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GC–MS explores health care components in the extract of *Pterocarpus Macarocarpus* KurzJuntao Chen ^{a,1}, Shengbo Ge ^{a,1}, Zhenling Liu ^{b,1}, Dangquan Zhang ^b, Wanxi Peng ^{a,*}^a School of Materials Science and Engineering, Central South University of Forestry and Technology, Changsha 410004, China^b University of California Irvine, CA 92697, USA

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ABSTRACT

Pterocarpus is often used to make high-grade furniture, with beneficial health functions on the human body. Therefore, this article with large fruit red sandalwood as an example, to explore its extract on the human body beneficial health care ingredients. FT-IR analysis, in the 2855–3421 cm^{-1} wave segment, ethyl acetate after extraction of large fruit red sandalwood powder infrared transmittance increased the maximum value; GC–MS analysis, large fruit red sandalwood in the human body with a cough and phlegm, detoxification and enhance human immunity and other effects. Among them, Homoptercarpin in the inhibition and killing of cancer cell activity outstanding performance. Cryptomeridiol is a natural product with anti-Alzheimer's disease and antispasmodic properties, with significant medicinal value.

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1. Introduction

Pterocarpus Macarocarpus Kurz mainly grows in Myanmar, Laos and Thailand, belonging to the butterfly-shaped flower *Pterocarpus*, Rosewood mahogany. *Pterocarpus Macarocarpus* Kurz is a deciduous tree species and it has strong adaptability to growth environment, with the litter of the leaves to deal with drought or low temperature growth conditions (Azratul et al., 2017). When the growth environment is appropriate, deciduous period will become shorter and the grain growth rate will increase, Such as *Pterocarpus Macarocarpus* Kurz has straight trunk, branches few in hot and humid summer and it is excellent wood tree species (Francis, 2000).

The application value of *Pterocarpus Macarocarpus* Kurz lies in heartwood. *Pterocarpus Macarocarpus* Kurz heartwood is reddish-brown, texture clear and diverse, moreover it can give people visual enjoyment and psychological pleasure. It is more important

that the *Pterocarpus Macarocarpus* Kurz heartwood has a high density, large hardness and a unique woody flavor (Wisittipanich et al., 2012). Therefore, *Pterocarpus Macarocarpus* Kurz in life commonly used to create high-grade mahogany furniture, sculpture art and musical instruments and so on. Some of the ingredients in the wood aroma can improve the function of the human spleen through the respiratory organs or skin contact, so it play a role in promoting human blood circulation and enhancing the body's immune function (Li et al., 2009; Jalal et al., 2017)). For example, it has an impact on human behavior that essential oil extracted and concentrated in the mahogany wood volatilize gases, stimulating the brain through the olfactory nerve. These effects include regulating human emotions, enhancing physical strength, improving memory and so on. Therefore, the compounds or functional groups before and after extraction of three kinds of extractants were analyzed by FT-IR spectroscopy. The active molecules of the three extracts are analyzed by GC–MS to further explore the health function of the *Pterocarpus Macarocarpus* Kurz.

2. Materials and method

2.1. Materials

Pterocarpus Macarocarpus Kurz that used Experiments produced and exported in Myanmar. *Pterocarpus Macarocarpus* Kurz must be crushed, and then the powder is dried. The methanol, ethyl acetate,

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ethanol/benzene used in the experiment are the chromatographically pure. Quantitative filter paper should be extracted with ethanol/benzene (1:1 by volume) solution for 12 h. The three extractants used in the experiment were methanol, ethyl acetate and 1:1 volume ratio of ethanol/benzene solution.

2.2. Experimental methods

2.2.1. Extraction process

After drying process, the *Pterocarpus Macrocarpus Kurz* powder weigh 3 parts and the quality of 15 g respectively (accuracy of 1.0 mg). They were placed in three round bottom flasks with solid mass/liquid volume = 1:20. Next 300 ml of methanol, ethyl acetate and ethanol/benzene solution (1:1 by volume) were added and then refluxed at 65 °C to 80 °C for 6 h. The obtained extract was subjected to suction filtration on a circulating water type vacuum pump using a quantitative filter paper subjected to an ethanol/benzene extraction treatment for 12 h. Finally, the extract that obtained by suction filtration was steam-concentrated by a rotary evaporator.

