MOLECULES AND FUNCTIONS OF ROSEWOOD *Pterocarpus indicus*

by

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Pterocarpus indicus was extracted by three organic solvents: ethanol, ethanol/benzene (1:2), and ethanol/methanol (1:1). The extracts was analyzed by FT-IR, GC-MS, TG, Py-GC-MS, and TDS-GC-MS. Abundant bioactive ingredients in the Pterocarpus indicus extracts included alkanes, phenols, alcohols, esters, carboxylates, alkenes, acids, and aromatic compounds. The main active ingredients was Cinnamaldehyde, (E)-.This study of the chemical composition of Pterocarpus indicus provides a scientific basis for the development and utilization of the plant, with potential applications in the fields of biomedicine, the chemical industry, cosmetics, skin care products, and spices.

Key words: *Pterocarpus indicus, chemical composition, TG, Py-GC-MS, TDS-GC-MS*

Introduction

Rosewood (*Pterocarpus indicus*), a tropical talltree belonging to *Leguminosae*, is widely distributed in Southeast Asia, and is the national tree of the Philippines. Its sapwood is thin, yellow and white, and easily worm-eaten, whereas the thick heartwood is aubergine in color with dark stripes. This wood is fragrant, has a delicate, beautiful texture, and is durable and corrosion-resistant to termites. Its resin can be mixed with lacquer to make high-grade paint material, and its red pigment can be extracted to make a dye. In China, musical instruments, furniture, sculpture, watch boxes, and TV shells are crafted from its valuable timber, in addition to use in railings, parquet flooring, and interior decoration in buildings of quality [1-3].

Extracts of the leaves, wood, bark, roots, and red sap from *Pterocarpus indicus* have antimalarial, antidysenteric, antidiarrheal, astringent, and purgative properties, and are used as mouthwash to treat thrush, and for diuresis, bladder stones, sore throat, and minor wounds [1, 4, 5].

The research of Khanand and Omoloso [6] indicated that the leaves, root, and stem barks of *Pterocarpus indicus* could be partitioned with petrol, dichloromethane, ethyl acetate, butanol, and methanol. All fractions exhibited a wide spectrum of antibacterial activity, which was most pronounced in the butanol and methanol extracts. None were active against mold. A nondialyzable polyphenolic substance having antiplasmin activity was isolated by Takeuchi

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et al. [7] from the bark of *Pterocarpus indicus*, Willd as a brownish powder whose constituents differed from the known coniferous polyflavanols. The substance inhibited plasmin esterolytic activity and also showed a carcinostatic effect on mice bearing ascites Ehrlich carcinoma. Endo and Miyazaki [8] also described the suppressive effect of an acidic polypeptide fraction in the leaf extract on Ehrlich ascites carcinoma in mice. A methanol extract of *Pterocarpus indicus* Willd can inhibit 5α- reductase and alleviate prostatic hyperplasia in the rat [9]. Saponin of *Pterocarpus indicus* can significantly improve the pain threshold of animals by its strong analgesic effect [10].

We obtained extracts of *Pterocarpus indicus* wood powder by using three organic solvents: ethanol, ethanol/benzene, and ethanol/methanol. These extracts were analyzed by FT-IR, TG, GC-MS, pyrolysis GC-MS, and TDS-GC-MS. This revealed compounds of *Pterocarpus indicus* that are widely used in medicine and the chemical industry.

Material and methods

Experimental materials

The samples named B1, B2, and B3 were extracted by ethanol, ethanol/benzene (1:2), and ethanol/methanol (1:1). The residues extracted by the three solvents were named B1-1, B2-2 and B3-3 respectively. The original powder of the sample is named B0.

Experimental methods

Fourier transform infrared spectrometry

The spectra of samples were obtained by FT-IR spectrophotometer (IR100) using KBr wafers containing 1.00% finely ground samples [11-13].

