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REVIEW

Traditional vegetable salad (ulam) of Borneo as source of functional food

[1, 2]Awang-Kanak, F. and [1, 3, *]Abu Bakar, M.F.

[1]*Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia (UTHM), Hub Pendidikan Tinggi Pagoh, KM1, Jalan Panchor, 84600, Muar, Johor, Malaysia*
[2]*Preparatory Centre for Science and Technology, Universiti Malaysia Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, Malaysia*
[3]*Center of Research for Sustainable Uses of Natural Resources, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia (UTHM), Hub Pendidikan Tinggi Pagoh, KM1, Jalan Panchor, 84600, Muar, Johor, Malaysia*

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Abstract

Traditional vegetable salad or "ulam" are shown to have beneficial properties for health maintenance and should be further studied and used as a source of food as well as medicine. Apparently, the fern species are highlighted common plants that have been consumed as traditional vegetable all around Borneo, especially *Stenochlaena palustris* or locally known as "lemiding" (Brunei), "lambiding" (Sabah), "midin" (Sarawak), and "kalakai" (Kalimantan). *Stenochlaena palustris* was also studied for its phenolic contents and antioxidant properties. The extract of the edible young sterile frond of *Stenochlaena palustris* contained more anthocyanins (51.32 mg/100 g dry matter) compared to extracts of mature sterile, young fertile, and mature fertile fronds of the fern. The Penan people also used *Stenochlaena palustris* as herbal medicine to reduce high fever and served it to new mothers during the postpartum recovery period. Other fern species that have been cited used in Borneo are *Diplazium esculentum, Nephrolepis acutifolia*, and *Nephrolepis bisserata*. Fruit of *Solanum torvum*, leaves of *Cosmos caudatus,* the flower buds of *Etlingera* spp., young shoot of bamboo species, and banana inflorescence have been consumed as traditional vegetable in many parts of Borneo, the preparation being either fresh or used as a condiment in cooking. In previous literature also noted that seaweeds namely *Kappahycus alvarezzii* and *Eucheuma denticulatum*, as well as mushrooms like *Termitomyces aurantiacus,* have also been administered as traditional vegetable. It is scientifically shown that traditional vegetable from Borneo have potential as food that could bring health benefit to the consumer, especially in preventing oxidative damage related diseases, microbial infection, and metabolic disorder such as diabetes. Innovation on consumption method of traditional vegetable also suggested, for example, the traditional vegetable be developed into natural food products and food additive, e.g. herbal teas, essential oil.

1. Introduction

Borneo is the largest island with an area of 700,000 sq. m in Sunda Archipelago laid at the 4^0 S to 7^0N of the equator; it is home for one of the largest forested area in South East Asia (Barton and Paz, 2007; Brodie and Giodarno, 2011). It also has a unique geographical setting with altitude mainly below 1000 m, and the northern part of the island has a core with altitude ranging from 1000 m to 2000 m ASL (Barton and Paz, 2007). Politically, Borneo is made up three sovereign countries; Brunei Darussalam, Malaysia, and Indonesia (Hitchner, 2010). Edible vegetable is among products collected from the forest by indigenous people of the island (Hastin *et al*., 2013). Vegetable for consumption are also found cultivated in home gardens and sold in local markets (Kodoh *et al*., 2009; Kamarul *et al*., 2012; Hastin *et al*., 2013; Foo *et al*., 2016; Jualang *et al*., 2016). The significant of vegetable is not just as food sources, but also important for cultures, income generation, and scientific studies (Kodoh *et al*., 2009; Normiadilah and Noriah, 2012; Hastin *et al*., 2013; Wan Izatul, 2013; Solehah and Nasuruddin, 2014). Besides fulfilling nutritional needs, some bioactive compounds in

*Corresponding author.
Email: *fadzelly@uthm.edu.my*

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vegetable are even used as medicinal plants, believed to be effective in preventing and curing illness. For example, polyphenols that can be found in plant-based food are the biggest group of phytochemicals (Tsao, 2010). Intake of polyphenols diet could help prevent many illnesses that are related to free radical damage such as neurodegenerative diseases, cancers, and cardiovascular-related illnesses (Tsao, 2010). The vegetable also served a commercial purpose in generating income, as vegetable can be harvested from the local forest and traded in markets or produce in industrial scale farm for larger markets import (Kodoh *et al*., 2009; Hastin *et al*., 2013; Foo *et al*., 2016).

There is a practice of eating fresh and raw vegetable, and these eaten raw vegetable are called "ulam" (Faridah *et al.*, 2006). "Ulam" is a generic Malay word for freshly eaten plant, and the closest English translation for word "ulam" is salad. It is often coherent with raw, fresh, crunchy, leafy, boiled, steamed, soft textured side dish or appetizer, eaten with a dip made of fish sauce, chilies paste, shrimp paste, or dressing made of lime, salt, and chilies (Normiadilah and Noriah, 2012). Another Malay word that can be used as equivalent to salad is "kerabu". "Kerabu" is a term coined for a type of dish, when prepared with a mixture of many ingredients including lots of vegetable (Normiadilah and Noriah, 2012). The term "ulam" could invoke many definitions, as it is not necessarily fulfilling the botanical definition of herbs, or vegetable, or limited to part of the plant, but rather the usage or how it is administered (Normiadilah and Noriah, 2012). For example, cucumber or *Cucumis sativus* is a fruit, however many have consumed fresh cut cucumber as salad or "ulam", and "rebung" or bamboo shoot (*Bambusa* spp.) is a growing appendage of seed germination, it is commonly eaten as traditional vegetable (Kulip, 1996; Normiadilah and Noriah, 2012). The former fulfilled the basic definition of fruit, which is having seeds wrapped inside watery flesh and peel, meanwhile, the latter fulfilled the basic definition of vegetable, which is producing shoot as a vegetative body for growth, and both are treated as vegetable. The consumption of "ulam" also includes the consumption of edible mushrooms (Wong and Chye, 2009), which belongs to another separate kingdom, Fungi. In Borneo, administering edible mushrooms as vegetable are common among the community whose livelihood surrounded by nature (Chong *et al*., 2007; Abdullah and Rusea, 2009). Initiating question of "what is ulam?" could lead to a tangle of jargons and semantic confusion. Nevertheless, this paper aims to compile the plant, fruits, mushrooms, seaweed, which have been consumed or treated as traditional vegetable or "ulam" in Borneo and discussed the phytochemicals as well as the potential health benefits of the "ulam" as food and medicine.

