

The highly toxic *Aconitum carmichaelii* Debeaux as a root vegetable in the Qinling Mountains (Shaanxi, China)

Yongxiang Kang · Łukasz Jakub Łuczaj · Sebastian Ye

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Abstract *Aconitum* spp. are highly toxic due to the presence of aconitine-type alkaloids. *Aconitum carmichaelii* Debeaux is one of the most important and most studied Chinese medicines. However the scientific literature contains only anecdotal references to the use of *A. carmichaelii* as a food plant. The aim of the study was to document the traditional alimentary use of the species. Fifty people from three adjacent villages on Mount Taibai of the Qinling range (Shaanxi) were interviewed about the local use of the *Aconitum*. Most of them eat it on a regular basis every winter. The plant is widely cultivated in the area for food and nearly every family grows it. The tubers are cooked a few times during winter. Usually around 5 kg are prepared at one time and boiled, adding water four times, each time for at least 2 h, over a high flame. People usually eat one bowl a day (ca. 200 g). Respondents claim they eat them for two

reasons: they heat the body in winter (they are “hot by nature”) and they are nourishing like other staples.

Keywords *Aconitum carmichaelii* · Detoxification · Domestication · Ethnobotany · Tubers · Underground organs · Functional foods

Introduction

Carbohydrate rich storage organs have been used as human food since the origins of the human species. However, plants may defend themselves from having their storage parts consumed by the presence of toxic metabolites in their roots, tubers and rhizomes. It is argued that one of the most important functions of fire is its ability to detoxify poisonous plants in order for people to be able to eat them (e.g. Wrangham and Conklin-Brittain 2003). In human history many populations relied on staples requiring complicated detoxification procedures, involving prolonged cooking, baking or leaching (Johns 1990; Hanelt and Institut für Pflanzengenetik und Kulturpflanzenforschung Gatersleben 2001; Messner 2011; Turner et al. 2011). One of the most toxic plants used by humans for food and medicine is the genus *Aconitum* (known as aconite, monkshood or wolfsbane). Its medicinal aspects of use are quite well known and extensively studied, however the evidence of its use as food, in much larger quantities than if applied medicinally, is very scarce.

Y. Kang
College of Forestry, Northwest A&F University,
Yangling 712100, People’s Republic of China
e-mail: kangchenj@yahoo.com.cn

Ł. J. Łuczaj (✉)
Department of Ecotoxicology, Faculty of Biotechnology,
University of Rzeszów, Werynia 502,
36-100 Kolbuszowa, Poland
e-mail: lukasz.luczaj@interia.pl; zielna@luczaj.com

S. Ye
ul. Skargi 11 m 70, 39-300 Mielec, Poland
e-mail: sebcebula@yahoo.com

Aconites are perennials occurring mainly in the temperate regions in Eurasia, usually in the mountains as most species prefer cool and humid conditions. The plants from this genus produce tubers, which are caudexes, i.e. enlarged basal parts of the stem. They are known for their toxicity and were often used as poison to kill both animals and people. They have also been used in ethnomedicine, both in Europe and Asia (e.g. Buturǎ 1979; CP Commission 2005; Svanberg 2011; Singhuber et al. 2009). In modern European pharmacopeia they are not used, due to the danger of poisoning, in contrast to Traditional Chinese Medicine (TCM) where aconites are one of the main medicines, though used with great caution (Bisset 1981; Singhuber et al. 2009). As *Aconitum*-containing Chinese products more and more often appear on the European market, assessing their toxicity is a large challenge for the Western pharmaceutical regulatory bodies (Csupor et al. 2011). *Aconitum carmichaelii* is known in TCM under the name *fuzi* (附子) or *caowu* (草乌), depending on the kind of tuber, which is used. Several other species of the genus are also used, but much less frequently (Bisset 1981; Singhuber et al. 2009; He et al. 2010). Understanding the pharmacology of *Aconitum* is an important issue as more and more research confirms its potent healing properties, e.g. as an agent in the treatment of rheumatoid arthritis, epilepsy, kidney dysfunctions, abdominal colic and even some cardiovascular problems (Singhuber et al. 2009). The potential healing properties and risks of using *Aconitum* species, particularly *Aconitum carmichaelii*, were extensively discussed by Singhuber et al. (2009). The toxicity of *Aconitum* is mainly caused by diester diterpene alkaloids (DDAs) including aconitine (AC), mesaconitine (MA) and hypaconitine (HA). They can be decomposed by hydrolysis into less or non-toxic derivatives through traditional Chinese processing methods. The diester alkaloids are broken down under the influence of humidity and high temperatures to monoester alkaloids which are at least two thousand times less toxic (Zhou 2011; Zhao et al. 2011). However, improper processing causes numerous poisonings in China, Japan and India. *Aconitum* spp. are dangerous in use. The symptoms of poisoning are very quick, and usually occur within an hour or a few hours of ingestion. The cause of death is cardiovascular failure combined with neurotoxicity (Singhuber et al. 2009; Chan 2011). The mode of use of *Aconitum* in