Thermogravimetry

The samples of *Diospyroscelebica* were analyzed by thermogravimetric analyzer (TGA Q50 V20.8 Build 34). The nitrogen release rate was 60 ml/min, and the temperature program for TG started at 30 °C and rose to 250 °C at a rate of 5 °C/min [13-18].

Gas chromatography-mass spectrometry

The GC condition: quartz capillary column was 30 m × 0.25 mm × 0.25 μm, starting at 50 ºC, followed by a rate of 8 ºC/min up to 250 ºC without retention, and then finally at a rate of 5 ºC/min to 300 ºC without retention. The temperature of the inlet was 250 ºC, split ratio was 20:1, and the carrier gas was high helium. The MS condition: The ionization mode is EI, the temperature of ion source is 230 ºC, the temperature of quadrupole is 150 ºC, and the starting point of scanning is 30-600.

Pyrolysis GC-MS

The powder of *Diospyroscelebica* was analyzed by thermal cracking-gas chromatography-mass spectrometry (CDS5200-trace1310 ISQ). The carrier gas used is high purity helium, the pyrolysis temperature is 500 °C, the heating rate is 20 ºC/ms, and the pyrolysis time is 15 seconds. The shunt ratio is 60:1 and the shunt rate is 50 mL/min. The temperature of GC program starts at 40 ºC, rises to 120 ºC at the rate of 5 ºC/min, then rises to 200 ºC at the rate of 10 ºC/min for 15 minutes. The temperature of ion source (EI) is 280 ºC and the scanning range is 28 amu to 500 amu.

Thermal desorption system GC-MS

The TDS: The initial temperature was 30 ºC, reserved for 1 minute, at 10 ºC/min rate rose to 100 ºC, retained for 5 minute, and then 10 ºC/min rate rose to 200 ºC, not retained. The transmission line temperature was 230 ºC [19]. The method of GC-MS is the same as that of GC-MS.

Results and discussion

The FT-IR analysis

The relationship between the infrared spectrum of the organic compound and the functional group of *Pterocarpus indicus* was analyzed. Figure 1 shows the infrared contrast spectra of the *Pterocarpus indicus* and the three extracts.

Infrared spectroscopy, fig. 1, shows a strong and wide absorption peak near 3412 cm^{-1}, indicating O-H stretching vibration. It is an intermolecular association absorption peak [20-22]. At 1058 cm^{-1}, a strong absorption peak indicates the presence of alcohols or phenols compounds, which is consistent with the result of GC-MS [23]. The absorption peak at 2916 cm^{-1} is the stretching vibration of a saturated C-H bond. The absorption peak at 1734 cm^{-1} is attributed to C=O stretching vibration. It is possible to determine the presence of esters compounds. At 1608 cm^{-1} and 1521 cm^{-1}, the absorption peak is carboxylate [4]. The absorption peak at 1480--1300 cm^{-1} is mostly CH_2 and CH_3 bending vibration absorption. The absorption peaks near 1450 cm^{-1} and 1350 cm^{-1} are CH_2 stretching vibration and CH_3 stretching vibration, respectively. The absorption peak is mainly caused by C-C stretching vibration, C-O stretching vibration, and C-H bending vibration at 1300-650 cm^{-1} [24-26]. As can be seen from figs. 1 and 2, the absorption peaks of *Pterocarpus indicus* extract are mainly concentrated in the wave segments of 3700-3000 cm^{-1}, 3000-2800 cm^{-1}, and 1690-970 cm^{-1}.