2. Materials and methods

Google Scholar, Google, ScienceDirect, and using Research Gate portal databases were searched for this review. Studies on traditional salad food, indigenous vegetable, edible mushrooms, and seaweed which were reported from 1997 to 2017 for Borneo were selected and analysed. The keywords used were shuffled combination of "Borneo", "ethnics", "diversity", "ulam", "indigenous vegetable", "Sabah", "Sarawak", "Kalimantan", "Brunei", "ethnobotany", and "sayur". The literature found and used consisted of journals, proceedings, department reports, chapter in book, and thesis. These references are written in English, and some selected publications are in Bahasa Indonesia.

3. Ethnobotany and health benefit of traditional vegetable of Borneo

3.1 The variety of traditional vegetable salad and wild edible plants in Borneo.

There is no exclusive study on traditional vegetable salad or "ulam" of Borneo, in previous efforts, the study of traditional vegetable was often incorporated together in ethnobotany survey, medicinal plant research, phytochemical study, traditional ethnobotanical knowledge (TK) survey, and socio-cultural study. All these fields of research are rather broad and complex. Nevertheless, this work attempted to review "ulam" used in Borneo according to areas, Sabah, Sarawak, Brunei, and Kalimantan.

In Sabah, among the most common local vegetable eaten raw as salad food are, *Carica papaya, Centella asiatica, Clinacanthus nutans, Cosmus caudatus, Etlingera* spp*., Eryngium foetidum, Ipomoea batatas, Kaempfaria galanga, Morinda citriflora, Ocimum tenuiflorum, Peperomia pellucida, Parkia* sp*., Phaleria papuana, and Piper* sp. (Kulip, 1996; Kulip, 2003; Kulip, 2005; Foo *et al*., 2016; Jualang *et al*., 2016). All these plants are easily obtained from local traders in the weekly market and can be found planted in the home garden or cultivated in farmland (Kulip, 2005; Foo *et al*., 2016). A survey conducted among Kadazandusun and Murut communities of Crocker Range Park and surrounding area found that 82% of the respondents are dependent on the forest to collect their supply of wild vegetable, and another 18% collected to sell the wild vegetable in the local market (Noweg *et al*., 2003). The most popular to be collected as vegetable are bamboo shoots, 45.96% from all collected wild vegetable, and they are low herbaceous plants from dry area (19.88%). Young shoots of two bamboo species, locally known as "buluh betung" or *Dendrocalamus asper* and "buluh bukit" or *Bambusa* sp. were consumed raw or briefly

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boiled as salad food. Meanwhile, there were notable species of ferns consumed as vegetable, namely; *Acrosticum aureum, Cyclosorus aridus, Diplazium esculentum, Helminthostachys zeylanica, Nephrolepis acutifolia,* and *Stenochaleana palustris.* Out of these six species, only *Cyclosoru saridus* or locally known as paku and *Nephrolepis acutifolia* or "paku putih", were consumed raw as salad (Noweg *et al*., 2003). The detail of edible fern preparation methods and part used is shown in Table 1.

Other than consuming forest vegetable as ulam, Sabahan also consumed dried seaweed namely; *Kappahycus alvarezzii* and *Eucheuma denticulatum* as salad food (Sade *et al*., 2006; Varaippan and Mikio, 2008). The seaweed cultivation is commonly practiced in the east coastal district of Semporna, Kunak, Lahad Datu, and other districts in the west coast of Sabah, such as Kota Belud, Kudat, and Kota Marudu (Sade *et al*., 2006). Seaweed is believed and proven as nutritional dietary resources, and consisting antioxidant properties (Sade *et al*., 2006; Vairappan and Mikio, 2008; Fisal *et al*., 2012; Ling *et al*., 2014). The demographics of these aforementioned coastal districts are mainly the heartland of Bajau people, Sama-Bajau in the West Coast, and Sea -Bajau or Semporna-Bajau in the East Coast. Thus, the practice of eating raw seaweed is related to the dietary habit of the Bajau, especially Semporna-Bajau who are known historically as the skilful seafaring tribe (Table 1). List of wild edible ferns consumed by Kadazandusun and Murut communities of Crocker Range Park and the surrounding area, in Sabah.

