

## Research Article

# Distribution and ethnomycological knowledge of wild edible mushrooms in Sabah (Northern Borneo), Malaysia

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## Abstract

Ethnomycological knowledge is a combination of biological resources, cultural and human patterns, in particular collective traditional uses and the importance of fungi in daily life. Despite the large number of ethnic groups in Sabah, the native ethnomycological knowledge of wild edible mushrooms and poisonous mushrooms are poorly documented. This study attempted to document wild edible mushrooms and their ethnomycological uses and practices in the tropical rainforest of Sabah, Borneo. Opportunistic samplings and ethnomycological surveys were made within the indigenous communities of Sabah. Collectively, 50 respondents from four different ethnic communities i.e. Dusun, Kadazan, Orang Sungai, and Bisaya were interviewed. A total of 25 wild mushroom species were documented as edible mushroom for food, and five species for medicinal uses. The highest number of wild edible mushroom collected and reported were of the Pleurotaceae family (five species), followed by Polyporaceae family (three species) and Auriculariaceae family (three species). The results also showed that *Schizophyllum commune* (Kulat Kodop), *Volvariella volvacea* (Kulat Sawit), *Pleurotus* spp., (Cendawan Tiram) *Auricularia* spp., (Kulat Korong) and *Marasmiellus* species were mostly consumed by the indigenous people of Sabah as part of their daily diet. Local names, culinary, and the edibility types were distinct among the different local communities. Elderly indigenous people possess vast knowledge on uses of wild mushrooms compared to the younger generation. Women play an important role in wild mushroom collection and its edibility, uses and practices. The findings from this study showed that ethnomycological knowledge of wild mushroom in Sabah is still lacking and more attention is needed. A study on the ethnomycological aspect in Borneo is a necessity in creating awareness among the public on edible and poisonous mushrooms, and its culinary and medicinal properties.

**Keywords:** Ethnomycology, wild mushrooms, native, ethnic, Sabah, Borneo

## Introduction

Sabah is one of the states in Malaysia and is home to a large number of ethnic groups. Collectively, more than thirty indigenous ethnic groups are associated with different cultures (Ooi, 2004). Ethnic Kadazan-Dusun is the dominant indigenous groups in Sabah (Hans et al., 2008). In the past, they sustained themselves in the forest with wild food and cultivation work to secure their daily diet especially wild mushrooms (Christensen, 2002; Chang & Lee, 2004; Chang et al., 2005; Antons & Logan, 2017). Ethnomycological knowledge is generally held by the older generation across most ethnicities (Alonso-Aguilar et al., 2014). Hence, Sabah is a great platform to collect knowledge on wild mushrooms and their uses in scientific studies.

Wild mushrooms are the natural reservoir of many benefits which are very fundamental to many industrial applications i.e. agriculture, medicine and pharmacy. Countries like China, Japan, India and Thailand have broadly studied their native mushrooms as a sustainable practice and species conservation among local communities. The knowledge on identification of edible and inedible mushrooms is limited in terms of records and there is no systematic documentation available for Malaysian Borneo and Peninsular Malaysia (Chang & Lee, 2004; Abdullah & Rusea, 2009; Lee et al., 2009). There are a few ethnomycological studies of macrofungi in Peninsular Malaysia (Abdullah & Rusea, 2009; Lee et al., 2009), but very sparse information on wild mushroom in Sabah, Borneo (Corner, 1981; Pegler, 1997). Awareness efforts to conserve the genetic resources of wild mushrooms are not well nurtured among local communities in Sabah, Borneo. This dearth of information is probably due to the shortage of adequately trained mycologists or taxonomists (Hyde, 2003), and urbanization and deforestation (Lee et al., 2009). In addition, drastic reduction of endemic fungi population in this region may be happening due to deforestation, climate change and conversion of forests into oil palm plantations has raised trepidation among many local conservation biologists. Higher fungi or larger fungi (Basidiomycota) is not well explored in tropical forests and has always been overlooked compared to plants and animals. Thus, the main aims of this study were (i) to document the wild edible mushrooms in Sabah, and (ii) to determine ethnomycological knowledge (mainly uses and practices) from indigenous communities of Sabah.