TCM is well known. Only small amounts are used, usually after cooking for at least an hour to decrease its toxicity (CP Commission 2005; Singhuber et al. 2009).

Aconitum as food

The use of larger quantities of *Aconitum* tubers as food, or at least medicinal food, is little studied. Hu (2005), in her reference book on the traditional food plants of China, reported that *A. carmichaelii* tubers are used as an ingredient of a tonic soup, e.g. in the Sichuan province. In Jiangyou County (Sichuan Province, SW China), *Aconitum* is used as a vegetable, by cutting the roots into slices and boiling between 25 and 150 g (sometimes even more) in a soup. The soup is usually mixed with meat and vegetables. It should be cooked for several hours to a couple of days, depending on the amount of aconite used, in order to reduce its toxicity. The detoxification of its roots is bound to a hydrolysis procedure (Tang and Eisenbrand 1992). Traditionally, the boiled tubers will only be consumed if the tongue or the buccal part of the mouth does not feel numb after tasting the decoction (Zhang 2007). Also in some other provinces such as Guizhou or Hunan, there are similar branches of this culinary tradition, particularly in mountain areas (Zhu 2006). The recently published overview of Shaanxi ethnomedicine (the province where our research was performed) also reports that the tubers of *A. carmichaelii* are, together with meat, used to make a kind of soup (Teng et al. 2011).

There is very scarce evidence of the use of *Aconitum* as food also in other countries. *A. heterophyllum* Wall. was sometimes used as a vegetable in the Himalayas (Daniel 2006). According to Flückiger and Hanbury (1879; after Hedrick 1972) *A. napellus* L. tubers were eaten in Kunawar, in the Indian Himalayas, as a tonic (nowadays this aconite is probably classified as a distinct species). *A. lycoctonum* L. was boiled as fodder for the cattle in northern Scandinavia (Høeg 1974). However its use as human food in northern Sweden, as claimed by Linnaeus in his *Flora lapponica* from 1737, is based on a false statement by the famous botanist and has become a kind of booklore in the economic botanical literature (Svanberg 2005; cf. Hedrick 1972).

Aconitum tubers can be potentially, after detoxification, a source of energy for humans as they

contain starch and other polysaccharides (Taki et al. 2004; Gao et al. 2010). However we found no papers, which directly deal with *Aconitum* tubers as a source of calories.

The aim of the study was to characterize the use of *A. carmichaelii* as food in a selected area of the Shaanxi province in central China, where the authors had the information that is used.

Aconitum carmichaelii description

Aconitum carmichaelii Debeaux, Acta Soc. Linn. Bordeaux. 33: 87. 1879 (official Chinese name: 乌头 wu tou) is one of 211 species of the genus in China (Wu and Raven 2001). Synonymous names include: *A. fischeri* Forbes et Hemsl., *A. bodinieri* Lév. et Vaniot, *A. kusnezoffii* var. *bodinieri* Fin. et Gagnep., *A. wilsonii* Stapf ex Veitch and *A. fischeri* var. *wilsonii* Davis (Hanelt and Institut für Pflanzen-genetik und Kulturpflanzenforschung Gatersleben 2001).