2.2.2. FT-IR analysis

The powder of the *Pterocarpus Macrocarpus Kurz* and the powder after the reflux of the three kinds of extracts were subjected to FT-IR detection (Thermo Fisher Nicolet, 670FT-IR). Scanning of each powder was collected at a spectral resolution of 4 cm^{-1} and the spectral range was 400–4000 cm^{-1} .

2.2.3. GC-MS analysis

The extracts obtained from the three extractants were analyzed using a gas chromatography-mass spectrometer (Agilent GC-MS 7890B 5977). Elastic quartz capillary column DB-5MS (30 m \times 250 μm \times 0.25 μm). The carrier gas used was high purity helium and the constant flow rate of helium was 1 mL/min. Split injection ratio was 20:1. The temperature of the GC started at 50 °C, raised to 170 °C at a rate of 20 °C/min for 3 min and then raised to 200 °C at 5 °C/min for 5 min and then to 280 °C at 10 °C/min for 20 min. MS program scanned quality range of 30–600 amu, ionization voltage of 70 eV, ionization current of 150 μA (EI). The ion source and the quadrupole temperature were set at 230 °C and 150 °C respectively.

3. Results and discussion

3.1. The changes in functional groups after extraction

As shown in Figs. 1–3, there is a comparison of the infrared spectra of *Pterocarpus Macrocarpus Kurz* powder and *Pterocarpus Macrocarpus Kurz* powder refluxed with methanol, ethyl acetate and ethanol/benzene solution. The infrared spectra of 3421 cm^{-1} , 3415 cm^{-1} and 3405 cm^{-1} are phenolic compounds, acid compounds and alcohol compounds in the –OH stretching vibration (Li et al., 2015; Noor and Ashraf, 2017). The infrared spectrum of 2924 cm^{-1} , 2855 cm^{-1} , 1462 cm^{-1} , 1458 cm^{-1} , 1382 cm^{-1} , 1386 cm^{-1} are the stretching vibration of methylene and methyl (Lu et al., 2005). The infrared spectra of 1600 cm^{-1} , 1510 cm^{-1} and 1330 cm^{-1} are the peak band of co-phenolic compounds (Rezaee et al., 2006; Thaldiri et al., 2017). The absorption peak at 1270 cm^{-1} is the G-ring telescopic vibration, the carbon-oxygen double bond stretching vibration (Paganelli et al., 1991); The infrared spectrum of 1220 cm^{-1} , 1125 cm^{-1} , 1030 cm^{-1} and 878 cm^{-1} is O–C–O–CHCH₂– on the carbon-oxygen single bond stretching vibration, C–C single bond stretching vibration, aromatic compounds deformation bending vibration of carbon–hydrogen of aromatic compounds bonds on a certain plane, the β -bond

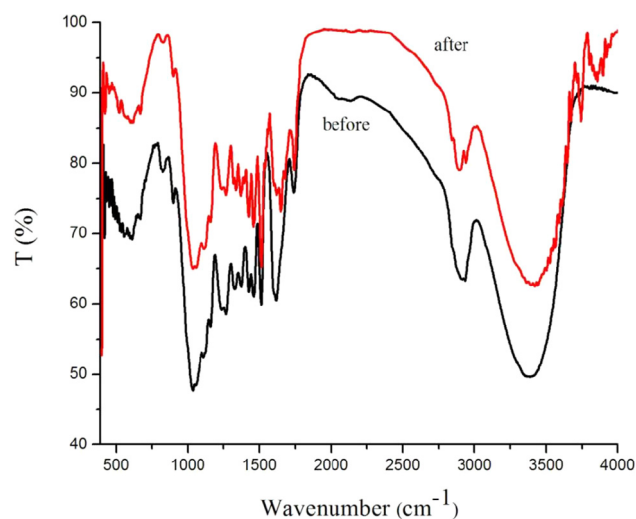


Fig. 1. FT-IR spectrums of *Pterocarpus macrocarpus Kurz* before and after methanol extraction.