## Materials and Methods

### *Study area*

Different forest types (lowland, highland, dipterocarp, primary and secondary forests) and local markets in Sabah were explored in this study. The average temperature at lowlands is 32 °C, and at highlands it is 21 °C. The mean annual rainfall is 250-350 mm, with the rainy season stretching from October to February. Mushroom (fruit bodies) samples were collected at Kinabalu Park, Kundasang (Ranau), Crocker Range Park (Sungoi Kiulu, Tambunan district), Tun Mustapha Park (Bambangan and Banggi islands, Kudat), Tawau Hills Park (Tawau), Kota Belud, Kota Marudu, and Lower Kinabatangan (Sandakan) (Figure 1). We also randomly surveyed the local markets (Kota Belud and Kota Marudu) for wild and domesticated mushroom collections throughout 2015-2017.

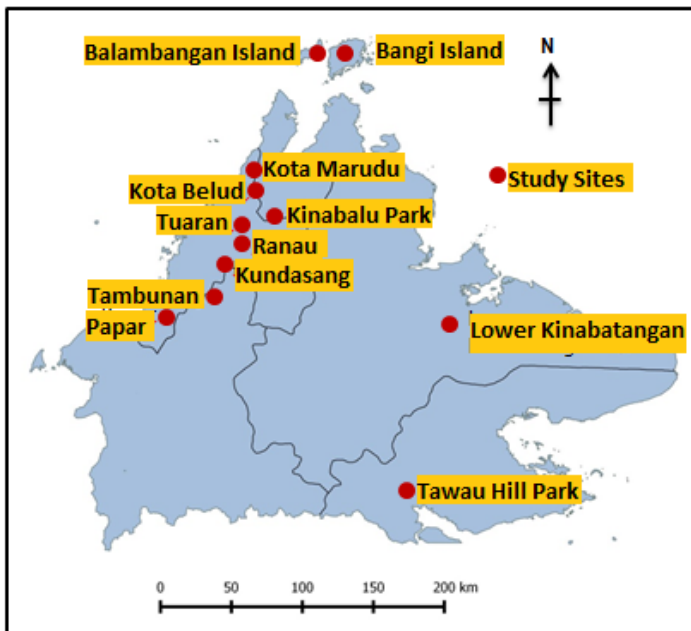


Figure 1. Map of Sabah showing the study sites.

### *Macrofungi collection*

Sampling trips were conducted during the rainy season (August till December each year 2015-2017) (Figure 1). Opportunistic sampling of fruiting body was used for the sample collection of different types of substrates (i.e. soil, twigs, dead wood, living tree trunk). A Global Positioning System (GPS) device was used to record the points or coordinates at which the fruiting bodies were found.

Three to five fruiting bodies of macrofungi were collected for each sample. All collected samples were dried in a mushroom dryer and sealed in paper bags. All dried specimens were deposited in the Herbarium BORNEENSIS, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah (UMS). Each specimen was given a voucher number (i.e. BORH/F 0001).

#### *Morphological identification*

The collections were brought to the laboratory for identification and characterization using standard mycological keys and literature (Pegler, 1983). All macro-morphological characters were described based on fresh material, and documented by photographs. Simple descriptions of the habitat, substrate, physical morphology, and colouration of each specimen were noted. Photographs of the macro-morphological characters of all the specimens were also compiled. Thin sections were cut with a razor blade from dried specimens and mounted on slides with 5% KOH and Congo Red. The mounted slide was observed and measured using a compound microscope (Zeiss Axioskope 40). Colour designations were adapted from Kornerup and Wanscher (1978). Some mushrooms were indicated only as sp. by their taxonomic complexity, such as *Agaricus*, *Auricularia*, *Lignosus* and *Marasmiellus*.

#### *Ethnomycological and local market survey*

Kadazan, Dusun, Orang Sungai and Bisaya communities were randomly found for interview sessions related to ethnomycology of wild mushroom in Sabah. A questionnaire was used in the interview and the questions were specially designed for attaining information on ethnomycological knowledge of wild mushroom (edibility, uses, culinary, identification method). A sample size of 50 respondents was targeted with different ethnic groups (Kadazan, Dusun, Orang Sungai and Bisaya). Interviews with local people (mostly Dusun) were done. Two major groups of respondents were categorized; I) older generation (>45 years old) and II) young generation (<46 years old). Each interview session was aided with photographs of targeted fleshy mushrooms and dried mushroom samples. Vernacular names were also documented and species identifications were mainly based on the morphological characteristics. Local mushroom market surveys were also conducted in Kota Belud and Kota Marudu. The collected information was related to names in the local language (vernacular names) and dialect used among the villagers, and types of wild and domesticated mushrooms sold in local markets. All information was compiled from villagers and farmers or mushroom sellers in the market.

