Wild food plants and fungi sold in the markets of Luang Prabang, Lao PDR

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Abstract

Background: Open air markets hold an important position for ethnobiologists. In Southeast Asia, they are seriously understudied, in spite of their incredible biocultural diversity. In order to fill this gap we recorded plants and fungi sold in the open air markets of Luang Prabang, Lao PDR.

Methods: The markets were visited 38 times in four seasons: the dry season, early monsoon, mid-monsoon, and end-of-monsoon, at least 8 times per season. All items were photographed and voucher specimens were collected. Fungi were identified using DNA barcoding techniques.

Results: We recorded 110 species of wild edible plants and 54 species of fungi, including 49 wild-collected species. The sold plants included 86 species of green vegetables, 18 species of fruits and 3 species of flowers. Products from woody species constitute around half of all taxa sold. These include the young shoots of tree leaves, which are used for salads—an interesting feature of Lao cuisine. A large number of extremely rare Russula, with no reference sequences represented in databases or even species unknown to science is present on sale in the markets.

Conclusions: Luang Prabang markets are some of the richest in species of wild edible plants and fungi in Asia, and indeed in the whole world. It is worth pointing out the exceptionally long list of wild edible mushrooms which are sold in Luang Prabang (and probably elsewhere in Laos). We view the Morning Market of Luang Prabang as a cultural treasure that unites the traditions of eating a large number of living species with very diverse flora and fauna. Measures should be taken to strike a balance between local foraging traditions and nature conservation priorities.

Keywords: Wild edible plants, Wild vegetables, Edible mushrooms, Mekong region, Ethnobotany, Ethnomycology

Background

Open air markets hold an important position for ethnobiologists [1–3]. They are places where one can usually find the plants, animals, and fungi which are most important to a given culture, e.g., commonly eaten fruits, vegetables, or medicinal plants. Of course, some highly valued goods—plants with a sacred status (like entheogens) or illegal items, such as protected bush meat—may not be present in open air markets, but the bulk of most commonly consumed organisms usually is. Ethnobotanical studies of open air markets are a frequent topic of ethnobotanical enquiry and they have been performed in most geographical regions, including several countries of Eurasia (e.g., [4–37]). The oldest known ethnobiological market surveys were carried out by Hungarian and Polish researchers in the early twentieth century, in Budapest [38, 39], Wilno (now Vilnius in Lithuania) [40] and Poznań [41, 42]. Recently, return studies in the markets of Budapest and Poznań showed large changes in the list of sold plants and fungi compared to what was...
sold in the beginning of the twentieth century [4, 43].
Bye’s study from Mexico [1] was another important early
work based on market surveys.

Ethnobiological studies of markets are an ethnobiolo-
gist’s entry point to local food systems. This research
situation allows for establishing quick contact with plant
sellers (who are often responsible for their collection, or
whose families collect the plants for them). The meeting
in a public space enables a quick exchange of informa-
tion of an ethnobiological character, concerning names
of the sold organisms, their occurrence and properties.
One of the disadvantages of market surveys is sometimes
the difficulty of collecting classic voucher specimens, as
usually only organs or parts of plants are on sale [2].
Fortunately, the difficulties in proper biological identifi-
cation of these fragmentary items can be overcome by
DNA barcoding [28, 31, 37].

Bearing in mind how easy it is to perform a mar-
ket study, it is surprising that there are many parts
of the world in which such studies have been made
rarely or not at all. Open air markets are an impor-
tant part of the eastern and south Asian rural eco-
nomy, and even though Asia is the largest, most
populous, and perhaps the most diverse of all conti-
nents, such studies are quite few and far between
([4–33];). Although surveys of wild edible plants and
fungi sold in Southeast Asia are rare, some research
effort has been put into studying the socioeconomic
aspects of “green” open markets in general [44–47]
as well as the contamination of plants with heavy
metals [48] or parasites and pathogens [49–51].
Some studies from Southeast Asia performed in
open air markets concern plant genetic resources
from a single species, genus or family; the identifica-
tion of the main cultivated plants (e.g., [52–56]); or
medicinal plants [24, 57].

Lao PDR is a diverse country with over 40 ethnic mi-
norities and 11 thousand vascular plants species. Due to
the very turbulent political and economic situation in
Southeast Asia in the twentieth century, the biological
diversity of Laos is still poorly described, in spite of in-
creasing efforts to document its Traditional Knowledge
and identify its non-timber forest products [58–69].

No lists of plants or fungi sold in particular markets
have ever been published in Laos apart from a list of
wild vegetables collected in rice fields and sold locally in
Houaphan Province [23]. More surveys concerning ani-
mals, both vertebrates [70–73] and insects [74], have
been performed. Some new species have been found in
Lao markets, e.g., a new species of Impatiens (a dicot
plant) [75] and a new species of rodent belonging to a
new family, which was found being sold for meat in a
local market [76]. Wildlife—both flora and fauna—is
present in most Lao markets. Wild plants and animals
are an important part of national cuisine, both because
of the country’s low economic status, but also because of
low human density, easy access to nature and wide-
spread beliefs about the health benefits of eating wild
foods. In a recent quick survey of 7 Lao markets, mam-
mals from as many as 12 families were recorded for sale
as bush meat [72].

All the towns in Laos have one or a few markets where
both cultivated and wild products are sold. Luang
Prabang is one of the largest towns in Laos, with a popu-
lation of 90,000 people. It is the biggest tourist hotspot
of the country. Luang Prabang used to be the capital of
Laos until 1975 and hosts many monuments important
to the history of the country. As it is located in the cen-
ter of the city, the Morning Market in the center of the
historical part of Luang Prabang is probably the market
most visited by foreigners. In spite of this, although
some products are tourist-oriented, it mainly serves the
local community. Thus, numerous vegetables, fruits, and
wild and domesticated animals are sold there each day.
A few other open air markets are located in the city and
its peripheries.

Lao markets are worth investigating not only in
search of endangered and rare organisms. Lao cuisine
is very rich in ingredients [77] and many wild vegeta-
bles and fungi are gathered. Lao PDR is undergoing
deep cultural changes as it is becomes increasingly in-
volved in the global market economy, and traditional
subsistence economy is gradually being replaced by
commercial agriculture and the tourist industry, espe-
cially in towns. The richness of Lao NTFP products
and local traditions of plant use have attracted a lot
of research attention in the last three decades, but
what is sold in the local markets was never a subject
of study. The traditional foods of the Luang Prabang
royal court in the mid-twentieth century were docu-
mented in a unique cook book written by the king’s
cook, Phia Sing [77]. A provisional list of edible
plants used in Laos was reported by Jaques Vidal in
the mid-twentieth century, with one of the main sites
of observation being Luang Prabang [78–80].

Mushrooms are an important part of Lao cuisine and
a commonly exploited NTFP. That is why they are fea-
tured in many local rural development studies and some
tries have been made to list the fungi species most
commonly sold in Laos [62–65, 81, 82].

