College, 1977). In Zhuxi County, it is used as an insecticidal plant. However, it was also cited as a low-proportion forage plant for pig feed. It contains neurotoxic sesquiterpene lactone compounds, such as coriamyrtin (De Haro et al., 2005) and tutin (Wei et al., 1998; Zhao et al., 2012; Larsen et al., 2015; Watkins et al., 2018; J. Yang et al., 2020). C. nepalensis is therefore not recommended for use as a forage plant.

5. Conclusion

In this study, the traditional knowledge of local people about forage plant resources for pig feeding was investigated in Zhuxi County as a case study from the Qinba mountainous area of Central China. A total of 145 forage plants were documented, and the life forms, most commonly used parts for forage, palatability, gathering season, and preparation methods were also recorded. According to their RFC values, the top 14 forage species were considered important forage resources in Zhuxi County. To some extent, small-scale farming is a way for local people to adapt to the unique ecological environment. However, the preservation of traditional knowledge about forage plants in Zhuxi County may be threatened because of the changes in pig feeding modes and the lack of successors to carry on this traditional knowledge. For the conservation of traditional knowledge associated with biodiversity and the sustainable use of forage species resources, the following points are required for serious consideration in the future:

1) Targeted measures should be taken to record and protect forage plant resources and the associated traditional knowledge.

2) Further studies are needed, such as evaluations of the nutritive value, digestibility, and other functions of forage plants in pigs. In particular, the most frequently cited species and species with multiple uses, such as Taraxacum mongolicum, Bidens pilosa, Sonchus oleraceus, Pilea verrucosa, and Pilea pumila var. obtusifolia, should be considered as environmentally friendly feed additives in the future.

3) Population assessment of the forage species in natural habitats is required to clear their status to avoid ecological damage caused by unrestrained collection by local people.

4) The publicity and popularization of poisonous forage plants such as C. nepalensis should be strengthened to reduce the economic loss to the local communities caused by poisoning of livestock.

Authors’ contributions

Yuehu Wang and Fuwei Zhao conceived of and designed the study. Jun Yang, Jifeng Luo, Qiliang Gan, Leiyu Ke, Fengming Zhang, Hairu Guo, Fuwei Zhao and Yuehu Wang participated in field surveys and data collection. Jun Yang and Qiliang Gan identified the plants. Jun Yang interpreted data, analyzed it and wrote the manuscript. Yuehu Wang and Fuwei Zhao modified the manuscript.

Declaration of competing interest

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pld.2020.12.008.

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