Phytochemical compounds identification of three bajakah species (Salacia sp., Uncaria acida, and Uncaria gambir) using GC-MS pyrolysis

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Abstract. Bajakah is a woody-liana known for traditional medicine by the Dayak and Banjar tribes in Central Kalimantan. Three bajakah, which were identified as Salacia sp., Uncaria acida, and Uncaria gambir, were collected from their natural habitats in peatland hydrological unit of Sebangau–Kahayan rivers. GC-MS pyrolysis was used to analyze the identity of phytochemical compounds in the wood and bark of bajakah. The results showed that phytochemical compounds were varied both in the woods and barks which ranges from 30 to 40 types, with the largest component is phenol. Seven phytochemical compounds were not identified. Phenolic compounds varied among 3-8 types. The next step was determining total flavonoid and phenol content using Folin-Ciocalteu method. Results showed that bark of Uncaria acida has the highest total phenol and flavonoid content, which were 0.013% and 0.028%, respectively. Wood of Salacia sp. has the lowest total phenolic and flavonoid content, which were 0.013% and 0.028%, respectively. The commercial bajakah that are usually sold in the market, which was unidentified, has medium total phenolic and flavonoid content, which are 0.010% and 0.025%, respectively. In summary, the composition and content of phytochemical compounds in bajakah were determined by the species.

1. Introduction
Indonesia has known as a mega-biodiversity country and has wide variety of medicinal plants. Various medicinal plants grow naturally in their habitat, and they have been used by indigenous people as traditional medicine and healing. Dayak tribes in Kalimantan have utilized bajakah as traditional medicine and nutraceuticals [1,2]. Indigenous people recognized that there are two types of bajakah based on color of liquid that comes out from the stem, e.g., white, and red bajakah. In fact, bajakah belongs to various species of more than one genus. Earlier report showed that identification of bajakah must contain complete organs, such as leaves, hooks, and stipules [2].

Traditional people believe that boiled bajakah may be cured cancer, tumors, mioms and cysts [1,2]. Bajakah has been sold in traditional market in Central Kalimantan as ‘jamu’ or raw materials of sliced stems [2]. Three species can be identified as bajakah from the peatland ecosystem of Central Kalimantan, those were the genus of Uncaria and Salacia [2]. In addition, Uncaria nervosa was also reported as bajakah from East Kalimantan [1]. Some studies reported that not all bajakah species can be used to cure tumors and cancer [2]. However, until recently very limited information is available about ethnobotany and pharmacognosy of bajakah lives on peatlands.
The genus of *Uncaria* and *Salacia* have been used as traditional medicine [3,4]. *Uncaria* genus is a member of the Rubiaceae family, contains 55 species and varieties, and 8 species were encountered in Borneo [5]. *Salacia* genus belongs to Celastraceae family and it comprises of 100 species [6]. *Uncaria* has been used as traditional medicine in Peninsular Malaysia as a treatment for wound, ulcer, gastrointestinal illness, fevers, headaches, and bacterial/ fungal infection [7]. A recent in vitro study reported that *U. gambir* has an anticancer activity [8].

There are many methods can be used to identify phytochemical contents of plants. Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS) is one of many ways to quantitatively analyze chemical compound of biomass [9]. Py-GC/MS allows analysis of nonvolatile materials by thermally degrades the sample using controlled and reproducible heat to break macromolecules into smaller, volatile, and more analytically useful fragments that can be separated on a GC column and detect in a MS instrument. As Py-GC/MS decomposes instantly, aggregates of pyrolysates and other side products rarely occur. Thus, chemically unchanged pyrolysates can be examined [10,11]. The resulting chromatogram may provide qualitative information concerning the composition or identity of the sample, quantitative data on its constitution, or it may enable mechanistic and kinetic studies of thermal fragmentation processes [12].

Although some novel compounds of some species of *Uncaria* and *Salacia* have been identified and reported [6, 13-17], however, few studies reported identification of compounds of bajakah using Py-GC/MS. This study aimed to identify the phytochemical compounds of bajakah using Py-GC-MS and to analyze the total phenolic and flavonoid contents of bark and wood of three bajakah species grow naturally on peatlands, namely *Salacia* sp., *Uncaria acida* and *Uncaria gambir*, and unidentified dried bajakah wood sold in a market.