Meanwhile, in Sarawak, ethnobotanical works have been scientifically carried out since 1980s and at the same time, Sarawak Department of Agriculture had been doing substantial and collective research efforts in cultivation and domestication of Sarawak indigenous wild vegetable (Voon and Kueh, 1999; Mertz, 2007). A survey was conducted among Iban of Lubok Antu, Sri Aman on wild vegetable cultivated in farm trial and found five wild vegetable species valued important as local diet and have agronomic and economic value. Two of these wild vegetables are ferns, two gingers, and another one is a member of Acanthaceae family (Metrz, 2007). The list of these selected cultivated wild vegetable by Iban community of Lubok Antu, Sri Aman is as in Table 2. Voon and Kueh (1999) enumerated a total of 46 of indigenous edible wild plants of Sarawak, including leafy vegetable, fruits, shoots, and inflorescent. The study also includes the inventory of Sarawak wild fruits which are known as a source of nutrients by locals and also have the potential for commercialisation. The list of Sarawak indigenous leafy vegetable and fruit vegetable is as presented in Table 3.

A study of the usage of fruits and wild vegetable among Dayak Kenyah community in East Kalimantan found sprout of *Cyperus bancanus* and *Imperata cylindirca* being consumed as "lalapan" or "lalap". "Lalapan" or "lalap" can be generally translated as salad in Bahasa Indonesia (Hendra, 2002). The community also consumed wild ferns as vegetable, namely; *Cyathea contaminans* or "paku tiang", *Diplazium* sp., *Nephrolepis bisserata*, and *Stenochlaena* sp. (Hendra, 2002). Hastin

Table 1. List of wild edible ferns consumed by Kadazandusun and Murut communities of Crocker Range Park and surrounding area, in Sabah.

Family	Scientific name	Recorded local	Part consumed	Preparation method
Athyriacaeae	*Diplazium esculentum*	Pakis	Young shoots, leaves bud	Fried with garlic and anchovies
Blechnaceae	*Stenochlaena palustris*	Lambiding	Young shoots, leaves bud	Fried with garlic, anchovies or shrimp paste
Oleandraceae	**Nephrolepis acutifolia*	Paku putih	Young shoots, leaves bud	Boiled, fried, eaten as salad
Ophioglossaceae	*Helminthostachys zeylanica*	Arukaruk	Young shoots, leaves bud	Cooked, fried with garlic and anchovies
Pteridaceae	*Acrosticum aureum*	Paku besar	Young curled bud, leaves	Fried
Theylypteridaceae	**Cyclosorus aridus*	Paku	Young shoots	Eaten as salad, simmered briefly in boiling water

*Fern species that have been consumed as traditional vegetable salad (ulam) by the community. Adopted from Noweg *et al.* (2003)

Table 2. Selected wild vegetable cultivated in farm plot by Iban in Lubok Antu, Sri Aman, Sarawak.

Family	Scientific name	Recorded local name (Iban)	Part used
Acanthaceae	*Pseuderanthum bornense*	Gelabak	Young/older leaves as spinach
Athyriacaeae	*Diplazium esculentum*	Pakuikan	Young fronds fried or boiled
Blechnaceae	*Stenochlaena palustris*	Kemiding	Young fronds fried or boiled
Zingiberaceae	*Etlingera elatior*	Kechala	Heart of young shoots, flower buds, fruits. Condiment for vegetable
Zingiberaceae	*Etlingera punicea*	Tepus	Heart of young shoots, flower buds, fruits.

Adopted from Mertz (2007)

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Table 3. Sarawak indigenous leafy vegetable and fruit vegetable.

Family	Scientific name	Vernecular name	Part used
Amaranthaceae	*Alternanthera sessilis*	Keremak	Leaves
Arecaceae	*Eleiodoxa conferta*	Asam paya	Fruits
Asteraceae	*Sonchus sp.*	Anak mambung	Leaves
Asteraceae	*Vernonia sp.*	Rinyuh	Leaves
Asteraceae	*Erechtites hieraciifolius*	Sawi Rusa	Leaves
Athyriacaeae	*Diplazium esculentum*	Paku ikan	Leaves, young fronds
Begoniaceae	*Begonia chlorsticia*	Riang batu	Leaves
Blechnaceae	*Stenochlaena plaustris*	Miding	Leaves, young fronds
Blechanceae	*Blechnum orientale*	Paku kelindang	Leaves, young fronds
Costaceae	*Costa speciosus*	Sempulang padi	Leaves
Cucurbitaceae	*Cucumis sativus*	Timun dayak	Fruits
Euphorbiaceae	*Acalypha sp.*	Sepang	Leaves
Euphorbiaceae	*Baccaurea lanceota*	Empang	Fruits
Fabaceae	*Pithecellobium lobatum*	Jering	Beans
Fabaceae	*Parkia javanicus*	Petai	Beans
Flacourtiaceae	*Pangium edule*	Kepayang	Leaves, fruits
Gnetaceae	*Gnetum gnemon*	Melinjau	Leaves, fruits
Gnetaceae	*Gnetum sp.*	Tegang	Leaves
Lythraceae	*Sonneratia caseolaris*	Pedada	Fruits
Menispermaceae	*Pycnarrhena tumetacta*	Tubu	Leaves
Moraceae	*Ficus sp.*	Ara	Fruits
Myrsinaceae	*Embelia sp.*	Kacam rumpang	Leaves
Myrtaceae	*Eugenia sp.*	Bungkang	Leaves
Olacaceae	*Scorodocarpus borneensis*	Sindu	Leaves
Oleandraceae	*Nephrolepis acutifolia*	Paku kubuk	Leaves, young fronds
Ophioglossaceae	*Helminthostachy ssp.*	Tongkat langit	Leaves
Passifloraceae	*Passiflora foetida*	Letup	Leaves
Portulacaceae	*Portulaca oleracea*	Germi	Leaves
Smilacaceae	*Smilax barbata*	Merudang	Leaves
Solanaceae	*Solanum ferox*	Terung bulu	Fruits
Solanaceae	*Solanum lasiocarpum*	Terung dayak	Fruits
Solanaceae	*Solanum torvum*	Terung pipit	Fruits
Urticaceae	*Leucosyke capitellata*	Teh Kampung	Leaves
Verbenaceae	*Premna cordifolia*	Singkil	Leaves
Vitaceae	*Cissus sp.*	Akar kura	Leaves
Vitaceae	*Vitis triloba*	Lakom	Fruits