## Results

In total, 50 indigenous respondents (27 females, 23 males) were interviewed (Table 2). The age of respondents ranged from 36 to 81 years old. Of the 50 respondents, 34% were aged >45 years, and 66% were <46 years old. From the entire sample, the Dusun people were the major indigenous group with 29 respondents (58%), while the rest were Kadazan (26%), Orang Sungai (12%) and Bisaya (4%). Two main components of ethnomycological knowledge were reported: distribution of wild edible mushrooms, and ethnomycological knowledge from indigenous people in Sabah.

### *Distribution of wild edible mushrooms at Sabah*

The wild edible mushrooms consumed by the local populations within Sabah belong to two major classes of fungi, Ascomycota and Basidiomycota. A total of 12 families within Basidiomycota and two families within Ascomycota were recorded in this survey. A list of 25 wild edible mushrooms was documented for Sabah (Table 1). The highest number of wild edible mushroom species recorded was of the Pleurotaceae family (*Pleurotus pulmonarius*, *P. giganteus*, *P. tuberregium*, *P. djamor* var. *djamor*, and *P. djamor* var. *roseus*). The second highest number of species recorded was from the Polyporaceae family (*Lentinus sajor-caju*, *L. squarrosulus*, and *Panus lecomtei*). All three species are white rot fungi with distant or crowded lamellae (as in Agaricales). Auriculariaceae family also comprises three species (*Auricularia polythrica*, *Auricularia auricular-judae* and *Auricularia* sp. 1) which are all edible.

Among 25 wild edible mushrooms, only five were reported for medicinal uses. These mushrooms are *Pleurotus tuber-regium*, *Auricularia* sp., *Xylaria* sp., *Lignosus* sp. and *Schizophyllum commune*. The rare species of *Termitomyces eurhizae* (Lyophyllaceae) and *Hygrocybe miniata* (Hygrophoraceae) from lowland forests was found in this study. An edible, *Calostoma insignis* (Calostomataceae) and poisonous *Agaricus pracelaresquamosus* were recorded for the first time at Serinsim lowland forest. Photographs of wild edible mushrooms found in Sabah is shown in Figure 2.

**Table 1.** List of wild edible mushrooms found at Sabah. n.a: Not available; Local name varies for same or different species.

| Family          | Scientific name                     | Local name                                | Dusun names                                | Uses                   | Ecology         |
|-----------------|-------------------------------------|---|--|------------------------|-----------------|
| Polyporaceae    | <i>Lentinus sajor-caju</i>          | Ring mushroom                             | <i>Kulat Lengkugan/ Ungkugan</i>           | Edible only when young | Saprophytic     |
|                 | <i>Lentinus squarrosulus</i>        | <i>Kulat Susu</i> (milky mushroom)        | n.a  | Edible                 | Saprophytic     |
|                 | <i>Panus lecomtei</i>               | <i>Kulat Kari-Kari</i> (Curry Mushroom)   | n.a  | Edible only when young | Saprophytic     |
|                 | <i>Lignosus</i> sp.                 | <i>Cendawan susu harimau</i>              | n.a  | Edible (tuber part)    | Saprophytic     |
| Pleurotaceae    | <i>Pleurotus giganteus</i>          | <i>Kulat perut lembu</i> ,                | <i>Salimmatuwo</i>                         | Edible                 | Saprophytic     |
|                 | <i>Pleurotus tuber-regium</i>       | <i>Kulat Ubi</i> (potato mushroom)        | <i>Dunsul</i>                              | Edible/ medicinal      | Saprophytic     |
|                 | <i>Pleurotus djamor var. djamor</i> | <i>Kulat tiram putih</i>                  | <i>Tombongongong putih/ Tahang ngungut</i> | Edible                 | Saprophytic     |
|                 | <i>Pleurotus djamor var. roseus</i> | <i>Kulat tiram merah</i>                  | <i>Tombongongong merah/ Tahang ngungut</i> | Edible                 | Saprophytic     |
| Auriculariaceae | <i>Auricularia polythrica</i>       | <i>Kulat Telinga kera</i> (monkey ear)    | <i>Korong</i>                              | Edible/medicinal       | Saprophytic     |
|                 | <i>Auricularia</i> sp. 1            | <i>Kulat Telinga Gajah</i> (Elephant ear) | <i>Korong</i>                              | Edible                 | Saprophytic     |
|                 | <i>Auricularia auricular-judae</i>  | <i>Kulat Telinga</i>                      | <i>Korong</i>                              | Edible                 | Saprophytic     |
| Agaricaceae     | <i>Agaricus subrutilescens</i>      | n.a                                       | n.a  | Edible                 | Ectomycorrhizal |
|                 | <i>Agaricus</i> sp. 1               | n.a                                       | n.a  | Edible                 | Ectomycorrhizal |
| Marasmiaceae    | <i>Marasmiellus</i> sp.             | <i>Kulat sawit putih</i>                  | n.a  | Edible                 | Saprophytic     |
|                 | <i>Lentinula edodes</i>             | <i>Kulat Jipun</i> (wild shitake)         |  | Edible                 | Saprophytic     |
| Tremellaceae    | <i>Tremella fuciformis</i>          | <i>Kulat Jeli putih</i> (white jelly)     | n.a  | Edible                 | Saprophytic     |
| Hygrophoraceae  | <i>Hygrocybe miniata</i>            | <i>Kulat Topi</i>                         | n.a  | Edible                 | Ectomycorrhizal |