2. Methods

2.1. Study site

Bajakah samples were collected in the Peatland Hydrological Unit (PHU) of Kahayan-Sebangau rivers, in the district of Pulang Pisau, Central Kalimantan. A local people recognized the three species of bajakahs as white and red bajakah. Unidentified dried bajakah wood was also bought in a traditional market of Palangkaraya, Central Kalimantan.

Specimen herbariums were identified in the Herbarium Bogoriense, Bogor. The three bajakahs used as sample are woody lianas. The white bajakah was identified as *Salacia* sp. (belongs to Celastraceae), and two red bajakah were identified as *Uncaria acida* and *Uncaria gambir* (belongs to Rubiaceae). Morphology characters of white bajakah (*Salacia* sp.), and red bajakah (*U. acida* and *U. gambir*) have been shortly described [2].

2.2. Sample preparation

Stems of *Salacia* sp., *U. acida* and *U. gambir* were brought to the laboratory of Silviculture of Forest Research and Development Center in Bogor. Stems of bajakah were washed under running water to remove dirt and other unwanted materials. The barks were pilled-off using knife and separated from its wood. Barks and woods of bajakah were cut into smaller parts and dried under indirect sun light in room temperature. The dry samples were mashed using a grinder machine to produce fine powder and stored in a cool-dry place until further use. The samples were named based on its species, respectively as (1) wood of *Salacia* sp. (DBB), (2) wood of *U. acida* (DBS), (3) wood of *U. gambir* (DBK), (4) wood of unidentified bajakah (DBP), (5) bark of of *Salacia* sp. (KBB), (6) bark of *U. acida* (KBS), and (7) bark of *U. gambir* (KKB), as shown in Figure 1.
Figure 1. Bajakah samples. (a) wood of *U. acida* (DBS), (b) unidentified bajakah from market (DBP), (c) bark of *U. acida* (KBS), (d) simplisia of *Salacia* sp. wood (DBB), (e) simplisia of *U. acida* wood (DBS), (f) simplisia of *U. gambir* wood (DBK), (g) simplisia of unidentified bajakah wood (DBP), (h) simplisia of *Salacia* sp. bark (KBB), and (i) simplisia of *U. acida* bark (KBS).

2.3. Total phenolic contents analysis
Total phenolic contents were measured using Folin-Ciocalteu methods and performed using spectrophotometry UV-Vis (Agilent, type Cary 60 UV-Vis). Half gram (0.5 gram) samples were added with 5 ml of methanol solution 80% (v/v) and sonicated for 20 minutes. 1 ml sample and standard solution of gallic acid was added into a 25 ml volumetric flask containing 9 ml of aquadest. 0.5 ml Folin-Ciocalteu reagent (1:4 v/v) were added into the mixture and shaken. After being left for 5 minutes, the mixture was added with 5 ml of sodium bicarbonate (Na\textsubscript{2}CO\textsubscript{3}) 7% (w/v) and diluted up to the volume of the flask (25 ml) using aquadest [18]. The mixture was incubated for 90 minutes in room temperature, then the absorbance was measured at 765 nm. The concentration of total phenolic content was calculated by comparing the absorbance of the sample and standard used (gallic acid) [18].

2.4. Total flavonoid contents analysis
Total flavonoid contents were determined by using aluminum chloride colorimetric method. Samples (2-4 grams) were extracted beforehand using maceration method for 24 hours with 20 ml of ethanol 80% ethanol (v/v) as diluent. 1 ml of extract were added by 5 ml of 80% ethanol and shaken until homogeneous. The mixture was added with 1 ml of aluminum chloride (AlCl\textsubscript{3}) 5%, shaken and followed by adding 1 ml of potassium acetate (CH\textsubscript{3}COOK) and shaken until homogenous. The absorbance was measured at 432 nm using spectrophotometry UV-Vis.

2.5. Py-GC/MS analysis
Pyrolysis–Gas Chromatography/ Mass Spectrometry (Py-GC/MS) is a method for chemical analysis which used GC column to separate samples into smaller fragment based on its volatility and Mass
Spectrometry to identify the detected compound [10]. For this purpose, a Shimadzu GCMS-QP 2010 was used. In characterization process, the pyrolysis temperature of 400°C was used. The chromatographic separation of the volatile products was performed using a Rtx-5MS Capillary Column (60.0 m x 0.25 mm x 0.25 µm). Before the chromatograph separation, the temperature of the chromatographic column was progressively increased, starting from 50°C for 5 min then increased until 280°C. Helium was used as carrier gas at a constant flow of 0.85 ml/min. 1 mg of each dried solid sample was used for this analysis. Sample was placed in a quartz tube or cell inside a heated chamber or a metal (platinum) coil. This placement maximised heat transfer to the sample. During the pyrolysis, the platinum coil heats the sample up the desired temperature and the carrier gas (helium) transports the vapours to the GC inlet. Because of this pyrolytic technique, sample in their solid form were able to be vaporized then analysed [19]. The decomposition products were identified by means of the comparison between the experimental mass spectrum and the mass spectrum library attached to the Py–GC/MS apparatus. The analysis was done in the laboratory of The Forest Engineering and Forest Products Processing Research and Development Center in Bogor.