Aconitum carmichaelii is a tall perennial, with stems 0.6–2 m tall, with leaves equally arranged along the stem. It forms obconical caudexes, 2–4 cm long, 1–1.6 in diameter. Purple-blue flowers appear in September or October (for further morphological characteristics see Wu and Raven 2001). The native range of *A. carmichaelii* encompasses large parts of China (mainly its central and southern parts)—Anhui, Fujian, SE Gansu, N Guangdong, N Guangxi, Guizhou, Hebei, S Henan, W Hubei, Hunan, Jiangsu, Jiangxi, S Liaoning, Nei Mongol, S and SW Shaanxi, Shandong, Shanxi, Sichuan, Yunnan, Zhejiang (Wu and Raven 2001). *A. carmichaelii* is a native plant for the Qinling mountains. It grows there at the altitude of 1,000–1,800 m (Northwest Institute of Botany 1974). However it is much more common there as a cultivated plant.

Aconitum carmichaelii is widely cultivated in China and Korea as a medicinal plant (Baik et al. 1986; Hu 2005). It is the main cultivated species of *Aconitum* in China (Hanelt and Institut für Pflanzen-genetik und Kulturpflanzenforschung Gatersleben 2001; CP Commission 2005; Hu 2005). It is also occasionally grown in other temperate and subtropical parts of the world, e.g. North America and Europe, but usually only for ornamental purposes (authors observations).

Materials and methods

The study was focused on documenting the culinary use of *A. carmichaelii* in three neighbouring villages: Houzhenzi, Diaoyutai and Huaerping. The studied villages are located on the south slope of Mount Taibai (peak at 3,767 m a.s.l.), that is the highest peak within Qinling Mountains, at altitudes between 1,100 and 1,400 m a.s.l. The villages are relatively isolated, connected to the nearest town, Zhouzhi, by a 2.5 h drive through a narrow, desolate, precipitous gorge. Houzhenzi is the largest village, with several shops and restaurants mainly serving hikers climbing Mount Taibai. Diaoyutai and Huaerping are small hamlets, each with a few dozen houses. The Taibai Nature Reserve, protecting a highly diverse ancient forest vegetation and populations of golden monkey, pandas and takins, lies in the direct vicinity of the villages. A detailed description of the economic status of villages in a neighbouring valley of Qinling Mountains, also applicable to this valley, was given by Neurauter et al. (2009).

On two visits to the area, one in June and another in August 2011, fifty people (20 from Diaoyutai, 20 from Houzhenzi and 10 from Huaerping), aged 20–69 (median age 50) were interviewed about the use of *wuyao*. Semi-structured interviews were applied. We asked the respondents how frequently they eat *wuyao* and why, how much of it they eat, how to detoxify the plant and who can eat it. We also asked them about the cultivation and productivity of the species. Respondents were interviewed in their native language—Mandarin Chinese (*putonghua*), and were informed that the data were gathered for the purposes of scientific publication. One of the interviewed families was asked to detoxify the tubers for the researchers. Data were supplemented by observations on cultivation and winter-time use of the species from 2007 to 2009, when the third author (S.Y.) visited the villages of Houzhenzi and Diaoyutai a few times.

Results

Aconitum carmichaelii is cultivated by most farmer families in the study area, where it is uniformly called *wuyao* (i.e. ‘dark/raven medicine’) or *wuyou* (the pronunciation of the standard Mandarin *wuyao* in the



Fig. 1 A bowl of *wu yao* soup before consumption

local dialect). All the interviewed inhabitants of Diaoyutai and Huaerping have eaten *wuyao*. Most of them eat it every winter (17 out of 20 in Diaoyutai and 7 out of 10 in Huaerping). Three inhabitants of Houzhenzi have never tried it as they are not native to the area, the remaining 17 have, and out of them 14 eat it every winter. A very clear generational division seems to explain the differences in the frequency of the use of *wuyao*. Out of the people who do not eat it regularly eight are <35 years old and one is around 50 and she does not eat *wuyao* because she has stomach reflux. All other middle-aged and elderly people eat the plant at least once every winter, as well as two younger adults. *Wuyao* is eaten only in the cold season, mainly winter, occasionally in spring and autumn, when the weather is cool. Eating it in summer may, according to the respondents, cause “hotness of the stomach”.