Adopted from Voon and Kueh (1999).

et al. (2011) had surveyed local vegetable used by Dayak people of Central Kalimantan. They found a total of 42 types of local vegetable consumed by Dayak people, which were prepared as stir-fried dishes, soups, or eaten as lalap. The list of local vegetable from Central Kalimantan is shown in Table 4, fungus is also included in this list. In local name, generic term for fungi is "kulat".

The Dayak of Central Kalimantan's preparation methods for eating wild vegetable varies from stir-fried, light soup, "jahu" or coconut milk added dish, and freshly eaten. Irawan *et al*. (2006) noted, "paria" leaves (*Momordica charantia*) and "senggau" (*Solanum torvum*) are plainly boiled as a "lalap" or salad. These delicacies are often served as side dish, eaten with hot chilies dip and the main dish.

Compare to Sabah, Sarawak, and Kalimantan, Brunei Darussalam has the least documentation or literature available that studied on ulam or wild vegetable. Nevertheless, there was a proximate analysis of *Artocarpus odoratissimus* or "tarap" from Brunei Darussalam by Tang *et al*. (2013). It is also noted that consuming "tarap", which is a fruit tree, is not limited to eating its fleshy aril, the tarap's flower is also used as ingredients in salad or eaten as vegetable (Tang *et al*., 2013). There was also older ethnobotanical work which involved Dusun community in Merimbun village, Tutong, Brunei by Bernstein *et al*. (1997). The plot survey in ethnobotanical work found that the Dusun relied significantly on rice farming, and at the same time they also cultivated fruit trees and vegetable (known as "umbus" or "sancam") in their orchard and gathered wild edible leafy plants from forest, especially ferns. There are five types of ferns consumed among the Dusun of Merimbun; "gerajai", "paku", "limputong", "engkubuk",

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Table 4. List of local vegetable consumed by Dayak people of Central Kalimantan.

Family	Scientific name	Recorded local name (Dayak)	Part used
Alismatacaeae	*Limnocharis flava*	Genjer	Plant body, young leaves
Amarylidaceae	*Crinum asiaticum*	Bakung	Inner trunk
Anacardiaceae	*Spondiaspinnata*	Dawen kedondong	Young leaves
Araceae	*Colocasia esculentum*	Lantar kujang	Young plant
Arecaceae	*Bambusa spinose*	Ujau puring manis/ujau betung	Shoot
Arecaceae	*Calamus sp.*	Singkah/ Rotan	Shoot
Arecaceae	*Cocos nucifera*	Singkah enyuh	Shoot
Arecaceae	*Elaeis guinensis*	Singkah undus	Shoot
Asteracaeae	*Vernonia cinerea*	Segau/Sansawi	Leaves
Asteraceae	*Lactuca indika*	Singkah potok/kenyem	Shoot
Auricauleriaceae	*Auriacaularia auricaula*	Kulat bitak	Main body
Blenachnaceae	*Stenochlaena palustris*	Kalakai	Young leaves
Bromeliaceae	*Ananas comosus*	Kanas	Young fruit
Cucurbitaceae	*Cucumis sativus*	Tantimun batu	Fruit
Cucurbitaceae	*Cucurbita moschata*	Baluh bahenda	Flower, fruit, young leaves.
Cucurbitaceae	*Momordica charantia*	Dawen paria	Young leaves
Cucurbitaceae	*Cucumis sativus*	Dawen mantimun	Young leaves
Cucurbitaceae	*Gymnopetalum sp.*	Kanjat	Young fruit
Dioscoreaceae	*Dioscorea aculeate*	Uwiturus	Tuber
Euphorbiaceae	*Carica papaya*	Mantela	Flower, young fruit, young leaves.
Euphorbiaceae	*Manihot esculenta*	Dawen jawau	Young leaves
Euphorbiaceae	*Cnesmone javanica*	Lampinak/dawen kalamenga	Leaves
Hygrophoraceae	*Hygrocybeconica*	Kulat tiaw	Main body
Leguminosae	*Mimosa pudica*	Uruk mahamen	Young leaves
Liliaceae	*Alliums choenoprasum*	Bawang suna	Bulbs, leaves
Malvaceae	*Abelmochus esculentum*	Jagung Belanda	Fruit
Marattiaceae	*Christensenia aesculifolia*	Teken parei	Young leaves
Musaceae	*Musa paradasiaca*	Pisang	Inflorescence, immature fruit, inner trunk.
Phyllanthaceae	*Sauropus androgynous*	Dawen katuk	Young leaves
Physalacriaceae	*Oudemansiella sp.*	Kulat enyak	Main body
Pleurotaceae	*Pleurotus sp.*	Kulat danum	Main body
Pluteaceae	*Volvariellla volvacea*	Kulat baputi	Main body
Poacaeae	*Cymbopogon citratus*	Sarai	Plant body
Pteridaceae	*Ceratopteris thalictroides*	Bajei	Young leaves
Rubiaceae	*Nauclea sp.*	Dawen taya	Young leaves
Schizophyllaceae	*Schizophyllum commune*	Kulat keritip	Main body
Solanaceae	*Solanum ferox*	Rimbang masem	Fruit
Solanaceae	*Solanum mammosum*	Terung tanteloh	Fruit
Solanaceae	*Solanum torvum*	Senggau/Terung pipit	Fruit
Zingiberaceae	*Curcuma zanthorrhiza*	Kambang herda	Flower

Modified from Hastin *et al.* (2011).

and "kuban" (Bernstein *et al*., 1997). Besides gathering ferns, they also planted some gingers and palm species, namely *Daemonorops fissa, Licuala paludosa*, and *Licuala spinosa* (Bernstein *et al*., 1997).