(Continued on next page)

Table 1. (continued)

| Family           | Scientific name  | Local name  | Dusun names              | Uses                 | Ecology                                   |
|------------------|--|---|--------------------------|----------------------|---|
| Pluteaceae       | <i>Volvariella volvacea</i>                            | Kulat sawit (Paddy Straw mushroom)                              | <i>n.a</i>               | Edible               | Saprophytic                               |
| Schizophyllaceae | <i>Schizophyllum commune</i>                           | Kulat Kodop   | <i>n.a</i>               | Edible/<br>medicinal | Saprophytic                               |
| Lyophyllaceae    | <i>Termitomyces eurhizus</i>                           | Kulat busut (termite mushroom)                                  | Tamburong                | Edible               | Symbiotic-<br>Termites<br>Ectomycorrhizal |
| Cantharellaceae  | <i>Chanterellus cerinoalbus</i>                        | <i>n.a</i>  | <i>n.a</i>               | Edible               | Ectomycorrhizal                           |
| Calostomataceae  | <i>Calostoma insignis</i>                              | Kulat Mata Babi (Pig's eye mushroom)                            | <i>n.a</i>               | Edible               | Ectomycorrhizal                           |
| Sarcoscyphaceae  | <i>Cookeina sulcipes</i><br><i>Cookeina tricholoma</i> | Kulat mangkuk (plate mushroom)<br>Kulat Rambut (Hairy mushroom) | <i>n.a</i><br><i>n.a</i> | Edible<br>Edible     | Saprophytic<br>Saprophytic                |
| Sarcosomataceae  | <i>Galiella rufa</i>                                   | Kulat Mata Rusa (Deer's eye mushroom)                           |                          | Edible               | Saprophytic                               |



Figure 2. Wild edible mushrooms. A. *Panus lecomtei*. B. *Schizophyllum commune*. C. *Termitomyces eurrhizus*. D. *Auricularia* sp. E. *Tramella fuciformis*. F. *Cookeina sulcipe*. G. *Volvariella volvacea*. H. *Auricularia* sp. I. *Marasmiellus* sp. J. *Auricularia* sp. K. *Lentinus sajor-caju*. L. *Pleurotus djamar* var. *djamar*. M. *Pleurotus djamar* var. *roseus*. N-O. *Chanterellus cerinoalbus*. P. *Gaiella rufa*. Q. *Pleurotus giganteus*. R. *Pleurotus tuber-regium*. S. *Calostoma insignis*. T. *Lentinula edodes* (wild Borneo shitake). U. *Pleurotus tuber-regium*. V. *Pleurotus pulmonarius*.