Wuyao is always dried before use, never eaten when freshly dug out (it is extracted at the end of summer). Everyone agreed that the plant should be constantly boiled for at least 8 h. Some respondents advised that it should be eaten only after boiling for 9 or 10 h. The tubers become very soft when they are ready (like well-boiled potatoes) and any sign of hardness of the tubers’ interior (e.g. fibrous remnants) suggests that they are not ready for consumption. One respondent said that no cold drinks should be consumed for 2 h after eating *wuyao*.

Tubers must be soaked overnight. Then they are either put in a hot, boiling wok or, if put in cold water, the first water is discharged straight after having been boiled. The tubers are boiled until nearly

all the water evaporates, which lasts about 2 h. Altogether water is added four times (wok diameter 60 cm), or three times if a larger wok is used (which means the boiling water takes more time to evaporate). All the contents at the bottom of the wok (the tubers and small amounts of liquid covering the tubers) are always left in the wok.

Although the season was not right for eating *wuyao*, we asked our hosts to prepare the tubers for us. The host prepared 3 kg of *wuyao* (weighed after soaking overnight). She poured 17 l of water on it (the tubers filled half the wok). Boiling started in the morning. Water was added four times (each time the same volume of 17 l), and the tubers were cooked for 9 h. The host tried the tubers first in the evening, although according to most respondents, she should have left them till morning. After an hour we tried our portions.

The host showed us the bowl in which she eats *wuyao*—the average tuber portion weighed 200 g, but she can eat two full bowls—500 g of wet tubers (Fig. 1). Most other respondents admit eating it in the quantity of around one bowl at a time. The authors ate *wuyao* on four consecutive days, 50–200 g a day. The host ate much more (we estimate 200–300 g a day). No unusual symptoms were observed. Every time *wuyao* was used, it was boiled again and served hot. According to the interviewers boiled tubers spoil quickly and should be kept away from warmth, they can be stored for a few days in low above-freezing temperatures. Water is not changed, more is added. The black ‘soup’ (called *tang*, the Chinese word for soups, by the locals) is also drunk and believed to contain the essence of *wuyao*. After processing the tubers are kept in a cool place (but not refrigerated) and eaten every day until the portion finishes. Then another portion is processed. The family who cooked *wuyao* uses about 15 kg of dry *wuyao* (per two people) per winter, but some families can store even more, producing up to 50 kg of dry *wuyao*, mainly for their own use.

The lady who made *wuyao* for us mentioned that her relative had started processing the tubers in a pressure cooker (normally used for rice). This means that *wuyao* is cooked only for 3 h and does not need attention. However, she was scared to use this method for us, as she thought it was a new, not fully tested invention.

One respondent emphasized that *wuyao* is commonly used to nourish women after giving birth.

Aconite is usually cooked without any additions. Sometimes a small amount of soya beans and jujube fruits are added before the last cooking (the authors ate such a version of the dish). One respondent said that it can be used medicinally, cooked with wild boar meat and another medicine. Most respondents were surprised when we told them that the literature reports that *Aconitum* is often cooked with meat or vegetables.

Aconitum carmichaelii is grown near houses, usually in rows, in the shade of *Cornus officinalis* plantations (Fig. 2). It is protected from weeds, nowadays often by spraying non-selective herbicides around it. Respondents claim that the plant is easy to grow, though the yield may vary considerably from year to year. It is one of the largest crops in the villages.

Respondents are well aware of the deadly danger of consumption of the plants. Within the last decade a whole family apart from one of its members died from eating undercooked tubers. Our host recently slightly undercooked the tubers once and felt strange



Fig. 2 An *Aconitum carmichaelii* plantation in a home garden in Diaoyutai (Mount Taibai range, southern Shaanxi, China)

tingling on the skin all over the body, without any further symptoms.