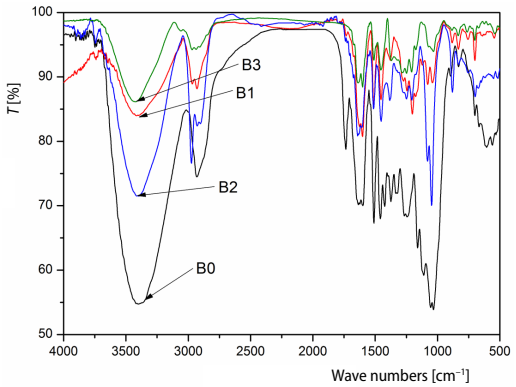

Figure 1. The FT-IR spectra of samples B0, B1, B2, and B3

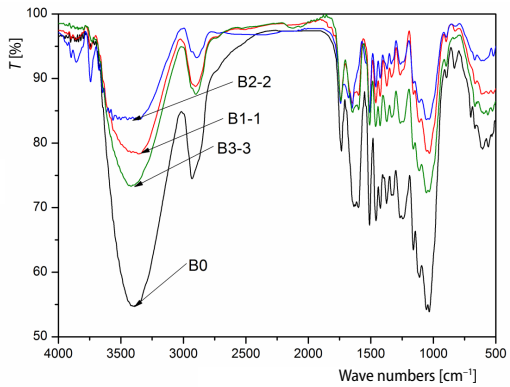

Figure 2. The FT-IR spectra of samples B0, B1-1, B2-2, and B3-3

Thermogravimetric analysis (TGA) and differential thermal analysis (DTG)

The TGA, or change in sample weight of *Pterocarpus indicus,* fig. 3, was used to study thermal stability, which determines flame retardant properties. The $T_{1wt.\%}$, $T_{2wt.\%}$, and $T_{5wt.\%}$ demonstratedweight loss of 1 wt.%, 2 wt.%, and 5 wt.%, respectively. The $T_{1wt.\%}$, $T_{2wt.\%}$, and $T_{5wt.\%}$ are 62 ºC, 78 ºC, and 224 ºC, respectively. The TGA is divided into two stages: the low temperature is mainly water evaporation, while the high temperature between 50-250 ºC is aerobic combustion

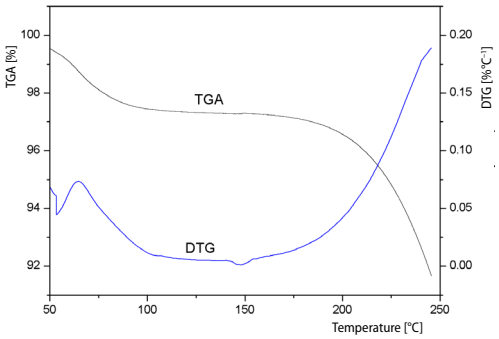

Figure 3. The TGA and DTG thermal curves of *Pterocarpus indicus*

of coke. As seen in fig. 3, the thermal weightlessness of *Pterocarpus indicus* is less, just approximately 8.5%, which indicates that *Pterocarpus indicus* has thermal stability.

Gas chromatography-mass spectrometry

The total ion chromatograms of three kinds of extracts analyzed by GC-MS are shown in figs. 4-6. The identification was performed using a computer and a Wiley7n.1 standard spectrometer, and the peak area normalization method was used to calculate the content of each component.

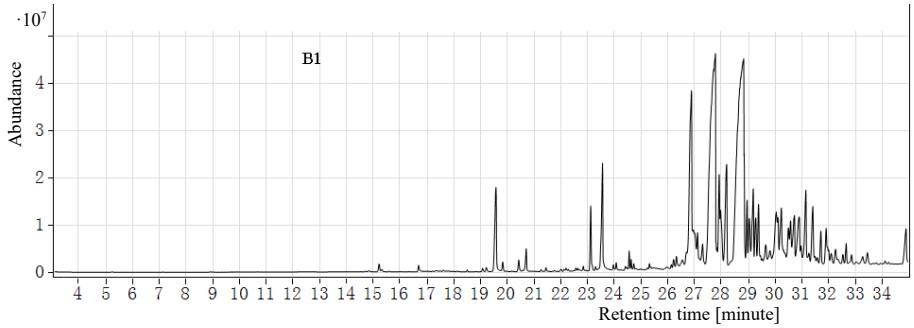

Figure 4. Total ion chromatograms of *Pterocarpus indicus* which were extracted by ethanol