Table 2. Indigenous communities and their ability in identification of wild mushrooms based on gender and age groups.

| Community           | No. of respondents | Age group |     | Gender |        | Ability to identify at least one species of wild mushroom |        |     |     |
|---------------------|--------------------|-----------|-----|--------|--------|---|--------|-----|-----|
|                     |                    | <46       | >45 | Male   | Female | Male  | Female | <46 | >45 |
| <i>Dusun</i>        | 29                 | 11        | 18  | 12     | 17     | 11  | 14     | 11  | 14  |
| <i>Kadazan</i>      | 13                 | 5         | 8   | 7      | 6      | 5   | 6      | 4   | 7   |
| <i>Orang Sungai</i> | 6                  | 1         | 5   | 3      | 3      | 2   | 3      | 1   | 4   |
| <i>Bisaya</i>       | 2                  | 0         | 2   | 1      | 1      | 1   | 1      | 0   | 2   |
| Total               | 50                 | 17        | 33  | 23     | 27     | 19  | 24     | 16  | 27  |

### *Ethnomycological knowledge from indigenous communities*

#### *A) Ethnolycological knowledge of wild mushrooms*

The native communities of Sabah have been collecting wild mushrooms as part of their diet. Majority of the respondents (86%) were able to identify at least one species of wild mushroom, while 14% of the respondents indicated that they are not confident on the edibility of wild mushrooms (Table 2). Female respondents possess slightly more knowledge on wild mushrooms compared to males. A total of 89% female respondents knew at least one species and 82.6% native males knew about wild mushroom. The younger generation mostly knew the most common edible fungi, like *Schizophyllum commune*, which is locally known as 'Kodop'. They were also able to recognise other edible mushrooms, such as *Dunsul (Pleurotus tuber-regium)*, *Korong* (Jelly mushroom), *Kulat Tiram* (oyster mushroom). The knowledge on edible wild mushrooms seems to increase. The older generation (>45 years old) knew of more uses and had culinary use knowledge (81.8% of elderly respondents) compared to younger people. There are 94.1% young people (16 out of 17 young respondents) able to identify only one to two species of common wild mushrooms, but they have no idea on medicinal uses and culinary of wild edible mushroom. The information on culinary and wild mushrooms practices were mostly received from elderly people.

#### *B) Wild mushroom market*

Most of the local farmers are of Kadazan or Dusun origin. Both Malay and the local dialect (Dusun) are used by indigenous communities when speaking about mushrooms. The local farmers only grow and sell domesticated mushrooms such as *Pleurotus ostreatus* (Oyster mushroom, *Kulat Tiram Putih*), *P. pulmonarius* (*Kulat Tiram*), *Lentinula edodes* (*Kulat Jipun* or *Shitake*), *Auricularia auricular-judae* (wood ear, jelly fungi, *Kulat Telinga Kera* or in Dusun known as *Korong*) and *Tremella fuciformis* (jelly fungi) at the local market. All farmers mentioned that these cultivated mushroom substrate bags were supplied by the Rural Development Corporation (KPD), and that these are not native mushrooms (Figure 3A). However, *Schizophyllum commune* (*Kulat Kodop* in Dusun; in Peninsular Malaysia known as *Kulat Sisir*), *Volvariella volvaceae* (*Kulat Sawit*), *Marasimellus* species (*Kulat Sawit Putih*) and *Pleurotus djamor* var. *djamor* (*Kulat Tiram Putih*) which were sold at local market were from wild collections (Figure 3B-G). *Schizophyllum commune* is the only wild edible mushroom that is now popular and commonly seen at all local markets in Sabah.

The indigenous people in Kota Marudu and Kota Belud collect wild edible mushrooms near oil palm plantations. *Volvariella volvaceae* (straw mushroom), *Pleurotus djamor* (*Kulat Tiram*) and *Marasimellus* species (*Kulat Sawit Putih*)

were found on the empty fruit branches of palm kernel. Oil palm plantations are a preferred habitat for these three edible mushroom species (*Volvariella volvacea*, *Pleurotus djamor*, and *Marasmiellus* species). Both *Marasmiellus* sp. is collected together with *Pleurotus djamor* var. *djamor* (known as *Kulat Tiram*). *Termitomyces eurhizus* (Termite-fungus, locally known as *Tamburong*) was also collected from oil palm plantations where most of the area was covered with termite mounts. The plantation workers collect and sell the wild *Termitomyces* occasionally during the rainy season.



**Figure 3.** Local fresh wild mushroom market. A. Commercial edible mushrooms at Kudasang. B-D. Wild edible *Volvariella volvacea*. E. *Pleurotus djamor djamor* and *Marasmiellus* sp. F-G. Wild mushrooms sold at Kota Marudu along the way to Serinsim by roadside.