Overall, the aim of our study was to make an inven-
tory of wild edible plants and fungi sold in the markets
of Luang Prabang, with special reference to the following
issues:

- Documenting traditional foods.
- Monitoring the presence of any endangered species.
- The possibility of discovering taxa new to science.
**Methods**

**Fieldwork**
The most species-rich Morning Market was surveyed regularly in four different seasons (dry season 10th to 19th of February 2018, end of monsoon/beginning of dry season 10th to 18th of November 2019, early monsoon 31st of May to 10th of June 2019 and mid-monsoon 31st of July to 7th of August 2019), each time for 8 to 11 consecutive days—38 days altogether. All the stalls were visited and most of them were photographed. Voucher specimens of wild vegetables and fungi were taken. Unstructured interviews about the uses and origins of each species were carried out with the market’s sellers, with the help of other co-authors or translators. However, they were not recorded. Apart from the Morning Market, four other markets in Luang Prabang (Phousi, Phanluang, Navieng Kham, Sayxoumxon) and two markets 20 km south of Luang Prabang (north of Xiang Ngeun) were also occasionally monitored and visited at least three times during our research. However, the market with the greatest diversity—the Morning Market—was the main focus. A list of sold taxa was compiled for each season. If possible, plants and fungi were preserved as herbarium specimens and deposited in duplicates: in the herbarium of Warsaw University (WA) and the National Herbarium of Laos (NHL).

**Plant and fungi identification**
Plants were identified using local field guides and literature available in our institutions and internet resources, taking into consideration recent Lao plant checklists [83, 84]. Altogether, 109 specimen vouchers of fungi were analyzed. They were first identified morphologically using the only available guide to the mycota of Laos [82]. The collected voucher specimens were identified with DNA barcoding [85, 86] following the guidelines of accepted methods for DNA barcoding of fungi [87]. Fungal DNA was extracted from a small part of the sporocarp (ca. 1 mm³ of dry mycelium taken from the cap) using a Plant and Fungi DNA Purification Kit (Eurx), following standard protocol. The PCR cocktail consisted of a 4 µl DNA extract, 0.5 µl of each of the primers (ITS5/ITS1f and ITS4 in 10 nmol concentration) and a 5-µl Type-it Microsatellite PCR Kit (Qiagen). PCR was carried out using the following thermocycling conditions: an initial 15 min at 95 °C, followed by 35 cycles at 95 °C for 30 s, 55 °C for 30 s, 72 °C for 1 min, and a final cycle of 10 min at 72 °C. The PCR products were estimated by running a 5-ml DNA amplicon on 1.5% agarose gel for 30 min. The PCR products were sequenced using ITS4 or ITS5 primers at the Laboratory of Molecular Biology of Adam Mickiewicz University (Poznań) and at the Institute of Biology and Biotechnology of the University of Rzeszów. Obtained sequences were compared with published sequences in UNITE databases using the BLAST tool. A positive identification of a specimen was confirmed if they shared > 97% ITS region sequence identity with the reference sequence. Nuclear ITS sequences obtained in this study have been deposited in GenBank [88] (with the accession numbers listed in Table 3). Nomenclature has been accepted according to the species hypothesis described in UNITE [89].

Plant nomenclature follows the Plant List [90] and fungi names follow Index Fungorum [91].

**Wild versus cultivated**
It is important to bear in mind that the studied area is a complex agroforestry ecosystem—the gardens have many trees and the numerous species that surround villages often come from spontaneous regeneration; thus, it is very difficult to establish if certain products come from planted or wild specimens. This concerns for example trees growing within villages as well as plants that are both cultivated and collected from the wild or merely tolerated within the agroecosystem, being a part of incipient cultivation (see e.g., [92]). We assume that wild and cultivated plants constitute a continuum. In our study, we decided to include all plants which are at least sometimes collected from spontaneously self-seeded specimens or plants and which are considered wild by the local population even if they are also cultivated. In this, we follow the emic approach to classifying whether a wild plant is wild (for a discussion of this approach, see paper by Sõukand and Kalle [93]). A very similar problem in identifying what is wild in a Southeast Asian market was encountered by the researchers in the markets of Khon Kaen in the Isaan Province of Thailand [15]. They wrote: “Given the extent to which rural ecosystems in Northeast Thailand have been subject to continuing human interference for hundreds of years, it is often difficult to determine if a species is truly wild or not. Wild species are defined as species that normally grow under natural conditions without deliberate human management” [15]. Further they give examples of star fruit (Averrhoa carambola L.) and tamarind (Tamarindus indica L.) often self-propagating and considered wild or numerous species transplanted to gardens from wild locations to enhance market yields.