Other than Dusun tribe, Orang Ulu or Penan is also another minority nomadic hunter-gatherer tribe in southern area of Brunei Darussalam. Their livelihood depends on nomadic hunting and gathering activity, and preparing sago starch from *Eugeissona utilis*, a wild palm, and known as "nangah" by the Penan (Voeks and Sercombe, 2000). The Penan is also involved in barter trading with Dusun in Sukang village, which is in the interior of Brunei (Voeks and Sercombe, 2000). In 2017, Farazimah *et al*. studied total phenolic, total flavonoid contents, and antioxidant activity for eight species of "ulam" from Brunei. Four from eight studied ulam species namely; *Litsea elliptica, Cosmos caudatus, Centella asiatica, Curcuma longa*, have shown good antioxidant activity. Even though there is lack of ethnobotanical documentation on ulam in Brunei Darussalam, the work on natural product chemistry of traditional fruits and vegetable is progressing (Tang *et al.*, 2013; Farazimah *et al*., 2017)

3.2 Similarity of traditional vegetable salad consumed in Borneo

It is apparent that fern species are consumed as traditional vegetable in different parts of Borneo. Even though there is high ethnic diversity in Borneo, fern species are consumed by many indigenous groups such as Kadazandusun and Murut communities in Sabah, Iban people in Sarawak, Dayak in East Kalimantan, and Dusun Merimbun in Brunei Darussalam (Bernstein *et al*.,

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1997; Voon and Kueh, 1999; Hendra, 2002; Noweg *et al*., 2003; Hastin *et al*., 2011). Ferns are known by their generic local names as "paku" or "pakis" (Malay).

Stenochlaena palustris is an all Bornean traditional vegetable; its young reddish fronds are harvested and consumed all over part of Borneo. This fern species is also well spread throughout Southeast Asia region, and known by many local names such as "lambiding", "lemiding", "midin", "kemiding", "kalakai", and "pakis merah" (Noweg *et al.,* 2003; Chai *et al*., 2012). It is believed to have nutritional and antioxidant values (Yim *et al*., 2009). Other than *Stenochlaeana palustris*, *Diplazium esculentum* is also a common edible fern that has been consumed as ulam in many parts of Borneo. Locally, *Diplazium esculentum* is called "paku ikan" or "pakis" (Bernstein *et al*., 1997; Voon and Kueh, 1999; Hendra, 2002; Noweg *et al*., 2003).

Beside ferns, fungi are also consumed as traditional salad or ulam by people of Borneo (Wong and Chye 2008; Abdullah and Rusea 2009; Yim *et al*., 2009). However, the species of edible mushrooms varied and identified as edible mushrooms and are locally known by their generic name as "kulat" or "cendawan" (Malay*). Schizophyllum commune* or "kodop" is a popular edible mushroom in Sabah and is known as "kulat keritip" in Kalimantan, and as "cendawan sisir" in Sarawak (Abdullah and Rusea, 2009; Hastin *et al.,* 2011). Fruit of *Solanum torvum* and leaves of *Momordica charantia* have been treated as traditional vegetable in Kalimantan, Sabah, and Sarawak (Voon and Kueh, 1999; Kulip, 2003; Irawan *et al*., 2006; Hastin *et al*., 2011). Similarity of ulam consumed in Borneo is shown in Table 5.

3.3 Chemical composition, nutritional value, and health benefit potential of selected traditional vegetable of Borneo

Scientific studies have shown that vegetable have nutritional benefits, and some are claimed to have medicinal value. Polyphenols from fruits and vegetable are able to prevent further damage by reactive oxygen species (ROS) (Tsao, 2010). Subsequently, obtaining natural antioxidants from fruits and vegetable could help in lowering risk of having illness caused by oxidative stress (Wen *et al*., 2012; Abu Bakar *et al.*, 2015). The diseases are cardiovascular disease, cancer, diabetes, dementia, and Alzheimer (Faridah *et al*., 2006; Liliwirianis *et al*., 2011; Shirazi *et al.*, 2014). Vegetable

Table 5. Similarity of traditional vegetable or "ulam" consumed in Borneo.