### C) Wild mushroom culinary and medicinal uses

The Dusun, Kadazan, Bisaya and Orang Sungai consume wild edible mushrooms as part of their daily diet. Indigenous people collect wild mushrooms for culinary purposes within their surroundings and in forest areas. Wild mushrooms are considered as popular culinary items for their flavour, taste and nutrition. There were four methods of culinary preparation using wild edible mushrooms: (1) stir-fry, (2) soup, (3) steam and (4) boil. *Linopot* is a traditional food of the Dusun which contains hill rice wrapped in banana leaves (Figure 4A). The mushrooms are usually prepared with vegetables, sambal, *Kijang* (deer) meat and wild ginger flowers (*Tuhau*) and ginger roots (Figure 4B). Several indigenous respondents from Kota Marudu reported that *Pleurotus djamor* (*Kulat Tiram*) has the best taste and aroma when combined with *Volvariella volvaceae* mushroom. According to the indigenous people, *Volvariella volvacea* (*Kulat Sawit*) is cooked together with young shoots of ferns with garlic and soy sauce.

Local Dusun have been using *Schizophyllum commune* (*Kulat Kodop*) together with *Tuhau* (a local endemic ginger: *Etlingera* species) to produce a floss called “*serunding*”. The delicious floss contains dried *Schizophyllum commune* that is collected from wild forests. Indigenous communities also tend to deep fry *Kulat Kodop* and consume it with sambal sauce. The Dusun communities in Kundasang mostly use *Schizophyllum commune* (*Kulat Kodop*) in porridge mixed together with chicken, squirrel meat and white chillies. In addition, a local Dusun culinary called ‘*Tinamba Linopot*’ is prepared using *S. commune* with chicken, beef meat and wrapped in banana leaves (Figure 4C-D). They also prepare wild mushrooms to serve with curry paste and potatoes and ginger flower during special events or festival (Figure 4E-F). Apart from this, another popular edible mushroom *Termitomyces eurhizus* (*Kulat Temburung*) is usually prepared in soup and together with smoked squirrel meat. *Lentinus sajor-caju* (*Kulat Lengkuhan*) is prepared as soup only when it is young as the taste will become pungent and hard to chew if it is too old. The collective information on culinary preparation using wild edible mushrooms varies among individuals but Dusun people tend to maintain the same ingredients. Thus, the traditional way of culinary preparation of wild mushroom is very scarce among younger generation.

From the findings, Dusun people reported that *Lignosus* sp. (not the same species as *L. rhinocerus*) is used for wound healing and cough treatment. *Xylaria* sp. is used for making a wrist band for health purposes. An elderly man in a village, Patrick (81 years old) mentioned that *Schizophyllum commune* (*Kulat Kodop*), *Auricularia* species (*Kulat Telinga Kera* and *Korong*) and *Pleurotus tuber-regium*

(*Kulat Ubi*) were the common wild edible mushrooms in their soups that are used to treat cold and fever.



**Figure 4.** Indigenous delicacies of wild edible mushrooms in Sabah. **A.** *Linopot* contains hill rice wrapped with banana leaf. **B.** *Pleurotus djamor djamor* fried with barking deer (*kijang*) meat and wild ginger flower (*Bunga Kantan*). **C-D.** *Schizophyllum commune* fried with vegetables and chicken. **E-F.** Wild mushrooms culinary serve at festival or on any auspicious day.

#### *D) Identification criteria for wild mushrooms by indigenous people*

The indigenous people of Sabah have different criteria in determining the edibility of wild mushrooms. Indigenous people reported that the ethnomycological knowledge of edible wild mushroom was transferred from the elderly to the younger generation. They were able to identify and classify the edible and inedible mushrooms based on native culture or vernacular names. Dusun people call the edible mushroom, '*Kawanit*' and poisonous mushroom, '*Akanen*'. Insects are the indicator for identification of edible and inedible wild mushrooms in the forest. A wild mushroom is considered edible if insects are found on the fruiting body of the mushroom. Mushroom colour is an important criterion for the identification of edible mushrooms. Dusun people reported that *Chanterellus cerinoalbus* is a poisonous mushroom due to its strong and bright yellow colour. In addition, the mushroom size is one of the identification criteria

to determine the edible mushroom. In this study, the huge size of *Pleurotus giganteus* (320 mm in diameter of pileus, larger than normal edible mushrooms) was considered as poisonous species by Dusun and Kadazan people.