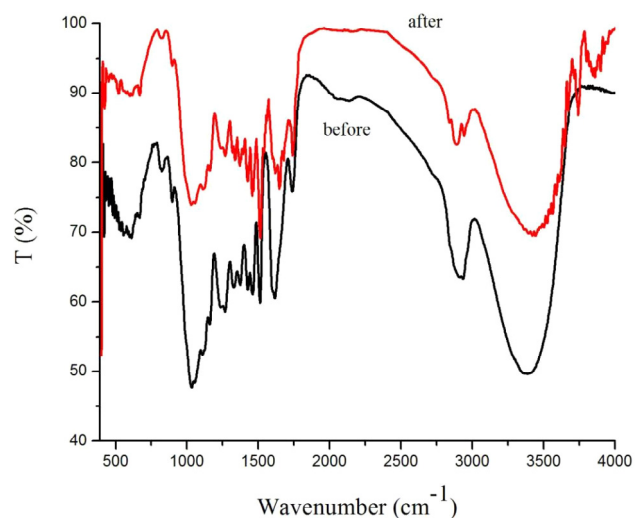


Fig. 2. FT-IR spectrums of *Pterocarpus macrocarpus Kurz* before and after Ethyl acetate extraction.

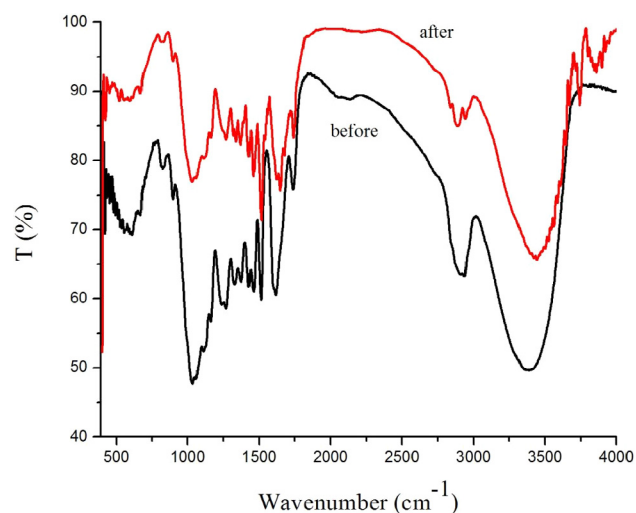


Fig. 3. FT-IR spectrums of *Pterocarpus macrocarpus Kurz* before and after Ethanol/benzene solution extraction.

absorption vibration of the cellulose-based compound (Evans et al., 2009, Dekkers et al., 2010).

In Fig. 1, we can see the change of the peak transmittance of the Pterocarpus Macrocarpus Kurz by methanol was as follows: the infrared transmittance increases from 50.3% to 62.6% at 3421 cm^{-1} , 3415 cm^{-1} and 3405 cm^{-1} . The infrared transmittance increased from 63.6% to 79.4% at 2924 cm^{-1} and 2855 cm^{-1} . The infrared transmittance increased from 62.6% to 73.2% at 1462 cm^{-1} , 1458 cm^{-1} , 1382 cm^{-1} , 1386 cm^{-1} . The infrared transmittance increased from 80.5% to 86.7%, 60.3% to 65.8%, and 64.2% to 80.1% at 1600 cm^{-1} , 1510 cm^{-1} , 1330 cm^{-1} respectively. The infrared transmittance increased from 59.4% to 75.7%, 60.3% to 76.5%, 79.6% to 97.7% at 1270 cm^{-1} , 1220 cm^{-1} , 875 cm^{-1} respectively. The infrared transmittance increased from 47.8% to 65.6% at 1125 cm^{-1} , 1030 cm^{-1} respectively.

In Fig. 2, we can see the change of the peak transmittance of the Pterocarpus Macrocarpus Kurz by Ethyl acetate was as follows: The infrared transmittance increased from 50.3% to 70.6% at 3421 cm^{-1} , 3415 cm^{-1} and 3405 cm^{-1} . The infrared transmittance increased from 63.6% to 83.5% at 2924 cm^{-1} and 2855 cm^{-1} . The infrared transmittance increased from 62.6% to 75.2% at 1462 cm^{-1} , 1458 cm^{-1} , 1382 cm^{-1} , 1386 cm^{-1} . The infrared transmittance increased from 80.5% to 90.2%, 60.3% to 68.4%, and 64.2% to 84.7% at 1600 cm^{-1} , 1510 cm^{-1} , 1330 cm^{-1} respectively. The infrared transmittance increased from 59.4% to 82.5%, 60.3% to 83.5%, and 79.6% to 98.5% at 1270 cm^{-1} , 1220 cm^{-1} , 875 cm^{-1} respectively. The infrared transmittance increased from 47.8% to 74.3% at 1125 cm^{-1} , 1030 cm^{-1} .