Type	Species name	Recorded local names	Locality	References
Ferns	*Diplazium esculentum*	Paku ikan, pakis	Bn, Kn, Sbh, Swk	Bernstein *et al.* (1997); Voon and Kueh (1999); Hendra (2002); Noweg *et al.* (2003)
	Nephrolepis acutifolia	Paku putih, kubuk, engkubuk	Bn, Sbh, Swk.	Bernstein *et al.* (1997); Voon and Kueh (1999); Hendra (2002); Noweg *et al.* (2003)
	Nephrolepis bisserata	Paku	Bn, Kn, Sbh	Bernstein *et al.* (1997); Hendra (2002); Kulip (2003)
	Stenochlaena palustris	Lemiding, lambiding, midin, kemiding, kalakai	Bn, Kn, Sbh, Swk	Bernstein *et al.* (1997); Voon and Kueh, 1999; Noweg *et al. (*2003); Hastin *et al.* (2011)
Mushrooms	*Auricaularia spp.*	Kulat tepik (Iban), kulat perk (Melanau), kulat bitak (Dayak)	Kn, Swk	Abdullah and Rusea (2009); Hastin *et al.* (2011)
	Cookeinasul cipes	Kulat mangkuk	Sbh, Swk	Abdullah and Rusea (2009)
	Galiella rufa	Mata kerbau, mata rusa	Sbh, Swk	Abdullah and Rusea (2009)
	Hygrocybe spp.	Kulat tiaw, kulat buah	Kn, Swk	Abdullah and Rusea (2009); Hastin *et al.* (2011)
	Schizophyllum commune	Kulat keritip, cendawan sisir, kodop (Dusun)	Kn, Sbh, Swk	Abdullah and Rusea (2009); Hastin *et al.* (2011)
	Termitomyces aurantiacus	Kulat tahun	Sbh, Swk	Abdullah and Rusea (2009)
Fruits	*Solanum torvum*	Terung pipit, terung tanteloh, lintahun (Murut), senggau	Kn, Sbh, Swk	Voon and Kueh (1999); Kulip (2003); Irawan *et al.* (2006); *Hastin et al.* (2011)
Leaves	*Manihot esculenta*	Dawenjawau (Dayak), lui (Murut)	Kn, Sbh	Kulip (2003); Hastin *et al.* (2011)
	Sauropus androgynus	Dawen katuk, Sayur manis	Kn, Sbh	Hastin *et al*. (2011); Muhammed and Muthu, (2015)
Flower buds	*Etlingera elatior*	Kechala (Iban), bungakantan	Sbh, Swk	Voon and Kueh (1999); Ng *et al.* (2012)
	Etlingera punicea	Tepus, tetubuh, tuhau (Dusun)	Sbh, Swk	Voon and Kueh (1999); Noweg *et al.* (2003)

Bn: Brunei Darussalam; Kn: Kalimantan; Sbh: Sabah, Swk: Sarawak

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have also been used as a folk medicine to treat microbial related illness, e.g. malaria, and common fever. These traditional practices by indigenous people on utilizing plant resources to treat diseases have been supported by the discovery of anti-microbial, and anti-inflammatory properties in vegetable (Suhaini *et al*., 2015; Jualang *et al.*, 2016). For example, crude methanolic extract of *Gleichenia truncate*, a type of local fern that has been consuming as traditional vegetable by people in Penampang, Sabah, are reported able to suppress the *in vivo* development of *Plasmodium berghei,* a parasite that causes malaria disease (Suhaini *et al.*, 2015).

In 2017, five species of indigenous leafy vegetable from Bintulu, Sarawak, namely; *Scorodocarpus borneensis*, *Pangium edule*, *Gnetum gnemon*, *Dracaena gracili*s, and *Helminthostachys zeylanica* were selected and analyzed to determine their mineral contents (Asyira *et al.*, 2016). *Pangium edule* is suggested as a good source of calcium since it contains the highest concentration of calcium (466.66 mg/100 g) among the evaluated species. Calcium is an important element that helps regulate nerve and muscle regulation, it is also vital for teeth and bone growth (Soetan *et al.*, 2009). Meanwhile, *Scorodocarpus borneensis* (343.86 mg/100 g) and *Dracaena gracili*s (342.69 mg/100 g) could be the alternative resources of phosphorus for patient with kidney problem. The phosphorus content per 100 g for both species does not exceed the recommended phosphorus intake for chronic kidney patient (<700 mg/ day) (González-Parra *et al.*, 2012; Asyira *et al.*, 2016). However, kidney patients should always consult physician for suitable diet that cater their need and health condition.

Etlingera is a member of ginger family or Zingiberaceae. Several species in *Etlingera* group are known as traditional plants that have been consumed widely in Borneo as fresh vegetable condiment or as pickled side dish. *Etlingera elatior* is known as "kechala" among Iban in Sarawak, or ginger torch or "bunga kantan" (Malay) in Peninsular Malaysia. Extracts of *Etlingera elatior* have been reported to have anti-bacterial and antioxidant activity. Meanwhile, *Etlingera punicea* is known as "tepus" (Iban) in Sarawak or "tuhau" (Dusun), in Sabah. The phytochemical composition and nutritional value of *Etlingera elatior*has been investigated by Ng *et al*. (2012) and found that it contains higher phenolic, flavonoid, and potassium contents than green leafy wild vegetable. Therefore, *Etlingera* is a reliable as antioxidant resource for those who consume it regularly. Crude extracts from rhizome of *Etlingera belalongensis* and *Etlingera velutina* that were collected from Tawau Hills Park, Sabah, displayed cytotoxic activity against MDA-MB-231 cancer cell line (Sabli *et al*., 2012). The total phenolic and total flavonoid content of these Etlingera species as shown in Table 6. In 2012, Vairappan *et al*. reported, essential oil extracted from five species of *Etlingera* collected in Borneo exhibits anti-bacterial activity against four strains of food pathogenic bacteria: *Staphylococcus aureus* (HP0808), *Staphylococcus* sp. (HP1008), *Streptococcus pyrogenes* (HP1208) and *Salmonella enteritidis* (HP0608), and anti-cancer activity against breast cancer cell (MCF-7). Scientific data on the effectiveness of *Etlingera* spp. as a potential source of herbal medicine could be further studied to preclinical and clinical level in order to add more credible value to the species and traditional knowledge from Borneo.