## Discussion

In Sabah, the basic ethnomycological knowledge is associated with age and gender. Ethnomycological knowledge is differently shared among the different age groups. Knowledge on edible mushrooms is usually transferred from the older generation to the younger generation. Indigenous people living in the rural forest mainly use natural resources to sustain their subsistence (Chang & Lee, 2004; Lee et al., 2009). Traditionally, older generations have vast knowledge on the uses of wild mushrooms. The younger generation only recognize the common edible wild mushrooms species. Currently, most of the younger generation have migrated to cities for job opportunities. Rural area have more forest coverage compared to urban centres. Previous studies have shown that depletion of ethnomycological knowledge may happen when people move to urban areas from rural villages (Boa, 2004; Tibuhwa, 2012).

A majority of elderly people shared that the depletion of wild mushroom distribution is tapering the traditional knowledge on wild mushrooms. Urbanization and land integration are two significant reasons that lead to the instant loss of their native knowledge from one generation to the next (Akpaja et al., 2003; Lee et al. 2009). Traditional knowledge among the indigenous people in Sabah was reported to be decreasing gradually due to change in land use for agriculture and human settlement. Due to the development of human settlements, many indigenous people are not been able to collect wild mushrooms within the surrounding areas.

Most of the culinary uses of wild mushrooms is mostly handled by women. Women tend to have slightly more knowledge on wild edible mushrooms compared to men. They are usually responsible in gathering forest resources, such as wild mushroom for culinary uses and practices in the family. In Sungoi Kiulu, Tambunan women are the most important mushroom collectors to sell mushrooms at the Donggonggon market. This finding concurs with reports from Tibuhwa (2013) and Teke et al. (2018).

In this study, different vernacular names were addressed to the same species by different ethnic groups. The identification methods on wild mushroom vary among the indigenous communities. Indigenous communities attribute the

names of the mushrooms based knowledge of elderly people. The Dusun community call *Pleurotus djamor* as “*Tombongongngong*” while others refer *Pleurotus djamor* with a different local name, “*Tahang ngungut*”. The unity in species identification using vernacular names are not thoroughly the same and this needs to be further studied to avoid any poisonous species consumption by mistake.

The indigenous people from Kota Marudu misidentified *Marasmiellus* species as *Pleurotus djamor* var. *djamor*. They use the same local name for both species. Deadly toxic species, *Trogia venenata* which is also similar as *Pleurotus djamor*, are always mixed together in the same bag that was collected from oil palm plantations due to their Pleurotoid shape. The farmers are not able to distinguish the differences because of the same colour and pleurotoid shape. This was an important observation during the survey and we educated them that both species were not the same. Mushroom poisoning awareness should be delivered to locals so that they could be careful when collecting mushrooms. This will avoid any misidentification and mushroom poisoning cases in Sabah.

The presence of insect or flies, mushroom colour, smell and morphological characters were the main criteria in determining the edible groups. Similar results on these criteria in determining the edible mushrooms have been reported from other studies as well (Kinge et al., 2011; Alvarez et al., 2016). *Lentinula edodes* (Kulat Jipun, locally known as *Shiitake*), is another example of edible mushroom previously (in the early 80s) was not regarded as an edible mushroom until the Japanese market introduced the non-native strains in Malaysia. As for Sabah, local people assumed that when it contains hairy pileus it was not edible. However, in our study we obtained the wild strain of *L. edodes* (local species) with less colouration compared to the Japanese strain. The Dusun people were not aware that locally grown *L. edodes* are also found in Mount Kinabalu, Sabah. The hairy pileus in *L. edodes* suggests that hairy pileus is considered as a morphological criteria in determining whether the mushrooms are edible or poisonous. Thus, local identification based on the morphology is not sufficient enough to verify species level identification.

Based on our findings, it was affirmed that the natives of Sabah are very knowledgeable on wild edible mushrooms and the culinary uses for cooking and medicinal uses. *Schizophyllum commune*, *Volvariella volvacea*, *Pleurotus* species, *Auricularia* species and *Marasmiellus* species were mostly preferred by the indigenous people in Sabah. The culinary uses of various wild mushrooms varied between Kadazan, Dusun, Bisaya, and Orang Sungai communities. They

consumed wild mushroom as a main food and substitute it for meat in their meals. Most people consume mushrooms because of their flavour in replacing meat (Grangeia et al., 2011). Indigenous people imply that several wild mushrooms have a great flavour and taste, and high nutrition benefits. Among the wild edible mushrooms, *Pleurotus*, *Volvariella* and *Lentinus* mushrooms were mostly preferred by the indigenous communities in Sabah.