In Fig. 3, we can see the change of the peak transmittance of the Pterocarpus Macrocarpus Kurz by Ethanol/Benzene was as follows: The infrared transmittance increased from 50.3% to 66.7% at 3421 cm^{-1} , 3415 cm^{-1} and 3405 cm^{-1} . The infrared transmittance

increased from 63.6% to 68.5% at 2924 cm^{-1} and 2855 cm^{-1} . The infrared transmittance increased from 62.6% to 83.3% at 1462 cm^{-1} , 1458 cm^{-1} , 1382 cm^{-1} , 1386 cm^{-1} . The infrared transmittance increased from 80.5% to 88.6%, 60.3% to 71.4%, and 64.2% to 86.7% at 1600 cm^{-1} , 1510 cm^{-1} , 1330 cm^{-1} respectively. The infrared transmittance increased from 59.4% to 84.6%, 60.3% to 85.6%, and 79.6% to 96.3% at 1270 cm^{-1} , 1220 cm^{-1} , 875 cm^{-1} respectively. The infrared transmittance increased from 47.8% to 76.3% at 1125 cm^{-1} , 1030 cm^{-1} .

The results showed that before and after extraction of the Pterocarpus Macrocarpus Kurz powder, the infrared transmittance of each peak is different; After the different extractants are extracted, the infrared transmittance of each peak is also different.

3.2. Ingredients of the Pterocarpus Macrocarpus Kurz extraction

As shown in Figs. 4, 5 and 6, respectively, total ion chromatograms of methanol, ethyl acetate and ethanol/benzene extractions. The GC–MS qualitative analysis technique can be used to determine the chemical composition of extract of the Pterocarpus Macrocarpus Kurz in methanol, ethyl acetate and ethanol/benzene solution. The chromatographic ion spectrum of the extract obtained by GC–MS analysis can be used to calculate the relative percentage of each component by area normalization method (Peng et al., 2014). The extracts were analyzed by GC–MS, and the NIST standard library and the available data were used to accurately determine the chemical constituents in the extract. Tables 1–3 are GC–MS analysis results for different extracts.

The methanol extract contained 29 peaks in the gas chromatogram of GC–MS and 10 compounds were identified from these peaks. Homopteroicarpin (23.94%), 10, 11-Dihydro-10-hydroxy-2, 3, 6-trimethoxydibenz(b, f) oxepin (23.36%), 2-

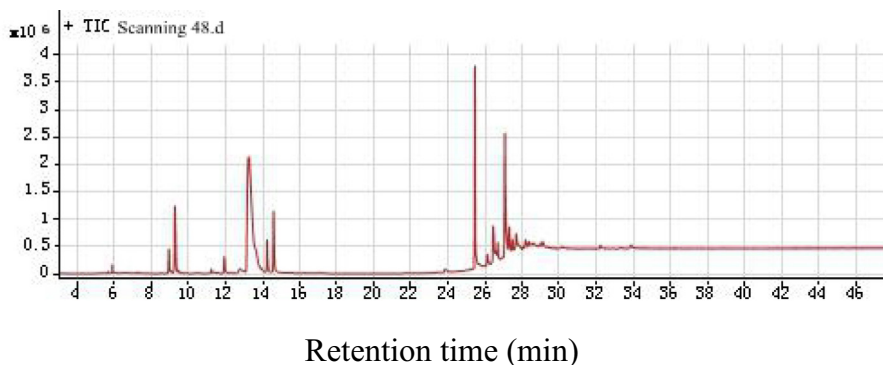


Fig. 4. Total ion chromatogram of methanol extract of Pterocarpus macrocarpus Kurz.

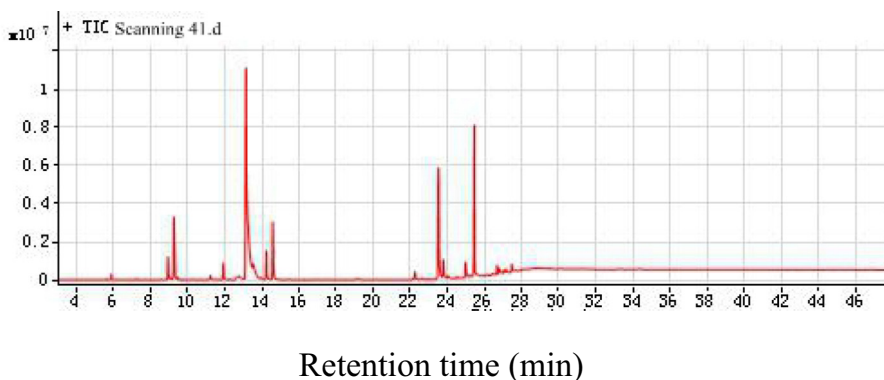


Fig. 5. Total ion chromatogram of Ethyl acetate extract of Pterocarpus macrocarpus Kurz.