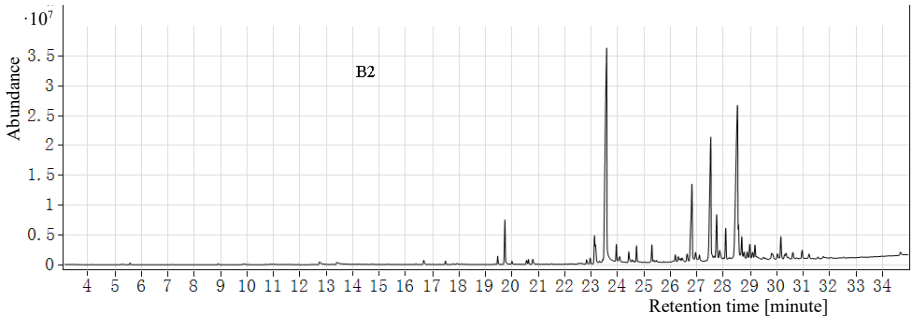

Figure 5. Total ion chromatograms of *Pterocarpus indicus* which were extracted by ethanol/benzene (1:2)

The GC-MS analysis revealed 57 peaks in B1, and the following 12 chemical constituents were identified: 10,11-Dihydro-10-hydroxy-2,3,6-trimethoxydibenz(b,f)oxepin (100%), Phenol, 4-Methyl-2-[5-(2-thienyl)pyrazol-3-yl]- (11.66%), Tricyclo[4.4.0.0(2,7)]dec-8-ene-3-methanol, .alpha.,.alpha.,6,8-tetramethyl-, stereoisomer (11.18%), 10,11-Dihydro-2,3,6-trimethoxydibenz(b,f)oxepin-10-one (8.25%), and 6a,12a-Dihydro-6H-(1,3)dioxolo(5,6)benzofuro(3,2-c)chromen-3-ol (5.47%).

The GC-MS analysisrevealed63 peaks in B2, and the following 17 chemical constituents were identified,: 10,11-Dihydro-10-hydroxy-2,3,6-trimethoxydibenz(b,f)oxepin

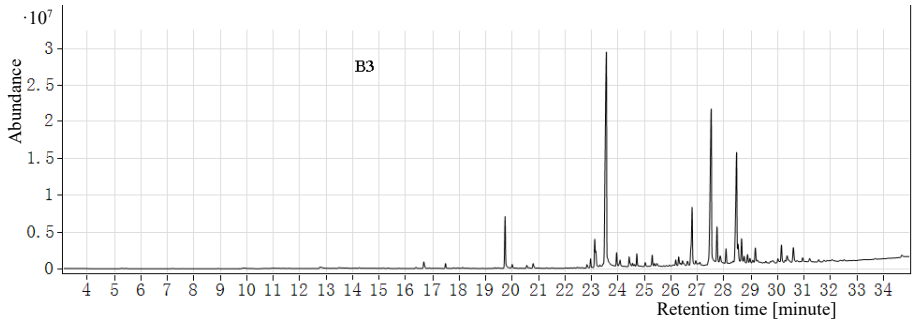

Figure 6. Total ion chromatograms of *Pterocarpus indicus* which were extracted by ethanol/methanol (1:1)

(79.75%), 10,11-Dihydro-10-hydroxy-2,3,6-trimethoxydibenz(b,f)oxepin (7.37%), 4H-1-Benzopyran-4-one, 2-(3,4-dimethoxyphenyl)-7-hydroxy- (7.33%), 10,11-Dihydro-2,3,6-trimethoxydibenz(b,f)oxepin-10-one (4.19%), and 6a,12a-Dihydro-6H-(1,3)dioxolo(5,6)benzofuro(3,2-c)chromen-3-ol (3.86%).