Some respondents claim that the species grows in the wild in the forest around the village (but they probably meant other *Aconitum* species), some others state that it is only cultivated. However, all the plants used in the villages come from cultivation. One respondent said that they do not use *Aconitum* tubers from the wild, as they are small and thin.

The plant, according to the respondents, had been eaten “since their grandparents remember” and *wuyao* is still commonly eaten in the study area, although older people complained that nowadays the younger generations eat the plant rather reluctantly. They said that the custom of eating the plant is not restricted to these two villages but occurs in most of the Zhouzhi county. They said that at lower elevations, at the foot of the Qinling Mts, people also eat large amounts of the plants and their yields are higher due to better soils. *Wuyao* is regarded by most respondents as more nutritious than meat, both in the sense of caloric value and “hotness”, and is clearly perceived as “filling food,” additionally having medicinal properties. It is also served at the Chinese New Year.

Discussion

The culinary use of *A. carmichaelii* in the Taibai Mountains is interesting for a few reasons. First of all it is used in the study area as a functional food (i.e. food used to prevent health problems) but it can also be treated as a seasonal winter staple (it probably has considerable caloric value), while it is very dangerous to use even as medicine. Nowadays most traditionally consumed functional foods are leafy vegetables or spices, which do not need complicated detoxification procedures (e.g. Pieroni et al. 2005; Etkin 2006; Leonti et al. 2006; Pieroni and Price 2006).

It should also be pointed out that aconite, as eaten by the villagers, is extremely bitter. Such tolerance for bitterness must have evolved culturally as a result of the combination of realizing its ‘healthy properties’ and limited food resources.

The second reason is the very long preparation procedure. Nowadays many human populations across the whole globe have abandoned food plants which need long detoxification processes. Although

some of these plants are still eaten (like bracken rhizomes in East Asia or acorns in remote areas of the Mediterranean), the geographical extent of their utilization and their cultural importance have shrunk. We can presume that the preservation of this long processing technique is a relic of the hunter–gatherer mode of life in the mountains of central Asia. Although it has been domesticated, the original preparation techniques have been preserved, similarly to the elaborate processing of acorns which has been preserved almost up to the present in Sardinia (Pignone and Laghetti 2010).

The preservation of old food preparation techniques is not a surprise in the Qinling Mountains. In the study area, famines were frequent until the mid-twentieth century, and some respondents themselves remember subsisting in their childhood on wild leafy vegetables (*ye cai*), the rhizomes of *Polygonatum* spp., *Pteridium aquilinum* (L.) Kuhn and *Sinacalia tangutica* (Maxim.) B. Nord. and the bulbs of *Lilium* spp., and recall their parents telling them about the food use of *Ulmus* spp. cambium. Thus knowledge of the processing of toxic underground organs was of crucial importance to the inhabitants.

In the study area *A. carmichaelii* tubers are usually eaten alone in a similar form as that reported by Hu (2005) from the neighbouring province of Sichuan. This contrasts with data from Tang and Eisenbrand (1992) and from Teng et al. (2011), the latter from the same province as our study, showing that the tubers are eaten with meat and vegetables. It should also be highlighted that in the studied villages tubers are cooked whole, not sliced. Thus it seems that a diversity of ways of processing and serving may exist in the areas of aconite food use. Similarly to data from Zhang (2007), the local people finally test the edibility cooked tubers by nibbling a piece of it and checking that it does not cause numbness of the tongue.

As studies on the medicinal use of *Aconitum* so far have concentrated on smaller doses of the tubers cooked for a shorter time, research is needed, which could clarify the content of tubers undergoing long thermic treatment. It must also be borne in mind that the alkaloid content may depend on temperature and season (Shoyama et al. 1993). Maybe larger amounts boiled for a long time could be a safer alternative to the TCM applications as, at least according to the inhabitants of the Taibai Mt. range, no volume limits apply to the consumption of the tubers. The

inhabitants of the study area could be ideal subjects for a study of the long term effects of life-long use of aconites on health.

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