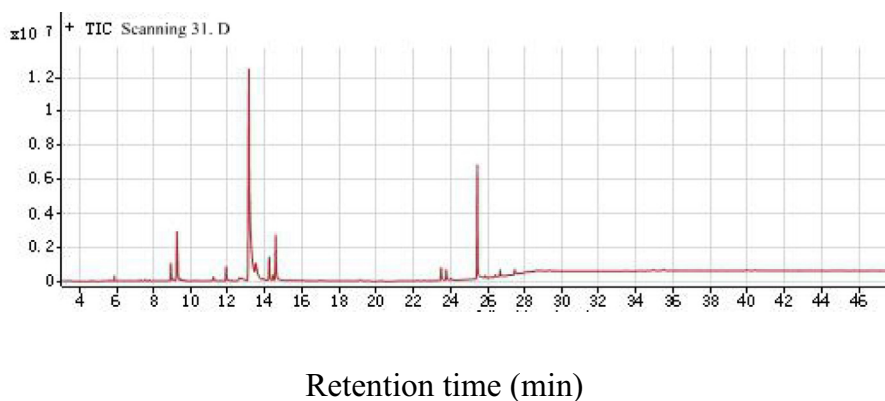


Fig. 6. Total ion chromatogram of Ethanol/benzene solution extract of *Pterocarpus macarocarpus* Kurz.

Table 1
Methanol extract of GC–MS analysis results.

Peak number	Keep time (min)	Area percentage (%)	Chemical formula
1	8.941	3.64	2-Naphthalenemethanol, 1,2,3,4,4a,5,6,7-octahydro-.alpha.,.alpha.,4a,8-tetramethyl-, (2R-cis)-
2	9.265	12.17	2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)]-
3	9.485	0.6	5-Azulenemethanol, 1,2,3,3a,4,5,6,7-octahydro-.alpha.,.alpha.,3,8-tetramethyl-, [3S-(3.alpha.,3a.beta.,5.alpha.)]-
4	11.238	0.72	Cryptomeridiol
5	11.93	3.31	(1R,4aR,7R,8aR)-7-(2-Hydroxypropan-2-yl)-1,4a-dimethyl decahydronaphthalen-1-ol
6	12.784	1.88	Alloaromadendrene oxide-(1)
7	13.243	10	(-)-Spathulenol
8	13.909	1.32	2,3,3-Trimethyl-2-(3-methylbuta-1,3-dienyl)-6-methylenecyclohexanone
9	25.449	23.94	Homopteroicarpin
10	27.067	23.36	10,11-Dihydro-10-hydroxy-2,3,6-trimethoxydibenz(b,f)oxepin

Table 2
Ethyl acetate extract of GC–MS analysis results.

Peak number	Keep time (min)	Area percentage (%)	Chemical formula
1	5.888	0.55	2(3H)-Furanone, 5-butylidihydro-4-methyl-
2	8.935	5.08	2-Naphthalenemethanol, 1,2,3,4,4a,5,6,7-octahydro-.alpha.,.alpha.,4a,8-tetramethyl-, (2R-cis)-
3	9.258	16.59	2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)]-
4	9.478	0.71	5-Azulenemethanol, 1,2,3,3a,4,5,6,7-octahydro-.alpha.,.alpha.,3,8-tetramethyl-, [3S-(3.alpha.,3a.beta.,5.alpha.)]-
5	11.231	1.5	Cryptomeridiol
6	11.917	4.25	(1R,4aR,7R,8aR)-7-(2-Hydroxypropan-2-yl)-1,4a-dimethyl decahydronaphthalen-1-ol
7	12.7	1.33	9-Isopropyl-1-methyl-2-methylene-5-oxatricyclo[5.4.0.0(3,8)]undecane
8	12.764	0.58	(-)-Spathulenol
9	13.146	10	Tricyclo[4.4.0.0(2,7)]dec-8-ene-3-methanol, .alpha.,.alpha.,6,8-tetramethyl-, stereoisomer
10	13.515	12.82	(-)-Spathulenol
11	13.903	0.6	(4aS,7R)-7-(2-Hydroxypropan-2-yl)-1,4a-dimethyl-4,4a,5,6,7,8-hexahydronaphthalen-2(3H)-one
12	25.456	27.83	Homopteroicarpin