3. Results

3.1. Total phenolic and flavonoid contents analysis

Total phenolic and flavonoid contents of the samples are shown in Table 1. Total phenolic and flavonoid contents in the tested sample of the three bajakah are very low. The biggest values of total phenolic and flavonoid compounds are shown by bark of *U. acida*, 0.013% and 0.028%, respectively.

| Species        | Part of stem | Total Phenolic Contents (%) | Total Flavonoid Contents (%) |
|----------------|--------------|----------------------------|------------------------------|
| *Salacia sp.*  | Wood         | 0.0102                     | 0.0246                       |
|                | Bark         | 0.0123                     | 0.0271                       |
| *U. acida*     | Wood         | 0.0127                     | 0.0269                       |
|                | Bark         | 0.0130                     | 0.0280                       |
| *U. gambir*    | Wood         | 0.0118                     | 0.0267                       |
|                | Bark         | 0.0126                     | 0.0275                       |
| Unidentified ‘bajakah’ | Wood | 0.0125                     | 0.0270                       |

3.2. Py-GC/MS Chromatogram Profile

Pyrolysis Gas Chromatography and Mass Spectrometry (Py-GC/MS) was used to analysed component of products in the samples. Spectrums detected was compared to spectrums library. Py-GC/MS analysis showed that the three different species have different phytochemicals compounds, ranging between 30 to 40 compounds, as shown in Figure 2.

Chemical compounds of *U. acida* bark sample is listed in Table 2.
Figure 2. Chromatogram of sample code (a) wood of Salacia sp., (b) wood of U. acida, (c) wood of U. gambir, (d) wood of unidentified bajakah, (e) bark of Salacia sp., (f) bark of U. acida, (g) bark of U. gambir.

Table 2. Chromatogram result of Py-GC/MS analysis on sample barks of Uncaria acida.