Regarding medicinal use, the Dusun people reported five wild mushrooms, *Schizophyllum commune* (*Kulat Kodop*), *Auricularia* species (*Kulat Telinga*), *Pleurotus tuber-regium* (*Kulat Ubi*), *Lignosus* sp. and *Xylaria* sp. as having high medicinal properties. The finding was similar to previous studies reported by Mirfar et al., (2014) as *Schizophyllum commune* contain antimicrobial properties against bacteria and fungi, and Sekara et al., (2015): *Auricularia* species have significant therapeutic properties to treat eye and throat infection. Several studies reported that *Pleurotus* species are valuable medicinal mushrooms (Lau et al., 2011; Phan et al., 2012; Wong et al., 2013). As an example, *Pleurotus djamor* var. *roseus* (*Kulat Tiram Merah*) is good in improving health of old people and children according to the Dusun community in this study. A study by Jegadeesh et al. (2014) showed *Pleurotus djamor* var. *roseus* is able to provide beneficial supplements for health. For *Lignosus* species, local people used the tuber part (sclerotia) for health purposes. *Lignosus* species has been recorded r as a high medicinal value mushroom in Lee et al. (2012).

The Dusun communities from Kundasang region tend to frequently use wild edible mushrooms collected from the mountains. It was noted that their families eat mushrooms throughout the year. The common collected wild mushrooms are *Kodop* (*Schizophyllum commune*), *Pleurotus djamor* (*Kulat Tiram Putih* and *Merah*), and *Auricularia auricular-judae* (*Kulat Telinga Kera*). This suggests the existence of a mycophilic culture in these regions which was similar to a study done by Akpaja et al. (2003).

In the Southeast Asia region, a diverse variety of wild mushroom have been found at local markets (Jones et al., 1994) and such a sight is rarely observed in Sabah. The documentation of tree associated mushrooms is well recorded in other regions compared to Borneo, particularly in Sabah, and most of the potential ectomycorrhizal mushrooms have not been studied well. Some of the ectomycorrhizal mushrooms, such as *Boletus* species are edible mushrooms. The dipterocarp trees are known for mutual relationship with ectomycorrhizal fungi (Peay et al., 2009). Borneo has been recorded for its rich diversity of Dipterocarpaceae trees (Slik et al., 2003) compared to Africa and America which



are dominated by the genus *Monotoidae* and *Pakaraimea* (Sasaki, 2008). Thus, extensive work on the cultural and economic potential of wild mushroom by researches needs to be highlighted.

## Conclusion

This study has listed 25 wild edible mushroom species in Sabah. The traditional knowledge of wild edible mushroom was different among local communities (Kadazan, Dusun, Orang Sungai and Bisaya). Different vernacular names were addressed to similar species from different ethnic groups. The older generation are more knowledgeable in the identification, local names, and traditional uses of wild mushrooms in forest. The information of wild mushroom culinary and identification are mainly collected from women compared to men. Indigenous communities in Sabah use wild mushrooms in their daily diet, particularly *Schizophyllum commune*, *Volvariella volvacea*, *Pleurotus* species, *Auricularia* species and *Marasmiellus* species. This study reported that *Schizophyllum commune* (*Kulat Kodop*), *Auricularia* species (*Kulat Telinga*), *Pleurotus tuberregium* (*Kulat Ubi*), *Lignosus* sp. (*Cendawan Susu Harimau*) and *Xylaria* sp. are valuable in health practices. There is a need to further their taxonomic fields for accurate identification, medicinal uses and cultivation basis of wild mushroom in Sabah. The findings of this study perhaps contribute to the knowledge of wild edible mushroom in Borneo and Malaysia. Ethnomycological knowledge has plenty of potential in terms of the conservation and preservation of our local culture and culinary practices related to wild mushrooms in order to encourage the public on the importance of wild strain mushrooms for both the environment and humans.

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## Authors' contributions

FSF and JSSS did sample collection, traditional knowledge data collection, data analysis and interpretation, laboratory work and manuscript writing. FHS and JK contributed in the traditional knowledge data analysis.

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