**Results**
We recorded the sales of 110 species of wild plants for food purposes (Table 1; Figs. 1, 2, and 3). They belong to 49 plant families. The taxa included 86 species of green wild vegetables, 19 species of fruits, and 3 species of flowers. Among plants, the most represented plant families were Fabaceae, Poaceae, Solanaceae, and
| Scientific name                  | Family           | Local name     | Local name | Voucher Number (WA) | Jun | Aug | Nov | Feb | Parts used | Use                                                                 |
|---------------------------------|------------------|----------------|------------|--------------------|-----|-----|-----|-----|------------|----------------------------------------------------------------------|
| *Acacia concinna* (Willd.) DC.   | Fabaceae         | som poi        | นิยมป้อม   | 72429              | x   | x   | x   | x   | green parts | in BS and MVS to give them sour taste                                |
| *Acacia pennata* (L.) Willd.    | Fabaceae         | phak kan kong  | นิยมก่าบ่อย | 72440              | x   | x   | x   | x   | green parts | BS, chicken soup                                                     |
| *Adenanthera pavonina* L.       | Fabaceae         | phak mak lam   | นิยมบานม่วง  | 72466              | x   |     |     |     | green parts | BS, MVS                                                              |
| *Aegle marmelos* (L.) Corrêa    | Rutaceae         | mak tum        | นิยมบานม่วง  | 72477              | x   | x   | x   | x   | fruit       | tea, also raw; sticky inside to make glue for paper; young leaf tasty but they don't sell it in the market |
| *Albizia procera* (Roxb.) Berth.| Fabaceae         | phak thon      | นิยมกรอบ    |                   |     |     |     |     | green parts | soup, raw                                                            |
| *Alternanthera sessilis* (L.) DC.| Amaranthaceae    | phak tan       | นิยมบานม่วง  | 72455              | x   |     |     |     | green parts | soup, MVS                                                            |
| *Amaranthus spinosus* L.        | Amaranthaceae    | phak hom nam   | นิยมบานม่วง  | 72447              | x   | x   | x   | x   | green parts | soup, MVS                                                            |
| *Amaranthus viridis* L.         | Amaranthaceae    | phak hom       | นิยมบานม่วง  | 72439              | x   | x   | x   | x   | green parts | soup, MVS                                                            |
| *Amocalyx microlobus* Pierre ex Spire | Apocynaceae     | mak sim        | นิยมบานม่วง  |                   |     |     |     |     | young fruits | raw or added to dishes to give them sour taste                       |
| *Amorphophallus paeoniifolius* (Dennst.) Nicolson | Araceae         | duk deu        | นิยมบานม่วง  | 72492              |     |     |     |     | stalks      | soup, MVS                                                            |
| *Anisomeles indica* (L.) Kuntze| Lamiaceae        | phak ki on     | นิยมบานม่วง  |                   |     |     |     |     | observed in previous years | observed in previous years | green parts | soup, MVS                                                               |
| *Antidesma acidum* Retz.        | Phyllanthaceae   | mak mao        | นิยมบานม่วง  | 72493              | x   |     |     |     | green parts with fruits | green parts added to a soup made with Russula species; always sold placed near a bowl of these mushrooms; fruits are first sour then turn sweet |
| *Arennga westerhoutii* Griff.   | Palmae           | mak tao        | นิยมบานม่วง  | 72478              | x   | x   |     |     | seed, sap for wine | seed to make a sweet dessert, sap for wine                           |
| *Averrhoa carambola* L.         | Euphorbiaceae    | mak fu yang    | นิยมบานม่วง  |                   |     |     |     |     | fruit       | raw, also in salads, chicken soup to give sourness                    |
| *Azadirachta indica* A. Juss.   | Meliaceae        | phak ka dao    | นิยมบานม่วง  | 72430              | x   | x   | x   | x   | green parts | MVS                                                                   |
| *Bambusae, including:*         | Poaceae          |                   |            |                    |     |     |     |     | shoots      | BS, bamboo MVS                                                        |
| *Bambusa blumeana* Schultes     | Poaceae          |                   |            |                    |     |     |     |     | shoots      | BS, bamboo MVS                                                        |
| *Bambusa longisculpulata* Gamble| Poaceae          |                   |            |                    |     |     |     |     | shoots      | BS, bamboo MVS                                                        |
| *Bambusa tulda* Roxb.           | Poaceae          |                   |            |                    |     |     |     |     | shoots      | BS, bamboo MVS                                                        |
| *Cephalostachyum virgatum* (Munro) Kurz | Poaceae       |                   |            |                    |     |     |     |     | shoots      | BS, bamboo MVS                                                        |
| *Gigantochloa albociliata* (Munro)Kurz | Poaceae         |                   |            |                    |     |     |     |     | shoots      | BS, bamboo MVS                                                        |
| *Indocalamus petelotii*         | Poaceae          |                   |            |                    |     |     |     |     | shoots      | BS, bamboo MVS                                                        |
| Scientific name                     | Family       | Local name | Local name                  | Voucher Number (WA) | Jun | Aug | Nov | Feb | Parts used                | Use                                                                                                                                 |
|-----------------------------------|--------------|------------|------------------------------|---------------------|-----|-----|-----|-----|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| *Bauhinia malabarica* Roxb.        | Fabaceae     | phak xiao  | บัวบูระเรือ                   | 72448               | x   | x   |     |     | green parts               | raw and boiled, soup, MVS - added to dishes to give them acidity                                                                 |
| *Caesalpinia mimosoides* Lam.     | Fabaceae     | nam phak kha  | ตองมิ้น, ตองมิ้น                   | 72418               | lv  | lv  | fl  | fl  | green parts, flowers      | flowers, raw with geaouw, jackfruit salad and other things; young shoots added to dishes to give them sourness                        |
| *Calamus viminalis* Willd.        | Palmae       | wai kom    | กระยิม                        |                     |     |     |     |     | x x x x stalk              | burn it for geaw also for soup and ‘o lam’ soup                                                                                   |
| *Canarium asperum* Benth.         | Burseraceae  | mak bai    | มะใบ                       |                     |     |     |     |     | shoots                    | soup, MVS                                                                                                                        |
| *Careya arborea* Roxb.            | Lecythidaceae| phak ka don | มะหว่าจะบิน                    |                     |     |     |     |     | green parts               | raw, as condiment for spicy salad                                                                                                |
| *Caryota urens* L.                | Palmae       | nyod tao   | ยอดแอก                        | 72491               | x   | x   |     |     | inside of stalk            | boiled in soup quite rare in the market, highly prized                                                                         |
| *Castanopsis hystrix* Hook. f. &  | Fagaceae     | mak ko     | มะแอก                         | 72480               | x   |     |     |     | fruit                     | after frying                                                                                                                    |
| *Celastrus paniculatus* Willd.    | Celastraceae | mak taek   | มะขามแอก                      | 72467               | x   |     |     |     | green parts               | soup, MVS                                                                                                                        |
| *Ceratopteryx asiatica* (L.) Urb. | Umbelliferae | phak nok   | มะขามแอก                      | 72421               | x   | x   | x   |     | green parts               | raw or boiled in soup, MVS                                                                                                      |
| *Chlorella sp.*                    | Cladophoraceae| khai       | ใบ                            | 72452               | x   | x   | x   | x   | whole plant (green parts) | sheets of dried algae spiced with sesame and garlic fried as a snack or sidedish; the fresh algae also eaten in a sort of vegetable porridge for breakfast |
| *Coccinia grandis* (L.)o’gilt.    | Cucurbitaceae| phak tam nin, phak tam ling | มะแอกมัน, มะแอกมัน                   | 72464               | x   | x   | x   | x   | green parts               | soup, MVS                                                                                                                        |
| *Colocasia esculenta* (L.)Schott  | Araceae      | bon van    | บัวบูระเรือ                    | 72458               | x   | x   | x   | x   | leaf stalk                | soup, MVS, require longer processing                                                                                             |
| *Colocasia gigantea* (Blume) Hook.f. | Araceae    | thoun      | บุบ                         |                     | x   | x   | x   | x   | leaf stalk                | papaya salad, soup, MVS                                                                                                         |
| *Colubrina longipes* Back.        | Rhamnaceae   | phak kan tong | ตองมัน                        | 72463               | x   |     |     |     | green parts               | soup, MVS                                                                                                                        |
| *Commelina diffusa* Burm.f.       | Commelinaceae| phak kab pi, phak pab | ตองมันบิน, ตองมันบิน                  |                     | x   |     |     |     | green parts               | soup, MVS                                                                                                                        |
| *Commelina zeylanica* Falkenb.    | Commelinaceae| phak kab pi, phak pab | ตองมันบิน, ตองมันบิน                  |                     | x   |     |     |     | green parts               | soup, MVS                                                                                                                        |
| *Crasocephalum crepidioides* (Benth.) S.Moore | Asteraceae | nya heu bin | ตองมันบิน                     | 72426               | x   | x   | x   |     | green parts               | soup, MVS                                                                                                                        |
| Scientific name | Family | Local name | Local name | Voucher Number (WA) | Jun | Aug | Nov | Feb | Parts used | Use |
|-----------------|--------|------------|------------|--------------------|-----|-----|-----|-----|------------|-----|
| **Jun Aug Nov Feb** |   |   |   |   |   |   |   |   |   |   |
| **Parts used** |   |   |   |   |   |   |   |   |   |   |
| **Use** |   |   |   |   |   |   |   |   |   |   |
| **Number of species** |   |   |   |   |   |   |   |   |   |   |
| Cratoxylum cochinchinense | Guttiferae | phak tio | น้ำถั่วจืด | 72409 | x | x | green parts | soup, MVS |
| Cyclea barbata | Menispermaceae | mo noy | เหมืองย้อย | 72411 | x | x | green parts | soup, MVS |
| Daemonorops jenkinsiana (Griff.) Mart. | Palmae | wai | ลายใหญ่ | 72479 | x | x | stalk | burned for geaw also for soup, 'o lam' and MVS |
| Delonix regia (Hook.) Raf. | Fabaceae | fang daeng, mak fang | น้ำถั่วมะระ, น้ำมะระ | 72490 | x | x | preserved fruit | endosperm of seeds eaten after boiling |
| Diplazium esculentum (Retz.)Sw. | Woodsiaceae | phak lud | น้ำถั่วอุ่น | 72425 | x | x | x | green parts | soup and MVS, needs boiling |
| Eichhornia crassipes (Mart.) Solms | Pontederiaceae | phak tob | น้ำถั่วป | 72487 | x | x | green parts | steamed and eaten in salad with sesame, fish sauce, coriander and onion, MVS, soup |
| Eleusine indica (L.) Gaertn. | Poaceae | nya phak khuai | น้ำถั่วเผ็ด | 72465 | x | green parts | MVS |
| Eryngium foetidum L. | Umbelliferae | phak hom pe | น้ำถั่วหอมจืด | 72422 | x | x | x | green parts | aromatic herb added to soups and other dishes |
| Erythrina stricta Roxb. | Fabaceae | dok thong, phak thong | น้ำถั่วถีบ, น้ำถีบหนู | 72407 | x | x | green parts, fruit | young leaves, fruits, raw or 5 min boiling |
| Ficus fistulosa Reinw. ex Blume | Moraceae | mak war | น้ำถั่วbanana | x | green parts, fruit | fruit and leaf |
| Flacourtia indica (Burm.f.) Merr. | Salicaceae | mak kvien, mak ken ta khuai | น้ำถั่วเห็ด, น้ำถั่วปิ้งก้าว | x | green and ripe fruits | to give acidity to dishes, also raw |
| Gnaphalium polycaulon Pers. | Asteraceae | phak kaeb | น้ำถั่วขาว | x | green parts | MVS |
| Hibiscus sabdariffa L. | Malvaceae | som pho di | น้ำถั่วส้ม | 72511 | x | x | fruit | leaf - soup, fruit - soup, jam |
| Houttuynia cordata Thunb. | Saururaceae | phak khao thong | น้ำถั่วทะลุ | 72427 | x | x | x | green parts | raw salad |
| Hydrocleys zealanica Vahl | Hydrophyllaceae | phak bi i ian | น้ำถั่วโก้ | 72461 | x | green parts | soup, MVS |
| Ipomoea aquatica Forssk. | Convolvulaceae | phak bong | น้ำถั่วบั้ง | 72434 | x | x | x | green parts | soup, MVS |
| Lasia spinosa (L.) Thwaites | Araceae | phak nam, bon nam | น้ำถั่วโบ้, น้ำถั่วบั้ง | 72431 | x | x | green parts | soup, MVS |
| Leucaena leucocephala (Lam.) de Wit | Fabaceae | phak ka thin | น้ำถั่วเมือง | 72488 | x | x | x | green parts | pods and leaves raw in papaya salad, also in 'lab' meat salad |
| Limnocharis flava (L.) Buchenau | Limnocharitaceae | phak khan chong | น้ำถั่วบางจูบ | 72424 | x | x | x | green parts | soup, MVS |
| Limnophila chinensis | Scrophulariaceae | phak kha | น้ำถั่วทอง | 72420 | x | x | x | green parts | soup, MVS, as an aromatic herb giving flavour |
| Scientific name | Family | Local name | Voucher Number (WA) | Jun | Aug | Nov | Feb | Parts used | Use |
|-----------------|--------|------------|---------------------|-----|-----|-----|-----|------------|-----|
| *Juniperus* | Scrophulariaceae | nya khai hao | 72454 | x | green parts | soup, MVS |
| *Lygodium flexuosum* | Lygodaceae | phak kud roy | 72437 | x | green parts | soup, MVS |
| *Moringa oleifera* | Moringaceae | phak i hoom | 72489 | x | green parts | soup, MVS |
| *Oxalis corniculata* | Oxalidaceae | som saeng ka | 72438 | x | x | x | x | green parts | soup |
| *Pandanus amaryllifolius* | Pandanaceae | bai toey | 72482 | x | x | x | x | green parts | soup, MVS |
| *Passiflora edulis* | Passifloraceae | mak nong | 72459 | x | x | x | x | green parts | soup, MVS |
| *Pattieria* | Passiaceae | phak kud | 72471 | x | x | x | x | green parts | soup, MVS |