| Peak | t_r  | Area (%) | Concentration (%) | Compound                                                                 | Molecular Formula |
|------|------|----------|-------------------|--------------------------------------------------------------------------|-------------------|
| 1    | 4.742| 3.0195   | 3.02              | (O-D) Ethenol                                                            | C_2H_5O           |
| 2    | 5.019| 3.1390   | 3.14              | 2-Hydroxypropionic acid                                                 | C_3H_6O_3         |
| 3    | 5.706| 5.2296   | 5.23              | Acetic acid ethenyl ester (CAS) Vinyl acetate                           | C_4H_6O_2         |
| 4    | 6.575| 3.7583   | 3.76              | Acetic acid (CAS) Ethyl acetate                                         | CH_3COOC_2H_5      |
| 5    | 6.983| 4.7297   | 4.73              | Propanedioic acid (CAS) Malonic acid                                   | C_3H_6O_4         |
| 6    | 7.242| 4.1407   | 4.14              | 1,2-Ethanediamine, N-methyl-                                             | C_4H_8N_2         |
| 7    | 8.926| 1.8791   | 1.88              | Propanedioic acid (CAS) Isobutyl alcohol                                | C_4H_8O_2         |
| 8    | 9.316| 3.0754   | 3.08              | Butanedioic acid (CAS) Succinaldehyde                                  | C_4H_8O_2         |
| 9    | 10.024| 2.2494  | 2.25              | 2-Furancarboxaldehyde (CAS) Furfural                                    | C_4H_8O_2         |
| 10   | 10.69| 0.9227   | 0.92              | 2,4-Pentanediene, 3-methyl- (CAS) 3-Methyl Acetylacetone                | C_5H_10O_2        |
| 11   | 10.867| 1.7695  | 1.77              | 2-Furamethanol (CAS) Furfuryl alcohol                                   | C_5H_10O_2        |
| 12   | 11.417| 0.5358  | 0.54              | 2-Buten-1-ol, 3-methyl- (CAS) Prenol                                     | C_5H_10O         |
| 13   | 12.129| 5.4741   | 5.47              | Cyclohexanone (CAS) Anon                                                | C_6H_10O         |
| 14   | 12.809| 0.7409   | 0.74              | Azocine, octahydro-1-nitroso- (CAS) N-Nitroso Aza Cyclooctane            | C_6H_11N_2O       |
| 15   | 13.117| 0.9673   | 0.97              | Carbamic acid, methyl-, phenyl ester (CAS) Phenyl N-methylcarbamate      | C_6H_9NO_2        |
| 16   | 13.534| 2.1966   | 2.2               | 2-Cyclopenten-1-one, 2-hydroxy-3-methyl- (CAS) Corylon                   | C_6H_10O_2        |
| 17   | 14.025| 3.6221   | 3.62              | Phenol, 2-methoxy- (CAS) Guaiacol                                       | C_6H_10O         |
| 18   | 14.603| 3.4774   | 3.48              | Oxetane, 2-propyl- (CAS) 2-N-Propyl-oxetane                             | C_6H_11O         |
| 19   | 15.176| 3.6598   | 3.66              | 2-Methoxy-4-methylphenol                                               | C_8H_10O_2        |
| No | M.W.    | m/z     | Retention Time | Compound Description                                                                 |
|----|---------|---------|----------------|--------------------------------------------------------------------------------------|
| 20 | 15.569  | 2.4522  | 2.45           | Phosphonic acid, methyl-, bis(trimethylsilyl) ester (CAS) Methylphosphonic acid       |
| 21 | 15.975  | 4.1125  | 4.11           | Benzene, p-di-tert-butoxy- (CAS) 1,4-Di-tert-butoxybenzene                             |
| 22 | 16.227  | 1.4078  | 1.41           | 2-Furancarboxaldehyde, 5-(hydroxymethyl)- (CAS) 5-Hydroxymethylfurfural               |
| 23 | 16.461  | 2.9591  | 2.96           | p-Hydroxyamphetamine                                                                 |
| 24 | 16.782  | 2.2737  | 2.27           | Phenol, 2-methoxy-4-(2-propenyl)- (CAS) Eugenol                                      |
| 25 | 17.192  | 2.1347  | 2.13           | Benzene, p-di-tert-butoxy- (CAS) 1,4-Di-tert-butoxybenzene                             |
| 26 | 17.679  | 3.5204  | 3.52           | Phenol, 2-methoxy-4-(2-propenyl)- (CAS) Eugenol                                      |
| 27 | 18.038  | 3.7404  | 3.74           | 5-Hydroxy-2-decenoic acid-lactone                                                     |
| 28 | 18.668  | 2.1958  | 2.2            | 4-Methyl-2,5-dimethoxybenzaldehyde                                                    |
| 29 | 18.899  | 3.0451  | 3.05           | Unidentified                                                                          |
| 30 | 19.242  | 6.8998  | 6.9            | 1,6-Anhydro-beta-d-glucopyranose (Levoglucom)                                          |
| 31 | 20.142  | 0.7374  | 0.74           | Unidentified                                                                          |
| 32 | 20.367  | 1.7845  | 1.78           | 3-(p-hydroxy-m-methoxyphenyl)-2-propanal                                              |
| 33 | 21.312  | 3.9829  | 3.98           | Hexadecanoic acid (CAS) Palmitic acid                                                |
| 34 | 21.842  | 0.2390  | 0.24           | Octadecanoic acid, 2-propenyl ester (CAS) Allyloctadecanoate                         |
| 35 | 22.067  | 0.5176  | 0.52           | 9-Octadecanoic acid (Z)-, methyl ester (CAS) Methyl oleate                           |
| 36 | 22.58   | 2.5453  | 2.55           | Heptadecene-(8)-carbonic acid-(1)                                                     |
| 37 | 27.379  | 0.1696  | 0.17           | Ethyl linoleate                                                                        |
| 38 | 8.316   | 0.2245  | 0.22           | Cyclohexene, 4-pentyl-1-(4-propylcyclohexyl)                                          |
| 39 | 30.394  | 0.2704  | 0.27           | Unidentified                                                                          |
| 40 | 37.053  | 0.2004  | 0.2            | Spathulenol                                                                            |