Table 6. Total phenolic and total flavonoid content of *Etlingera belalongensis* and *Etlingera velutina* collected from Tawau Hills Park, Sabah.

Species	Part	Total phenolic (mg GAE/g)	Total flavonoid (mg CE/g)
Etlingera belalongensis	Rhizome	17.07±0.32	3.77±0.15
	Stem	10.07±0.25	2.57±0.15
Etlingera velutina	Rhizome	25.03±0.46	7.63±0.06
	Stem	5.30±0.10	2.80±0.20

Adopted from Sabli *et al.* (2012).

Meanwhile, the fern that is commonly consumed as traditional vegetable and salad in Borneo, *Stenochlaena palustris*, is also utilized for its medicinal benefit. Chai *et al*. (2012) reported the total polyphenol, flavonoid, hydroxycinnamic acid and anthocyanin contents, as well as radical scavenging, ferric reducing and metal chelating activities of the extracts of *Stenochlaena palustris*. It also has potential as a good source of phosphorus and potassium. Relatively, mature sterile frond (51.69±1.28 mg GAE/g) has the highest total polyphenols compare to young sterile frond, young fertile frond, and mature fertile frond. Moreover, mature sterile frond (58.05±0.30 mg CE/g) is also reported to contain higher total flavonoid content than young sterile frond, young fertile frond, and mature fertile frond. Five new *O*-acylated flavonol glycosides have been isolated from *Stenochalaena palustris* leaves collected from Papua New Guinea, and among these compounds are found to have significant anti-bacterial contribution (Liu *et al*., 1999). However, there is a lack of study to further investigate the effectiveness of Bornean *Stenochlaena palustris* extract by using bioassay cell line and *in vivo* animal study. The Penan people in Sarawak have been utilizing this species as a dietary vegetable for new mother during postpartum confinement to regain energy. Meanwhile, the decoction of the leaves is consumed orally, and poultice is rubbed on the head to reduce high fever (Chai *et al.*, 2012). The detail of the total polyphenols content of *Stenochlaena palustris* is as shown in Table 7.

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Table 7. Total contents of polyphenols, flavonoids, hydroxycinnamic acids and anthocyanins of the leaf extracts of *Stenochlaeana palustris* from Sarawak.

Extract	Total polyphenols (mg GAE/g)	Total flavonoids (mg CE/g)	Total hydroxycinnamic acids (mg CE/g)	Total anthocyanins (mg CGE/100 g)
Young sterile frond	42.58±1.01	46.59±0.07	32.24±0.16	51.32±2.95
Mature sterile frond	51.69±1.28	58.05±0.30	48.80±0.18	2.56±0.80
Young fertile frond	41.68±0.19	57.21±0.41	38.93±0.41	2.67±0.77
Mature fertile frond	18.78±0.51	18.95±0.26	15.26±0.12	2.67±0.33

Adopted from Chai *et al.* (2012).

Cosmos caudatus or in Malay is known as "ulam raja", is a well-known traditional vegetable salad in Malay food culture and this species has also been administered and consumed as traditional vegetable in Borneo (Fatimah *et al*., 2012; Liliwirianis *et al*., 2012; Bachok *et al*., 2014; Jualang *et al*., 2016; Farazimah *et al.*, 2017). It is noted that "ulam raja" offers health benefits to the consumers, include providing a protective mechanism against oxidative damage and anti-aging (Fatimah *et al*., 2012; Liliwirianis *et al*., 2012; Farazimah *et al*., 2017). Liliwirianis *et al*. (2012) investigated the phytochemical content of *Cosmos caudatus* and reported that the leaves of the species contain alkaloid, saponin, steroid, phenolic, flavonoid, and terpenoid. The carotenoid compounds found in "ulam raja" are; lutein, β-carotene, and zeaxanthin (Fatimah *et al*., 2012). Moreover, Jualang *et al*. (2016) found that *Cosmos caudatus* (83.09±3.22) has high scavenging performance and comparable to catechin (90.96±1.09%). Ethanolic extract of *Cosmos caudatus* that was obtained from Kota Belud, Sabah, showed activity against P388 murine leukemia cell (Lee and Vairappan, 2011). Safe food product or natural additive could be developed from or using essential oil of *Cosmos caudatus*, this is due to potential of its essential oil against several food pathogens (Lee and Vairappan, 2011). The constituents of essential oils from *Cosmos caudatus* is as described in Table 8.

Table 8. Relative concentration of constituents in *Cosmos caudatus* essential oil collected from Kota Belud, Sabah.

Component	Relative concentration (%)
(*E*)-*Ocimene*	5.64
2,6-Dimethyl-1,3,5,7-octatetraene	4.69
α-Copaene	0.84
β-Elemene	3.3
Caryophyllene	9.73
α-Humulene	2.28
γ-Muurolene	0.75
γ-Cadinene	33.29
Bergamotene	2.92
β-Selinene	0.57
Bicyclogermacrene	3.17
α-Farnesene	6.06
δ-Cadinene	2.02

Adopted from Lee and Vairappan (2011).