(Continued...)

Łuczaj et al. Journal of Ethnobiology and Ethnomedicine (2021) 17:6 Page 7 of 27
| Scientific name                  | Family         | Local name (WA) | Use                                                                 |
|---------------------------------|----------------|-----------------|----------------------------------------------------------------------|
| **Phyllanthus emblica L.**      | Euphorbiaceae  | mak kaam pom    | soup, MVS                                                            |
| **Piper ribesoides Wall., Piper interruptum Opiz.** | Piperaceae  | sa khan         | stalk                                                                 |
| **Piper sarmentosum Roxb.**     | Piperaceae     | phak iloed      | green parts                                                           |
| **Polygonum odoratum Lour.**    | Polygonaceae   | phud phaeng      | aromatic herb added to soups, MV and other dishes                   |
| **Protium serratum (Wall.ex Colebr.)Engl.** | Burseraceae | mak phaen       | ripe fruits used to give acid taste to dishes                       |
| **Rhus chinensis Mill.**        | Anacardiaceae  | som fad          | used to add sour taste to dishes                                    |
| **Sauropsis androgynus (L.) Merr.** | Euphorbiaceae | phak wan ban    | soup, MW                                                             |
| **Schleichera oleosa (Lour.) Merr.** | Sapindaceae  | mak ko som       | used to give acid taste to dishes                                   |
| **Sechium edule (Jacquin) Swartz** | Cucurbitaceae | phak soe, mak soe | soup, MW                                                             |
| **Sesbania grandiflora (L.) Poir.** | Fabaceae      | phak khae khae, dok khae | flowers, green parts, raw                                          |
| **Solanum barbisetum Nees**    | Solanaceae     | mak pu mak nya   | raw                                                                  |
| **Solanum indicum L.**          | Solanaceae     | mak kaen kon     | fruit                                                                 |
| **Solanum latiscapum Dunal**    | Solanaceae     | mak oek          | papaya salad                                                         |
| **Solanum nigrum L.**           | Solanaceae     | phak did nam     | soup, MW, also used raw                                             |
| **Solanum spirale Roxb.**       | Solanaceae     | mak did          | soup, MW                                                             |
| **Spilanthes acmella (L.) Kurz** | Asteraceae     | phak khad hun    | raw, but mostly in soups, MVS, ‘o lam’                          |
| **Spilanthes paniculata Wall. ex DC.** | Asteraceae  | phak khad dok roy | soup, MW                                                             |
| **Spondias pinnata (Koenig ex Lf.)Kurz** | Anacardiaceae | mak kok         | fruit grilled for geauw, also chicken soup, o lam, also raw        |
| Scientific name              | Family            | Local name (WA) | Local name | Voucher Number (WA) | Jun | Aug | Nov | Feb | Parts used | Use                                                      |
|------------------------------|-------------------|-----------------|------------|---------------------|-----|-----|-----|-----|-------------|----------------------------------------------------------|
| Tamarindus indica L.         | Fabaceae          | mak kham        |            |                     | x   | x   | x   | x   | fruit       | raw or paste as condiment                                |
| Tiliacora triandra Diels.    | Menispermaceae    | bai ya nang     |            | 72433               | x   | x   | x   | x   | green parts | used to make yanang water used in bamboo soup            |
| Trapa natans L.              | Trapaceae         | mak ka chap     |            | 72514               |     |     |     |     | fruit       | boiled snack                                             |
| Zanthoxylum retsa (Roxb.)DC. | Anacardiaceae     | mak khaen       |            | 72486               | x   | x   | x   | x   | fruit (seed coating) | spice for all foods                                |
| Zizyphus sp.                 | Rhamnaceae        | mak ka than     |            |                     |     | x   |     |     | fruit       | raw snack                                                |
| unidentified                 |                   | mak noy tai     |            |                     |     |     |     |     | fruit       | raw snack                                                |
| unidentified                 |                   | phak i tu       |            |                     |     |     |     |     | green parts | soup. MW                                                |
| unidentified                 |                   | phak dit pa     |            |                     |     |     |     |     | green parts | soup. MW                                                |

Abbreviations: BS bamboo soup, MVS mixed vegetable salad, lv leaves, fl flowers, fr fruit
Fig. 1 (See legend on next page.)
Scrophulariaceae. Woody plants (trees, shrubs, and woody vines) constitute exactly half (50%) of the plants sold, and among them 36% are trees (bamboos were not included in this calculation).