4. Discussion

4.1. Total phenolic and flavonoid contents analysis

Simplisia of *U. acida* bark contains the highest total phenolic compounds, which were identified as guaiacol, 2-methoxy-4-methylphenol, and eugenol. Table 3 showed phenolic compounds present on each sample. In Table 3 can be seen that the variation of phenolic compound identified on the samples are similar to each other and eugenol presents in all sample. Eugenol is also called clove oil, which is used to treat toothache and gastrointestinal and respiratory complaint [20,21].
### Table 3. Phenolic compound present in the samples

| Phenolic compounds                      | Salacia sp. wood | U. acida wood | U. acida bark | U. gambir wood | U. gambir bark | wood of bajakah |
|-----------------------------------------|------------------|---------------|---------------|----------------|----------------|----------------|
| Guaiacol                                | v                | v             | v             | v              | v              | v              |
| p-Ethyl guaiacol                        | v                | v             | v             | v              | v              | v              |
| 2-Methoxy-4-methylphenol                | v                | v             | v             | v              | v              | v              |
| 2,6-Dimethoxyphenol                     | v                | v             | v             | v              | v              | v              |
| Eugenol                                 | v                | v             | v             | v              | v              | v              |
| Butylated hydroxy anisole               | v                | v             | v             | v              | v              | v              |
| 4-Allyl-2,6-dimethoxyphenol             | v                | v             | v             | v              | v              | v              |
| 4-Methoxyphenol (HQMME)                 | v                | v             | v             | v              | v              | v              |
| 3-Methylphenol (m-Cresol)               | v                | v             | v             | v              | v              | v              |
| 4-Ethenyl-2-methoxyphenol               | v                | v             | v             | v              | v              | v              |

Flavonoid is a group of phenolic compounds found in natural substances, which is beneficial effect on health, as anti-oxidative, anti-inflammatory, anti-mutagenic, and anti-carcinogenic properties due to its capacity to modulate key cellular enzyme function [22]. The three bajakah species and bajakah from the market contain flavonoids, however, they are not specifically identified.

4.2. Py-GC-MS Chromatogram Profile

The pyrolysis process on woody biomass, all three bajakah species samples produced lignin-based pyrolysates. Lignocellulosic biomass is primarily composed of hemicellulose, cellulose, and lignin. Pyrolysis of the lignin fraction produces useful product, such as phenolic compound as eugenol and 2-Methoxy-4-methylphenol which has potential application as flavors or fragrance. Upon pyrolysis, hemicellulose, and cellulose produce furans, anhydrosugar, such as levoglucosan, and small oxygenated compound, such as acetic acid [19].

The bark of U. acida sample has the highest total phenolic content and total flavonoid content. Table 3 shown the largest content is in compound 30, namely levoglucosan with concentration of 6.9%. Levoglucosan or 1,6-anhydro-beta-d-glucopyranose is formed by pyrolysis of glucans such as cellulose and starch [23].

Compound 2 is also known as lactic acid. Lactic acid can be used in food, chemicals, cosmetics, and pharmaceutical industries. For food purposes, lactic acid is classified as GRAS (Generally Regarded as Safe) according to Food and Drug Administration (FDA) in the USA, usually used in preparation of fermented products, to enhance flavors and to increase shelf life through controlling the growth of pathogenic microorganisms in food. In cosmetics, lactic acid has a role as a pH regulator on the skin therefore it is used to give skin hydration feature in cosmetics. Lactic acid also has skin lightening action due to the repression of the formation of tyrosine. Like its function in cosmetics, in pharmaceutical field lactic acid is used as pH regulator, chiral intermediate, and metal sequestration. Parenteral/I.V. electrolyte fluid and dialysis solution are several examples of pharmaceutical products that uses lactic acid [24].

Prenol or 2-Buten-1-ol, 3-methyl- is approved by The USA FDA [25] as flavoring agent with Flavor Extract Manufactures Association (FEMA) number 3647 and The Joint Expert Committee on Food Additives (JECFA) Flavor number 1200. This compound is found in bark sample of U. acida after 11.4 minutes of elucidation with the concentration of 0.54%.

2-Cyclopenten-1-one, 2-hydroxy-3-methyl- (CAS) Corylon, is also known as Cyclotene (compound 16) can be used as flavoring agents with FEMA number 2700 and JECFA number 418 [26].
Compound 17 is identified as guaiacol with concentration 3.62%. Guaiacol is a phenolic compound used as expectorant [27], antiseptic [28], local anesthetic, pulp sedative in dental practices [29], and approved by The USA FDA as flavoring agent with FEMA number 2532 and JECFA number 713 [30].