Naphthalenemethanol, decahydro-.alpha., .alpha., 4a-trimethyl-8-methylene-, [2R-(2.alpha., 4a.alpha., 8a.beta.)]- (12.17%), (-)-Spathulenol (10%), 2-Naphthalenemethanol, 1, 2, 3, 4, 4a, 5, 6, 7-octahydro-.alpha., .alpha., 4a, 8-tetramethyl-, (2R-cis)- (3.64%), (1R, 4aR, 7R, 8aR)-7-(2-Hydroxypropan-2-yl)-1, 4a-dimethyl decahydronaphthalen-1-ol (3.31%), Alloaromadendrene oxide-(1) (1.88%), 2, 3, 3-Trimethyl-2-(3-methylbuta-1, 3-dienyl)-6-methylene cyclohexanone (1.32%), Cryptomeridiol (0.72%), 5-Azulenemethanol, 1, 2, 3, 3a, 4, 5, 6, 7-octahydro-.alpha., .alpha., 3, 8-tetramethyl-, [3S-(3.alpha., 3a.beta., 5.alpha.)]- (0.6%).

The Ethyl acetate extract contained 29 peaks in the gas chromatogram of GC–MS and 11 compounds were identified from

these peaks. Homopteroicarpin (27.83%), 2-Naphthalenemethanol, decahydro-.alpha., .alpha., 4a-trimethyl-8-methylene-, [2R-(2.alpha., 4a.alpha., 8a.beta.)]- (16.59%), (-)-Spathulenol (13.40%), Tricyclo[4.4.0.0(2, 7)]dec-8-ene-3-methanol, .alpha., .alpha., 6, 8-tetramethyl-, stereoisomer (10%), 2-Naphthalenemethanol, 1, 2, 3, 4, 4a, 5, 6, 7-octahydro-.alpha., .alpha., 4a, 8-tetramethyl-, (2R-cis)- (5.08%), (1R, 4aR, 7R, 8aR)-7-(2-Hydroxypropan-2-yl)-1, 4a-dimethyl decahydronaphthalen-1-ol(4.25%), Cryptomeridiol (1.5%), 9-Isopropyl-1-methyl-2-methylene-5-oxatricyclo[5.4.0.0(3, 8)]undecane (1.33%), 5-Azulenemethanol, 1, 2, 3, 3a, 4, 5, 6, 7-octahydro-.alpha., .alpha.,3, 8-tetramethyl-, [3S-(3.alpha., 3a.beta., 5.alpha.)] (0.71%), (4aS, 7R)-7-(2-Hydroxypropan-2-yl)-1, 4a-

Table 3
Ethanol/Benzene extract of GC–MS analysis results.

Peak number	Keep time (min)	Area percentage (%)	Chemical formula
1	5.888	0.62	2(3H)-Furanone, 5-butylidihydro-4-methyl-
2	8.928	4.66	2-Naphthalenemethanol, 1,2,3,4,4a,5,6,7-octahydro-.alpha.,.alpha.,4a,8-tetramethyl-, (2R-cis)-
3	9.252	15.01	2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)]-
4	9.472	0.71	.alpha.-acorenol
5	11.225	1.37	Cryptomeridiol
6	11.911	3.9	(1R,4aR,7R,8aR)-7-(2-Hydroxypropan-2-yl)-1,4a-dimethyl decahydronaphthalen-1-ol
7	12.622	1.09	2-Propen-1-ol, 3-(2,6,6-trimethyl-1-cyclohexen-1-yl)-
8	12.758	0.81	(-)-Spathulenol
9	13.133	10	Tricyclo[4.4.0.0(2,7)]dec-8-ene-3-methanol, .alpha.,.alpha.,6,8-tetramethyl-, stereoisomer
10	13.502	11.42	(-)-Spathulenol
11	14.44	1.24	1,2-Benzenedicarboxylic acid, butyl 2-methylpropyl ester
12	25.443	24.42	Homopterocarpin

dimethyl-4, 4a, 5, 6, 7, 8-hexahydronaphthalen-2(3H)-one(0.6%), 2(3H)-Furanone, 5-butylidihydro-4-methyl- (0.55%).