The largest number of taxa was available in the early monsoon season (June), with a slightly lower number in the mid-monsoon and on the turn of the monsoon and dry season. A much lower choice of plants was available in the dry season (Table 1). However, in each season (observation period), some plants were observed which were not present in other periods.

Molecular investigation and morphological observation revealed a total of 54 fungal taxa from 17 fungi families (Tables 2 and 3; Figs. 3, 4, 5, and 6). Of these, 37 taxa were assigned down to species level and the rest to genus level. Russulaceae was best represented among fungi. The extraction of genetic material failed for some specimens; therefore, they could only be identified morphologically. The most common fungi sold in open air market were russuloid fungi, representing 16 taxa. Within this group, seven taxa were identified to species level and nine to genus level. Some differences between obtained sequences were recorded in this group. The phylogenetic analysis of ITS sequences placed these taxa in separate clades. Therefore, 9 unique taxa of unidentified Russula species have been distinguished, each with low similarity to the reference sequence (Table 3). Additionally, the differences between obtained Russula’ sequences was higher than 3%, which is the expected level of interspecific variation for fungi within ITS. This allows us to assume that a large number of extremely rare Russula, with no reference sequences represented in databases, or even species unknown to science may be present on sale in the markets.

Discussion

The number of food taxa sold in the studied markets is remarkable on a world scale (see e.g., a list of ethnobotanical market studies in Eurasia in a recent paper about Armenia [94]). We should especially note the long list of 54 fungal species sold, comparable to some of the markets of Mexico (over 90 species sold in 12 local markets [95] and 40 species in another market [96]) and Central Europe, e.g., Poland—32 species in Rzeszów [31], 56 species in Poznań [41] or Hungary, with 38 species in Budapest [38, 39]. Such a large number of fungi on sale have not yet been recorded anywhere in Asia outside Laos. Only 6 fungi species have been recorded in the Isaan Province of Thailand, which is culturally very close to Laos [15]. Two studies from Yunnan, China, both found 18 species of fungi on sale [14, 32]. In Armenia, 12 species of fungi are sold in the markets of its capital city—Yerevan [94]. Some of the Russula taxa recorded on sale in Luang Prabang may potentially be new species, but, due to the extremely complex taxonomy of the genus, we did not undertake the challenge of describing them. Also, some taxa found in the markets, i.e., Pisolithus orientalis, Polyporus usd, and Calvatia sp. have not been reported as used for consumption in Laos before.

The number of wild food plants—110—is also impressive. For comparison, in Khon Kaen (Bang Lam Phu) located in the Isaan Province, a neighboring region of Thailand, Shirai et al. recorded only half as many species (54) as we found in Luang Prabang [15]. Out of these 54 species 22 were recorded in Luang Prabang as well. In Jinping, Yunnan, China, 35 species of wild food plants were sold in markets [97]; in an area of Assam, India—29 [25]; in the Ukhrul District of Manipur, India [26]—55; and only 28 species of wild vegetables (out of 132 of all the plant taxa in the market) were found in a study of 10 markets in Myanmar [98].

The diversity of wild food plants sold can only be compared to Xishuangbangna in Yunnan, China, where 146 species were recorded in 10 markets [14]; to Armenia, where in Yerevan, the capital of the country, 148 wild food species were recorded on sale [94]; or to Turkey, where 143 wild edible plants were found in Mugla, Bodrum [9].

A large group of species sold are wild vegetables: leaves, shoots, inner stems, or flowers which are ingredients of traditional dishes. They are mainly used to make a dish called soup phak, a gently boiled salad flavored with spices. Sometimes the species are sold in a mix. A previous paper from another part of Laos (Houphuan) reports the use of mainly wild vegetable mixes [23], but here in Luang Prabang, most species are sold in bunches of single species. Only small rice field weeds are sold in a mix.

It is worth emphasizing that a large proportion of wild vegetables in the markets of Luang Prabang come from woody taxa. In most countries, agricultural weeds

Fig. 1 Selected edible plants sold in the markets. a–c Caesalpinia mimosoides: shoots (a), flowers (b), and flowers in traditional unripe jackfruit salad sold in the morning market; ferns: d Lygodium flexuosum. e Diplazium esculentum. f Marsilea crenata. g o laim, a traditional Luang Prabang stewed dish containing numerous wild ingredients served in restaurants in the city; some of its ingredients include wood of sakhan pepper (Piper ribesoides) (h) and juice from bai yanang (Tilia cordata) leaves (i). j Flowers of Markhamia stipulata. k–m Orophyllum indicum: flowers (k), unripe fruits (l); young leafy shoots (m).
Fig. 2 Selected edible plants sold in the markets. a Processed fruits of *Delonix regia*. b Fruits of *Livistona saribus*. c Young shoots of *Eleusine indica*. d–f *Cladophora* sp., raw plants (d), fried (e), boiled served as breakfast soup in the market (f). g *Moringa oleifera*. h *Acacia pennata*. i *Leucaena leucocephala*. j *Trapa natans*. k *Acacia concinna*. l Sellers of wild vegetables. m A mix of wild vegetables, mainly weeds of rice fields.
Fig. 3 Selected edible fungi and plants sold in the markets. 

- **a** Auricularia spp., mainly *A. delicosa*.
- **b** Pleurotus giganteus.
- **c** Flowers of *Sesbania grandiflora*.
- **d** *Cratoxylum cochinchinense*.
- **e** *Lasia spinosa*.
- **f** *Limnocharis flava*.
- **g** *Melianta suavis*.
- **h** *Neptunia oleracea*.
- **i** *Pandanus amaryllifolius*.
- **j** *Piper sarmentosum*.
- **k** *Bauhinia malabarica*.
- **l** *Crassocephalum crepidioides*.
### Table 2: List of the recorded fungi taxa