Compound 24 and 26 in bark sample of U. acida are identified as eugenol (C10H14O2), present with concentration of 5.79%. Time retention of eugenol is around 17 minutes and present in all samples which are wood of Salacia sp. (4.28%, compound 22), wood of U. acida (5.56%, compound 16 and 17), wood of U. gambir (8.22%, compound 19 and 20), wood of unidentified bajakah (5%, compound 13 and 15), bark of Salacia sp. (4.56%, compound 21), bark of U. gambir (2.99%, compound 25). Eugenol is a phenolic constituent from the class of phenylpropanoids and usually obtained from cloves (Syzygium aromaticum) buds and leaves [31]. As a phenolic compound, it has an antioxidant and free scavenging activity [32]. Eugenol had the inhibitory effect on lipid peroxidation, with an IC50 value of about 80 μM [33]. The mechanism of this inhibitory activity happens in two steps, interference in the chain reactions by trapping the active oxygen and eugenol is metabolized to dimer which inhibits lipid peroxidation [34]. Its antiseptic and analgesic properties is used in dentistry for cement forming as temporary filler of the teeth together with zinc oxide [21]. A study by Leem [35] showed that eugenol is able to suppress the expression of cyclooxygenase II (COX-II) enzyme. Anti-inflammatory effects of eugenol can be used as treatment for arthritis as supplement [36]. Eugenol also shows antibacterial activity on the growth of some species of Gram-positive (Bacillus cereus; Bacillus subtilis; Staphylococcus aureus) and Gram-negative (Escherichia coli; Salmonella typhi; Pseudomonas aeruginosa) [37].

In a review article [21], it was reported that human tumor cell growth inhibitory effect is shown by eugenol compound and its derivateis activity against human tumor cells on DU-145 and KB cell lines by MTT assay, a calorimetric assay for assessing cell metabolic activity. Its anticancer activity is shown due to its inhibitory effect against various types of cancer cell lines. Eugenol has an inhibitory effect on cell proliferation via suppression of NF-kappa B (NF-κB) that plays role in regulation of inflammation, stress responses, immune functions, apoptosis, cell proliferation, cell survival, metastasis, and angiogenesis. Eugenol suppresses the activation of NF-κB, resulting a chemopreventive activity. Its ability to inhibit proliferation is also shown towards melanoma cells. The anticancer activity mechanism of eugenol is also due to induction of apoptosis through Reactive Oxygen Species (ROS) and mitochondria-dependent mechanism and expressed a possibility to develop it as chemotherapeutic or chemopreventive agent [38]. The FDA of the USA has declared eugenol to be safe and considered non-carcinogenic and non-mutagenic. Food and Agriculture Organization (FAO) and World Health Organization (WHO) have specified its permissible uptake limit per day up to 2.5 mg/kg body weight for humans [39].

Compound 40 was identified as spathulenol, a sesquiterpene volatile component usually used as essential oils. Spathulenol, with an immunoinhibitory effect showed a decrease in the proliferation of lymphocytes with an IC (50) of 85.4 ± 11.08 μg/ml [40].

Piperidine is a heterocyclic amine alkaloid which usually present in pepper (Piper nigrum L.) extract. This compound is reported to have several biological activities such as antimicrobial, anti-inflammatory, antiviral, antimalarial, general anesthetic, antidepressant, antioxidant, antiepileptic, antitumor, anticonvulsant, and antihyperlipidemic activities. Its antioxidant activity is due its ability to inhibit free radicals (hydroxy and ROS). Antioxidants plays role to prevent oxidative stress-related diseases such as tumors, inflammation, and beneficial as hepatoprotection, antiplatelet, antihypertension, and antiasthma activities [41]. Piperidine was found in the wood of Salacia sp. sample as 3-methylpiperidine (C6H13N) after 14.5 minutes of elucidation in small concentration (1.55%).

To summarize, all three species of bajakah (Salacia sp, U. acida and U. gambir) and unidentified bajakah that was purchased in the market, contain beneficial phytochemicals properties. Further analysis is needed to determine the biologically beneficial phytochemical compound that can be used as marker compound identification of bajakah. In addition, proper identification of wood bajakah that
are sold in the market is necessary to be undertaken to validate its species and to avoid false bajakah to the customers.

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