The fruit of *Solanum torvum*, or locally known as "terung pipit", "terung tanteloh", "senggau" (Dayak), "lintahun" (Murut) has been consumed as traditional vegetable, condiment in cooking, and as well as eaten fresh. The fruit *of Solanum torvum* contains isoflavonoidsulfate and steroidal glycoside, which are anti-viral agents (Arthan *et al*., 2002). Effective antioxidant properties in the fruit extract also contribute as cardio protective function (Jaiswal, 2012). Steroidal glycoside was also found in the shoot and root of *Solanum torvum* (Yahara *et al*., 1996). However, the record of consumption of shoot and root of this plant by local people in Borneo is not available. Meanwhile, the aqueous extract of the leaves contains anti-inflammatory and pain reducing properties, as the extract was effectively halting unpleasant syndrome induced by acetic acid in rats (Ndebia *et al*., 2007). Other than that, oral administration of methyl caffeate isolated from fruit of *Solanum torvum* had shown dose-dependent anti-hyperglycemic effect through *in vivo* study (Jaiswal, 2012). The Murut people in Sabah, use *Solanum torvum* fruit as a condiment for cooking meat, the Lundayeh, another indigenous people in Sipitang district, Sabah, and Dayak in Kalimantan, consume the fruit fresh (Kulip *et al*., 2000; Kulip, 2003; Hastin *et al*., 2011). These local tribes of Borneo can obtain direct health benefit of the plant through their traditional diet practice.

Clinacanthus nutans is a functional vegetable that locally known in Sabah, as "lindau" (Dusun) or "Sabah Snake Grass" or "belalai gajah" and is called as "dandang gendis" in Indonesia (Lusia *et al.*, 2015). Traditionally, this species has been consumed as vegetable, and serve double functions as traditional medicine, as the fresh leaves could be made into paste or poultice, and use to treat rashes on the skin, insect bite, and snake bite (Lusia *et al*., 2015). Due to its potential as traditional medicine, in 2015, *Clinacanthus nutans* fresh leaves that were collected from Ranau, Sabah, was made into fermented and unfermented tea leaves. These herbal drinks were later investigated for antioxidant assays, and the potential of unfermented tea is higher than fermented tea (reference). The total phenolics content of *Clinacanthus nutans* herbal teas as shown in Table 9. This innovation offers more option on how local vegetable can be consumed, which is not just eaten as

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Table 9. Total phenolics content of Clinacanthus nutans herbal tea, collected from Ranau, Sabah.

Type of *Clinacanthus nutans* herbal tea	Infusion Time	Drying technique	
		Freeze dried (mg TAE/L)	Microwave oven dried (mg TAE/L)
Unfermented	1	132.60±18.57	131.24±8.71
	2	140.08±12.23	143.92±18.76
	5	143.96±14.44	143.56±8.95
	10	162.48±12.58	164.48±14.37
	15	158.48±15.11	146.80±11.7
	20	160.68±5.49	177.80±19.10
Fermented	1	88.56±4.40	101.48±15.79
	2	96.12±15.55	111.2±13.59
	5	105.88±14.74	137.08±18.41
	10	108.72±8.94	136.92±7.43
	15	110.40±7.68	134.52±26.38
	20	114.42±8.31	105.60±16.02

Adopted from Lusia *et al*. (2015)

fresh leaves, but also made into home beverages, and at the same time still maintain the health benefit of the product (Lusia *et al.*, 2015).

Antioxidants are microconstituents present in the diet that could delay or halt lipid oxidation and are also functional in scavenging free radical (Szôllôsi and Varga, 2002). Prevention of lipid oxidation by antioxidant properties could help protect cardiac tissue (Jaiswal, 2012). Many flavonoids such as quercetin, luteolin and catechins are better antioxidants than the antioxidant nutrients like vitamin C, vitamin E and ß-carotene (Zhonghong *et al.,* 1999). Numerous investigators have shown that foods containing phytocompounds with antioxidant potential act as a strong protective agent against chronic illness risks, including cancer and cardiovascular diseases (Osman *et al.,* 2004). Potential of local edible fern species as herbal medicine to treat tropical disease like malaria, could also open more opportunity for other species of edible ferns to be studied for their biomedical benefit (Suhaini *et al.*, 2015). Commonly, these are several highlighted species that have been consumed as traditional vegetable salad in Borneo and scientifically proven as good resources of nutrition, e.g. minerals, carbohydrates, antioxidant with high phenolic and flavonoid contents. In addition, they also indicated beneficial potentials for health as anti-microbial, anti-inflammatory, anti-hyperglycemic, and anti-cancer agents.

4. Conclusion

Despite the ongoing scientific interest on traditional vegetable especially in the exploration for its nutritional, pharmaceutical, and nutraceutical values, there are still many undiscovered parts of Borneo that are not known for the types of traditional vegetable salad or "ulam" consumed by the highly diverse indigenous ethnics. The concrete scientific medicinal values for traditional vegetable salad or "ulam" of Borneo in term of preparation, administration, quality, and safety have yet to be established. A comprehensive research approach on this domestic source of nutrition in Borneo and also how it affects livelihood, agriculture, socio-economy, wellness, and health of the Bornean shall be planned, as well as the establishment of collaboration between academics, research institutions, local authorities, local communities, and pharmaceutical companies. Research strategy must also consider the new technologies in screening, advancement in natural product biotechnology, and use of artificial intelligence in formulating pharmaceutical products. Commercial products by small to medium enterprises (SME) that utilize local traditional vegetable, e.g. herbal tea, herbal supplements, food additive, food flavouring, should be developed by considering effectiveness and safety of the products, sustainability of the selected plant species, the sensory attribute of the vegetable food products, and also access benefit sharing of the profit with the local people as the direct stakeholder of biodiversity in Borneo. All these will put more values on traditional vegetable of Borneo as beneficial biological resources and shall be able to place Borneo as a significant hub for nutraceutical, bioprospecting, and herbal medicine research.

Conflict of interest

The authors declare no conflict of interest.

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