| Scientific name | Family | Local Lao name transliteration | Local Lao name | Feb | Jun | Aug | Nov | Use | Status |
|-----------------|--------|---------------------------------|----------------|-----|-----|-----|-----|-----|--------|
| Amanita hemibapha (Berk. & Broome) Sacc. 1887 | Amanitaceae | het la ngok leuang |毡帽鹅膏菌 | x | x | | | food | wild |
| Amanita princeps Corner & Bas 1962 | Amanitaceae | het la ngok khoa |毡帽鹅膏菌 | x | x | | | food | wild |
| Amanita sp. | Amanitaceae | het la ngok |毡帽鹅膏菌 | x | x | | | food | wild |
| Astraeus odoratus Phasri, Watling, M.P. Martin & Whalley 2004 | Diplocystidiaceae | het pho |蜜环菌 | x | | | | food | wild |
| Auricularia spp., including: | Auriculariaceae | het hou nou |耳杯菌 | x | x | x | | food | wild |
| Auricularia aff. lbrilléa Kobayasi 1973 | | | | | | | | | |
| Auricularia delicata (Mont. ex Fr.) Henn. 1893 | | | | | | | | | |
| Auricularia mesenterica (Dicks.) Pers. 1822 or A. asiatica Bandara & K.D. Hyde 2016 | | | | | | | | | |
| Auricularia nigricans (Sw.) Birkebak, Looney & Sánchez-García 2013 | | | | | | | | | |
| Boletus aff. gertrudiae Peck 1911 | Boletaceae | het pheung |骆驼菌 | | | | | food | wild |
| Boletus reticulatus Schaeff. 1763 | Boletaceae | het pheung |骆驼菌 | | | | | food | wild |
| Calvatia sp. | Agaricaeae | het thang | | | | | | food | wild |
| Cantharellula sp. | Cantharellaceae | het saet || | | | | food | wild |
| Cantharellus spp. | Cantharellaceae | het saet || | | | | food | wild |
| Clavulina sp. | Cantharellaceae | het nuat || | | | | food | wild |
| Flammulina velutipes (Curtis) Singer 1951 | Agaricaeae | het sen nyai || | | | | food | wild |
| Ganoderma gibbosum (Cooke) Pat. 1897 | Ganodermataceae | het lin chu || | | | | medicine sold to Chinese tourists | wild |
| Ganoderma sp. | Ganodermataceae | het lin chu || | | | | medicine sold to Chinese tourists | wild |
| Lactifluus pinguis (Van de Putte & Verbeken) Van de Putte 2012 and Lactifluus volemus (Fr.) Kuntze 1891 | Russulaceae | het hat || | | | | food | wild |
| Lentinula edodes (Berk) Pegler 1976 | Omphalotaceae | het horn || | | | | food | cultivated |
| Lentinus polychrous Lév. 1844 | Polyporaceae | het bot || | | | | food | wild |
| Lentinus squarrosulus Mont. 1842 | Polyporaceae | het khoa || | | | | food | wild |
| Leucoagaricus meleagris (Gray) Singer 1951* | Agaricaeae | not recorded* || | | | | food | wild |
| Macrocybe gigantea (Massee) Pegler & Lodge 1998 | Tricholomataceae | het tin sang || | | | | food | cultivated |
| Scientific name | Family | Local Lao name transliteration | Local Lao name | Feb | Jun | Aug | Nov | Use | Status |
|-----------------|--------|--------------------------------|----------------|-----|-----|-----|-----|-----|--------|
| Phlebopus portentosus (Berk. & Broome) Boedijn 1951 | Boletinaceae | het pheung | het pheung | x | x | x | x | food | wild |
| Pisolithus orientalis Watling, Phosri & M.P. Martin 2012 | Sclerodermataceae | het mak kheua | het mak kheua | x | food | wild |
| Pleurotus aff. ferulaginis Zervakis, Venturella & Cattar. 2014 | Pleurotaceae | het nang lom | het nang lom | x | x | x | x | food | wild |
| Pleurotus eryngii (DC.) Quél. 1872 | Pleurotaceae | het tin haet | het tin haet | x | x | x | x | food | cultivated |
| Pleurotus giganteus (Berk) Karun. & K.D. Hyde 2011 | Pleurotaceae | het sang | het sang | x | x | x | x | food | wild |
| Pleurotus pulmonarius (Fr.) Quél. 1872 | Pleurotaceae | het nang lom | het nang lom | x | x | x | x | food | cultivated |
| Polyporus udus Jungh. 1840 | Polyporaceae | het ting moi | het ting moi | x | x | x | x | food | wild |
| Russula spp., all species sold mixed together, including: | Russulaceae | large variety of names used, e.g. het din, het nam mak, het le dou, het kok | large variety of names used, e.g. het din, het nam mak, het le dou, het kok | x | x | x | x | food | cultivated |

Russula alboareolata Hongo 1979
Russula delica Fr. 1838
Russula faustiana Samari 1992
Russula integra (L) Fr. 1838
Russula paludosa Britzelm. 1891
Russula sp. 1
Russula sp. 2
Russula sp. 3
Russula sp. 4
Russula sp. 5
Russula sp. 6
Russula sp. 7
Russula sp. 8
Russula sp. 9
Russula subfoetens W.G. Sm. 1873
Russula virescens (Schaeff) Fr. 1836
Schizophyllum commune Fr. 1815
Schizophyllaceae | het khaen | het khaen | x | x | x | x | food | wild |
Termitomyces fuliginosus R.Heim 1951
Termitomyces eurrhizus (Berk) R. Heim 1942
Termitomyces heimii Natarajan 1979
Lyophyllaceae | het khon kao | het khon kao | x | x | x | x | food | wild |
Lyophyllaceae | het pouak | het pouak | x | x | x | x | food | wild |
Table 2 List of the recorded fungi taxa (Continued)

| Scientific name | Family       | Local Lao name transliteration | Local Lao name | Feb | Jun | Aug | Nov | Use  | Status         |
|-----------------|--------------|--------------------------------|----------------|-----|-----|-----|-----|------|----------------|
| *Termitomyces microcarpus* (Berk. & Broome) R. Heim 1941 | Lyophyllaceae | het kai noy | x | x | x | food | wild |
| *Volvariella volvacea* (Bull) Singer 1951 | Pluteaceae | het feuong | x | x | x | x | food | wild and cultivated |
| unidentified   | ?            | het hai          | x |   |   | food | wild |

A single fruiting body found in the market, it may have been mistakenly collected instead of some other species.
| Voucher no. starting from WA00000 | Accession number | Molecular identification | Best match sequence | E value | Similarity (%) |
|----------------------------------|------------------|--------------------------|---------------------|---------|----------------|
| 72234                            |                  | Amanita hemibapa         | m. i.               |         |                |
| 72249                            | MT252579         | Amanita hemibapa         | KY349225            | 0.0     | 97.33          |
| 72256                            | MT252585         | Amanita princeps         | UDB033485           | 0.0     | 99.43          |
| 72255                            | MT252584         | Amanita sp.              | MH508508            | 0.0     | 90.97          |
| 72263                            |                  | Amanita sp.              | m. i.               |         |                |
| 72212                            | MT252558         | Astraeus odoratus        | LC307160            | 0.0     | 100.0          |
| 72205                            |                  | Auricularia aff. fibrillifera | m. i.        |         |                |
| 72172                            | MT252524         | Auricularia delicata     | KX022020            | 0.0     | 99.64          |
| 72174                            | MT252526         | Auricularia delicata     | KX022020            | 0.0     | 99.64          |
| 72181                            | MT252533         | Auricularia delicata     | KX022020            | 0.0     | 99.64          |
| 72216                            | MT252562         | Auricularia delicata     | KX022020            | 0.0     | 99.64          |
| 72220                            | MT252566         | Auricularia mesenterica  | UDB033860           | 0.0     | 99.82          |
| 72171                            | MT252523         | Auricularia nigricans    | KY293392            | 0.0     | 99.8           |
| 72173                            | MT252525         | Auricularia nigricans    | KY293392            | 0.0     | 99.8           |
| 72191                            | MT252541         | Auricularia nigricans    | KY293392            | 0.0     | 99.82          |
| 72209                            | MT252555         | Auricularia nigricans    | FJ617292            | 0.0     | 100.0          |
| 72217                            | MT252527         | Auricularia sp.          | UDB033911           | 0.0     | 99.64          |
| 72182                            | MT252534         | Auricularia sp.          | UDB033911           | 0.0     | 99.28          |
| 72233                            |                  | Boletaceae               | m. i.               |         |                |
| 72250                            |                  | Boletaceae               | m. i.               |         |                |
| 72272                            |                  | Boletus aff. gertrudiae  | m. i.               |         |                |
| 72217                            | MT252563         | Boletus reticulatus      | UDB032667           | 0.0     | 100.0          |
| 72244                            | MT252569         | Boletus reticulatus      | UDB032667           | 0.0     | 100.0          |
| 72230                            | MT252570         | Boletus reticulatus      | UDB032667           | 0.0     | 100.0          |
| 72240                            | MT252575         | Boletus reticulatus      | UDB032667           | 0.0     | 100.0          |
| 72275                            | MT252596         | Calvatia sp.             | MNS23227            | 0.0     | 99.11          |
| 72238                            |                  | Cantarellus sp.          | m. i.               |         |                |
| 72189                            |                  | Cantharellaceae          | m. i.               |         |                |
| 72187                            |                  | Cantharellula sp.        | m. i.               |         |                |
| 72204                            | MT252552         | Cantharellus sp.         | X907211             | 0.0     | 96.54          |
| 72241                            |                  | Cantharellus sp.         | m. i.               |         |                |
| 72242                            |                  | Cantharellus sp.         | m. i.               |         |                |
| 72247                            |                  | Cantharellus sp.         | m. i.               |         |                |
Table 3 The list of voucher specimens and the results of DNA barcoding (Continued)