The GC-MS analysis detected 65 peaks in B3, and the following 13 chemical constituents were identified:10,11-Dihydro-10-hydroxy-2,3,6-trimethoxydibenz(b,f)oxepin (45.97%), Tricyclo[4.4.0.0(2,7)]dec-8-ene-3-methanol, .alpha.,.alpha.,6,8-tetramethyl-, stereoisomer (14.7%), and 10,11-Dihydro-10-hydroxy-2,3,6-trimethoxydibenz(b,f)oxepin (6.29%).

Thermal desorption system-GC-MS

As shown in fig. 7, analysis of TDS-GC-MS revealed 33 chemical constituents in 56 peaks of *Pterocarpus indicus* volatiles. The main components are: 1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester (100%), 4-Methoxybenzene-1,2-diol (47.42%), Ethanol, 2-(2-butoxyethoxy)-, acetate (20.12%), Hexadecanoic acid, methyl ester (18.62%), Benzaldehyde (12.64%), m-Guaiacol (10.76%), 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate (7.22%), 1,4-Benzenediol, 2-methoxy- (6.71%), Cinnamaldehyde, (E)- (4.44%), Benzene, 1,2,3-trimethoxy-5-(2-propenyl)- (4.31%), p-Cresol (4.16%), and 1H-3a,7-Methanoazulene, 2,3,4,7,8,8a-hexahydro-3,6,8,8-tetramethyl-, [3R-(3.alpha.,3a.beta.,7.beta.,8a.alpha.)]- (3.85%).

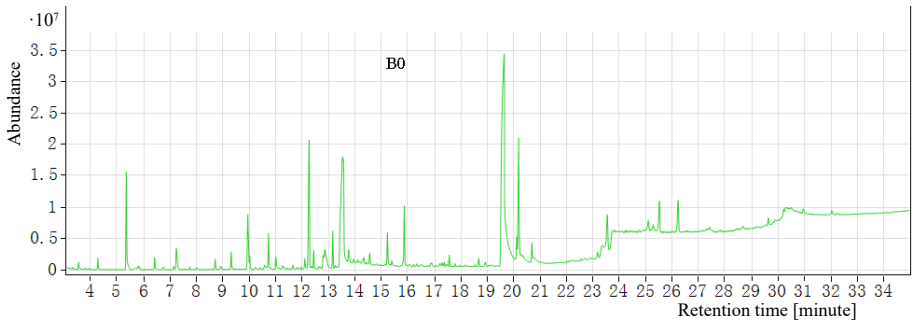

Figure 7. Total ion chromatograms of *Pterocarpus indicus* by TDS-GC-MS

According to the results of the TDS-GC-MS analysis, the main volatile components of *Pterocarpus indicus*are alkanes, phenols, alcohols, esters, alkenes, acids, ketones, and aldehydes.

Pyrolysis-GC-MS

As shown in fig. 8, analysis by Py-GC-MS identified 40 compounds. The peak area accounted for 88.74% of the total peak area, and contained: D-Allose (13.64%), trans-Isoeugenol (5.43%), 2-Methoxy-4-vinylphenol (3.61%), 5,8,11,14-Eicosatetraynoic acid (3.37%), Phenol, 2,6-Dimethoxy- (3.35%), 3',5'-Dimethoxyacetophenone (3.14%), Creosol (2.8%), Furfural (1.61%), Phenol, 4-ethyl-2-methoxy- (0.84%), 2-Cyclopenten-1-one, 2-hydroxy-3-methyl- (0.68%), and Styrene (0.63%).