The Ethanol/Benzene extract contained 24 peaks in the gas chromatogram of GC–MS and 11 compounds were identified from these peaks. Homopterocarpin(24.42%), 2-Naphthalenemethanol, decahydro-.alpha., .alpha., 4a-trimethyl-8-methylene-, [2R-(2.alpha., 4a.alpha., 8a.beta.)]- (15.01%), (-)-Spathulenol(12.23%), Tricyclo[4.4.0.0(2, 7)]dec-8-ene-3-methanol, .alpha., .alpha., 6, 8-tetramethyl-, stereoisomer (10%), 2-Naphthalenemethanol, 1, 2, 3, 4, 4a, 5, 6, 7-octahydro-.alpha., .alpha., 4a, 8-tetramethyl-, (2R-cis)- (4.66%), (1R, 4aR, 7R, 8aR)-7-(2-Hydroxypropan-2-yl)-1, 4a-dimethyl decahydronaphthalen-1-ol (3.9%), Cryptomeridiol (1.37%), 1, 2-Benzenedicarboxylic acid, butyl 2-methylpropyl ester(1.24%), 2-Propen-1-ol, 3-(2, 6, 6-trimethyl-1-cyclohexen-1-yl)- (1.09%), .alpha.-acorenol (0.71%), 2(3H)-Furanone, 5-butylidihydro-4-methyl- (0.62%).

3.3. The health care ingredients of the Pterocarpus Macrocarpus Kurz

Pterocarpus is not only a good material for making high-grade furniture, but also considered a treasure of human health care. For example, Pterocarpus has effect on soothe the nerves, speed up the body's metabolism and lower blood pressure, blood lipids. Through the analysis of the Pterocarpus Macrocarpus Kurz extract, we we also got some proven medicinal ingredients. 2-Naphthalenemethanol, 1, 2, 3, 4, 4a, 5, 6, 7-octahydro-.alpha.,.alpha.,4a,8-tetramethyl-, (2R-cis)- not only can inhibit the growth of *Staphylococcus aureus*, but also can inhibit the growth of *colibacillus*. It can also be used as cosmetics and food additives in industrial production (Wang et al., 2013). 2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)]- has a high value in the application of medicine, what's more it has cough and phlegm, detoxification and diuretic and other effects (Tu et al., 2009; Gao, et al., 2017). Cryptomeridiol is a natural product with anti-Alzheimer's disease and antispasmodic properties, and its medicinal value is significant (Mohamed et al., 2011). 2, 3, 3-Trimethyl-2-(3-methylbuta-1, 3-dienyl)-6-methylenecyclohexanone has the property of inhibiting alpha-amylase activity and it can be used to control alpha-amylase hydrolysis of starch to produce glucose, syrup, beer and monosodium glutamate (Ramsha and Dildar, 2015). Homopterocarpin inhibits and kills cancer cell activity. It can inhibit at low concentrations, kill at high concentrations human laryngeal cancer cells and human hepatocarcinoma cells (Kan et al., 1994; Li et al., 2001). 1, 2-Benzenedicarboxylic acid, butyl 2-methylpropyl ester has the function of heat cough and enhance the body's immune function (Han et al., 2004; Ataa et al., 2017).

4. Conclusion

The infrared transmittance of the extracted Pterocarpus Macrocarpus Kurz powder at each peak position became larger in the FT-IR analysis. However, after the extraction of different extracts, the increase in the infrared transmittance of each peak is different. The increase of the infrared transmittance of ethyl acetate is the highest in the wavenumber range of 2855–3421 cm^{-1} . The increase of the infrared transmittance of ethanol/benzene in 1030–1510 cm^{-1} wavenumber range is the highest.

By GC–MS analysis, 17 kinds of chemical components are identified in the Pterocarpus Macrocarpus Kurz extract. Some of them have been proven to have ingredients that are beneficial to human health. These beneficial ingredients have cough and phlegm, detoxification and enhance the function of human immunity. The Homopterocarpin is excellent in inhibiting and killing cancer cell activity. Cryptomeridiol is a natural product with anti-Alzheimer's disease and antispasmodic properties and its medicinal value is significant.

Acknowledgments

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