| Voucher no. starting from WA00000 | Accession number | Molecular identification | Best match sequence | E value | Similarity (%) |
|-----------------------------------|------------------|--------------------------|---------------------|---------|----------------|
| 72267                             |                  | *Cantharellus* sp. 2     |                     | m. i.   |                |
| 72262                             | MT252590         | *Clavulina* sp.          |                     | 0.0     | 90.2           |
| 72278                             | MT252597         | *Ganoderma gibbosum*    | UDB013455           | 0.0     | 99.6           |
| 72225                             |                  | *Ganoderma* sp.         |                     | m. i.   |                |
| 72226                             |                  | *Ganoderma* sp.         |                     | m. i.   |                |
| 72227                             |                  | *Ganoderma* sp.         |                     | m. i.   |                |
| 72228                             |                  | *Ganoderma* sp.         |                     | m. i.   |                |
| 72180                             | MT252532         | *Lactifluus pinguis*    | HQ318263            | 0.0     | 98.22          |
| 72261                             | MT252589         | *Lactifluus volmus*     | HQ318269            | 0.0     | 99.83          |
| 72235                             |                  | *Lactifluus/Lactarius* sp. |                     | m. i.   |                |
| 72236                             |                  | *Lactifluus/Lactarius* sp. |                     | m. i.   |                |
| 72192                             | MT252542         | *Lentinula edodes*      | MH444818            | 0.0     | 98.38          |
| 72206                             | MT252553         | *Lentinula edodes*      | MH444818            | 0.0     | 99.54          |
| 72186                             | MT252538         | *Lentinus polychrous*   | KX239770            | 0.0     | 98.54          |
| 72170                             | MT252522         | *Lentinus squarrosulus* | UDB034239           | 0.0     | 99.79          |
| 72210                             | MT252556         | *Lentinus squarrosulus* | UDB034239           | 0.0     | 98.78          |
| 72211                             | MT252557         | *Lentinus squarrosulus* | UDB034239           | 0.0     | 99.79          |
| 72218                             | MT252564         | *Lentinus squarrosulus* | UDB034239           | 0.0     | 98.78          |
| 72196                             |                  | *Lentinus squarrosulus* |                     | m. i.   |                |
| 72198                             |                  | *Lentinus squarrosulus* |                     | m. i.   |                |
| 72219                             | MT252565         | *Leucoagaricus meleagris* | MK412590           | 0.0     | 99.48          |
| 7244                              | MT252576         | *Leucoagaricus* sp.     | KP012716            | 0.0     | 100.0          |
| 72195                             | MT252544         | *Macrocybe gigantea*    | MK024240            | 0.0     | 99.83          |
| 72259                             |                  | *Macrocybe gigantea*    |                     | m. i.   |                |
| 72269                             | MT252593         | *Macrocybe gigantea*    | MK024240            | 0.0     | 99.32          |
| 72222                             |                  | *Phlebopus portentosus* |                     | m. i.   |                |
| 72232                             | MT252572         | *Phlebopus portentosus* | KJ489037            | 0.0     | 100.0          |
| 72224                             | MT252595         | *Pisolithus orientalis* | UDB034465           | 0.0     | 99.56          |
| 72207                             |                  | *Pleurotus aff. feruliginis* |                     | m. i.   |                |
| 72208                             | MT252554         | *Pleurotus eryngii*     | MH517521            | 0.0     | 99.68          |
| 72266                             | MT252591         | *Pleurotus giganteus*   | UDB032675           | 0.0     | 99.63          |
| 72190                             | MT252540         | *Pleurotus pulmonarius* | MN239983            | 0.0     | 100.0          |
| 72257                             | MT252586         | *Pleurotus pulmonarius* | MN239983            | 0.0     | 99.52          |
| 72260                             | MT252588         | *Pleurotus pulmonarius* | MN239983            | 0.0     | 99.84          |
| Voucher no. starting from WA00000 | Accession number | Molecular identification | Best match sequence | E value | Similarity (%) |
|----------------------------------|------------------|--------------------------|---------------------|---------|----------------|
| 72214                            | MT252560         | *Polyporus udus*         | KX851643            | 0.0     | 100.0          |
| 72251                            | MT252580         | *Russula alboareolata*   | AF345247            | 0.0     | 99.59          |
| 72291                            | MT252574         | *Russula delica*         | JN969380            | 0.0     | 97.96          |
| 72194                            | MT252543         | *Russula faustiana*      | KX655858            | 0.0     | 99.5           |
| 72177                            | MT252529         | *Russula integra*        | LC176765            | 0.0     | 99.5           |
| 72178                            | MT252530         | *Russula integra*        | LC176765            | 0.0     | 99.84          |
| 72270                            | MT252594         | *Russula paludosa*       | KU552086            | 0.0     | 97.0           |
| 72197                            |                  | *Russula sp. 1*          | m. i.               |         |                |
| 72176                            | MT252528         | *Russula sp. 2*          | FJ455025            | 0.0     | 94.25          |
| 72198                            | MT252546         | *Russula sp. 2*          | FJ455025            | 0.0     | 94.25          |
| 72200                            | MT252548         | *Russula sp. 3*          | UDB025264           | 0.0     | 99.24          |
| 72210                            | MT252549         | *Russula sp. 4*          | UDB000893           | 0.0     | 90.13          |
| 72221                            | MT252567         | *Russula sp. 5*          | UDB025229           | 0.0     | 96.76          |
| 72248                            | MT252578         | *Russula sp. 6*          | AB854696            | 0.0     | 99.72          |
| 72258                            | MT252587         | *Russula sp. 6*          | AB854696            | 0.0     | 99.7           |
| 72252                            | MT252581         | *Russula sp. 7*          | KY774273            | 0.0     | 94.22          |
| 72254                            | MT252583         | *Russula sp. 8*          | KU141238            | 0.0     | 98.06          |
| 72268                            | MT252592         | *Russula sp. 9*          | JQ991785            | 0.0     | 94.38          |
| 72202                            | MT252550         | *Russula subfoetens*     | KF002757            | 0.0     | 98.3           |
| 72185                            | MT252537         | *Russula virescens*      | UDB033741           | 0.0     | 100.0          |
| 72199                            | MT252547         | *Russula virescens*      | UDB033882           | 0.0     | 99.49          |
| 72203                            | MT252551         | *Russula virescens*      | UDB033882           | 0.0     | 99.4           |
| 72253                            | MT252582         | *Russula virescens*      | UDB033741           | 0.0     | 99.85          |
| 72183                            | MT252535         | *Schizophyllum commune*  | MK910772            | 0.0     | 100.0          |
| 72215                            | MT252561         | *Schizophyllum commune*  | MK910772            | 0.0     | 100.0          |
| 72231                            | MT252571         | *Termitomyces eurrhizus* | HM230658            | 0.0     | 99.14          |
| 72245                            |                  | *Termitomyces eurrhizus* | m. i.               |         |                |
| 72273                            |                  | *Termitomyces eurrhizus* | m. i.               |         |                |
| 72271                            |                  | *Termitomyces fuliginosus* | m. i.              |         |                |
| 72196                            | MT252545         | *Termitomyces heimii*    | MK920156            | 0.0     | 99.4           |
| 72246                            | MT252577         | *Termitomyces microcarpus* | UDB034442         | 0.0     | 100.0          |
| 72264                            |                  | *Termitomyces microcarpus* | m. i.             |         |                |
| 72276                            |                  | *Termitomyces microcarpus* | m. i.             |         |                |
| Voucher no. starting from WA00000 | Accession number | Molecular identification | Best match sequence | E value | Similarity (%) |
|----------------------------------|------------------|--------------------------|---------------------|---------|----------------|
| 72277                            |                  | *Termitomyces microcarpus* |                     |         |                |
| 72179                            | MT252531         | *Termitomyces* sp.       | KX646696            | 0.0     | 99.57          |
| 72184                            | MT252536         | *Termitomyces* sp.       | KX646696            | 0.0     | 99.42          |
| 72188                            | MT252539         | *Termitomyces* sp.       | KX646696            | 0.0     | 99.57          |
| 72223                            | MT252568         | *Termitomyces* sp.       | KX646696            | 0.0     | 99.24          |
| 72229                            |                  | *Termitomyces* sp.       |                     |         |                |
| 72237                            | MT252573         | *Termitomyces* sp.       | KY679707            | 0.0     | 99.61          |
| 72193                            |                  | Unidentified             | No PCR product      |         |                |
| 72213                            | MT252559         | *Volvariella volvacea*   | U15973              | 0.0     | 99.83          |