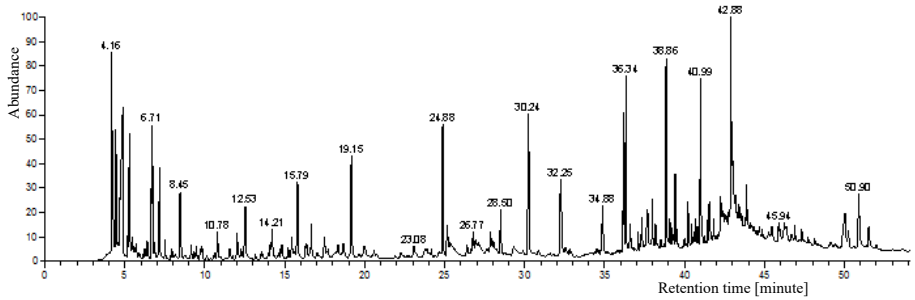

Figure 8. Total ion chromatograms of *Pterocarpus indicus*by Py-GC-MS

Functional analysis

Pterocarpus indicus is a precious wood, mainly used in high-end furniture. Extracts are widely used in the chemical industry, medicine, and for human health. The Py-GC-MS, TDS-GC-MS, and GC-MS techniques, plus review of relevant literature, were used to analyze the components of *Pterocarpus indicus*.

Cinnamaldehyde, (E)- has sterilizing and antiseptic effects, and can be used to treat many diseases caused by bacterial infections. It also has anti-ulcer and other gastrointestinal properties. Because of its fat decomposition effects, it can be used in glycemic control drugs to enhance the performance of insulin replacement glucose and to prevent diabetes. Cinnamaldehyde (E) also suppresses the influenza and SV10 viruses, and has anti-cancer, anti-mutagenic, and anti-radiation effects. Its ability to dilate blood vessels leads to antihypertensive effects, use as a male aphrodisiac, and application in beauty products that promote blood circulation, make the skin return to warm, tighten solid skin tissue, external massage, softening and removal of skin scars and fibroma. In short, Cinnamaldehyde, (E)- is not only used as a crude drug that can be added to all kinds of external drugs and finished drugs, it can further process and synthesize many powerful drugs.

The 1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester and Dibutyl phthalate from the extracts of *Pterocarpus indicus* are mainly used as plasticizer. Ethanol, 2-(2-butoxyethoxy)-, acetate is used to make paints, adhesives, plastics, and paint remover. Hexadecanoic acid, methyl ester, is used as an intermediate of emulsifier, wetting agent, stabilizer and plasticizer, and as a gas chromatography stationary liquid. Benzaldehyde; 2-Methoxy-4-vinylphenol; Creosol; Phenol, 4-ethyl-2-methoxy- and 2-Cyclopenten-1-one, 2-hydroxy-3-methyl- can be used as spices. Benzene, 1,2,3-trimethoxy-5-(2-propenyl)- can be used as an anesthetic. In all, most components of *Pterocarpus indicus* are healthy and abundant, indicating that there are natural health elements.

Conclusions

After extraction of *Pterocarpus indicus* by different solvents, the main FT-IR absorption peaks of the *Pterocarpus indicus* are at 3700-3000 cm^{-1}, 3000-2800 cm^{-1}, and 1690-970 cm^{-1}. The TGA is divided into two stages: predominantly water evaporated at low temperature, while at high temperatures the phase of coke through aerobic combustion occurs. To continue, TGA and DTG tests revealed that at 250 ºC below, the thermal weightlessness of *Pterocarpus indicus* is less, just approximately 8.5%, indicating that the thermal stability is better.

In the GC-MS test, extracts from three different solvent extractions identified more than 55 peaks and contained more than 12 chemical constituents. In the TDS-GC-MS test, *Pterocarpus indicus* volatiles were isolated from the 56 peaks, and 33 compounds were identified. In the Py-GC-MS test, 40 compounds were identified in the *Pterocarpus indicus*.

It can be observed from the above studies that the effective components in *Pterocarpus indicus* are antibacterial, anti-ulcer, anti-virus, anti-cancer, antihypertensive and analgesic. The Cinnamaldehyde, (E)- is widely used in medical, chemical industry and spices. The 1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester and Dibutyl phthalate are mainly used as plasticizer. The Benzaldehyde; 2-Methoxy-4-vinylphenol; Creosol; Phenol, 4-ethyl-2-methoxy- and 2-Cyclopenten-1-one, 2-hydroxy-3-methyl- both have good prospects for application of spices. In summation, most components of *Pterocarpus indicus* are healthy and abundant, indicating that there are natural health elements.

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