* m. i. failure to obtain genetic material, morphological identification only
Fig. 4 Selected edible fungi sold in the studied markets. 

- **A. Astraeus odoratus**
- **B. Pisolithus orientalis**
- **C. Calvatia sp.**
- **D-F. Polyporus udus**
- **G. Macrocybe gigantea**
- **H. Clavulina sp.**
- **I. Schizophyllum commune**
- **J. Boletus cf. gertrudiae**
- **K. B. reticulatus**
- **L. Phlebotus portentosus**

Łuczaj et al. Journal of Ethnobiology and Ethnomedicine (2021) 17:6 Page 21 of 27
Fig. 5 Selected edible fungi sold in the studied markets. a. Amanita hemibapha. b. Amanita princeps. c. Amanita sp. d. Lentinus squarrosus. e. L. polychrous. f. Lactarius pinguis. g. L. volemus. h. Termitomyces microcarpus. i. T. eurhizus. j. T. fuliginosus. k. The diversity of Cantharellus spp. l. Termitomyces heimii
Fig. 6 (See legend on next page.)
(predominantly annually and biennials) dominate among currently used wild vegetables. The Mediterranean and many parts of China are examples of such places. However, in more wooded areas with a high level of biodiversity, local populations preserve the knowledge about the edibility of local, indigenous woody plants. This is the case in the Qingling Mountains in Shaanxi, China, where—similarly to Lao PDR—young shoots of many species of local trees and shrubs are used for food [99].

Even though we recorded much higher numbers of wild plants and fungi than in any other previous study from Southeast Asia, we suspect that even more species may still occasionally appear due to the extreme diversity of ingredients used by the population of Lao PDR. We hope this is only the beginning of a more detailed surveillance of Lao markets. This also applies to animals, which, as has been pointed out by Greatorex et al. [72], are a potential epidemiological hazard, as proven by the recent coronavirus epidemic [100].

The ongoing process of modernization of Lao society may bring a decrease in the number of taxa used. In some cases (protected animals), this may be with benefit to nature. In the case of plants and fungi, the taxa for sale are common species originating from rice fields, gardens, and nearby forests, exploited to a level which does not endanger them. Forgetting them may bring large loss to the rich Lao culinary tradition. Fortunately, all the ingredients listed in the Phia Sing’s recipe book of the Lao royal court in Luang Prabang (including all the species of fungi) can still be found in markets, which demonstrate Lao cuisine’s great resistance to change. We did detect some identification mistakes in Phia Sing’s book: the plant listed as mak deed is not Ardisia crispa, but Solanum spirale Roxb., phak tam ling/phak tam nin listed as Melothria heterophylla is actually Coccinia grandis (L.) Voigt.

The large knowledge of forest products in Lao PDR can also serve as a model for tropical organic and permaculture movements, which advocate an increase in the number of food taxa we utilize with a minimal impact on nature [101]. However, this should be done without over-harvesting natural resources. Unfortunately, with the increasing population of Southeast Asia and the culinary popularity of “bush food”, there is a danger that many species will become decimated [100]. Fortunately, our study found that it is mainly common weeds and semi-cultivated common tropical trees that are used as food sources, while the danger of over-harvesting fungi is very unlikely and usually does not impact mushroom populations [102].

We hope that our study will add to the knowledge of edible fungi in SE Asia and help to distinguish them from the toxic taxa. This especially concerns the genus Amanita. There are many cases of fungi poisoning in Lao PDR. The recently published first atlas of Lao fungi [82] aims to help collectors, but many of the photographed taxa are only identified to the genus level and marked with numbers—this shows the vast need to perform mycotaxonomic and ethnomycolological studies in Lao PDR.

The availability of the lists of wild food plants used in particular areas, especially those sold in markets, is very important both on a local and on a global scale. Such research on local food items allows for the recording of traditional products. Their exact taxonomic identification will make further phytochemical and nutritional research easier and enable the characterization of local food culture, which if properly advertised, can highly improve the livelihoods of local populations through international marketing and increasing these products’ prices. The lists of plants used can also help increase existing local efforts to popularize Lao cuisine among tourists online [103] and by a small ethnobotanical market guidebooks [104]. Moreover, it enables the detection of protected species sold in the markets. On a global scale, the inventorying of all wild foods is an important task for developing further strategies for improving the nutrition of the human population and food security [31, 94, 105–108].

Conclusions
The markets of Luang Prabang are very rich in wild edible plants, especially in wild vegetables originating from woody species. The list of fungi sold in them is the longest ever recorded in Asia. The incredible biological diversity we found there has urged us to make similar documentation in other large market towns of Lao PDR.

Authors’ contributions
The first author conceived the study and took part in all the field visits and interviews. KP and VL identified the plants. MP and MK identified the fungi. Other authors took part in some of the interviews and manuscript preparation. The authors read and approved the final version of the paper.

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Availability of data and materials
For voucher specimens, see “Methods” section.

Ethics approval and consent to participate
The research adhered to the local traditions for such research, the Code of Ethics of the International Society of Ethnobiology [109]. Prior oral informed consent was obtained from all study participants. Copies of voucher specimens were transferred to Poland with the Material Transfer Agreement received from the authorities of Lao PDR. The research was carried out in close cooperation with the Ministry of Science and Technology of Lao People’s Democratic Republic and the regional authorities of Luang Prabang.

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

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