

Chemical Component Characterization and Potential Medicinal Utilization of Extracts and Pyrolyzates from *Jasminum nudiflorum* Lindl. Wood

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Utilization of lignocellulosic biomass is receiving increasing attention lately. In this study, *Jasminum nudiflorum* Lindl. (JNL) wood were extracted using methanol, ethanol, and benzene/ethanol (2:1, v:v) separately. Fourier transform-infrared spectroscopy (FTIR) and gas chromatography-mass spectroscopy (GC-MS) were used to study the chemical components of extracts. A thermogravimetric (TG) analyzer and pyrolysis (Py)-GC-MS investigated the characteristics of thermal loss law and pyrolyzates of JNL wood, respectively. The FTIR results showed that many functional groups were detected from the extracts of JNL wood, which were consistent with the chemical structures in the components detected by GC-MS. There were two obvious stages of thermal loss for removing moisture and decomposition of the organic constituents. The components of the extracts and pyrolyzates were esters, acids, aldehydes, alcohols, inositol, furfural, alkanes, phenols, ketones, antibiotics, saccharides, and glycosides. Among them, some components, such as ethyl iso-allochololate, scopoletin, isosorbide dinitrate, and idebenone, have high medicinal value. This study revealed the chemical component characterization and potential medicinal utilization of JNL wood. It provides the scientific basis for enhancing the utilization value of JNL wood.

DOI: 10.15376/biores.17.2.2525-2546

Keywords: *Jasminum nudiflorum* Lindl.; Wood; Extract; Chemical component; Pyrolysis; High-value application

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INTRODUCTION

Biorefining is an environmentally friendly method for developing chemicals by achieving the highest possible yield from limited and precious natural resources (Rosdiana *et al.* 2017). The concept of biorefining has attracted widespread attention. Many researchers have explored plants and their corresponding by-products as sources of value-added components to improve their utilization efficiency and promote sustainable development of ecology (Fernando *et al.* 2006; Dessbesell *et al.* 2017; Dugmore *et al.* 2017; Xie *et al.* 2017). Wood is an abundant renewable resource mainly composed of lignin, cellulose, and hemicellulose. Some applications of wood focus on energy and fuel production (Fitzpatrick *et al.* 2010), while others focus on wood extracts as a resource for

value-added components, such as chemicals, biomedicines, and biologically active components (Rosdiana *et al.* 2017).

Jasminum nudiflorum Lindl. (JNL) is a type of deciduous shrub. It was originally planted in the middle and Northern provinces of China and has now been planted throughout the country (Takenaka *et al.* 2002). The flowers and leaves of JNL have been used as crude drugs in Chinese folk medicine (Tanahashi *et al.* 1999). Li *et al.* (2010) reported that a leaf extract of JNL is non-poisonous and is rich in flavonoids, secoiridoids, and fatty acids to treat inflammatory swelling, purulent eruptions, bruises, and traumatic bleeding. However, little detailed information is available about the chemical composition and corresponding utilization value of JNL wood. Therefore, the lack of a systematic and in-depth analysis on the chemical composition of JNL wood has slowed the development of high-value-added products with suitable processing efficiency.

Extraction is usually used to investigate the composition of biomass. For example, a total of 54 active ingredients were detected in *Pterocarpus santalinus* wood extracts, which were extracted by ethanol, ethanol/benzene (1:1), and methanol/ethanol (1:1) solvents (Jiang *et al.* 2020). The compounds from the leaves of *Acacia nilotica* extracted successively with 70% of acetone, methanol, ethanol, and chloroform were mainly tannins, saponins, glycosides, and flavonoids by gas chromatography-mass spectrometry (GC-MS) analysis (Revathi *et al.* 2017).

Pyrolysis (Py) has gained more attention because it has proved to be a much cheaper, more effective and efficient thermochemical pathway than other methods such as gasification and fermentation (Xing *et al.* 2016). Moreover, Py provides lots of information about the pyrolysis properties and thermal decomposition process of biomass through thermogravimetric (TG) analysis and biomass compositions, including the organic matter and gaseous products by Py-GC-MS analysis (Wen *et al.* 2019). According to Huang *et al.* (2020), the main pyrolytic by-products were phenols (19.2%), and furans (12.4%) for water hyacinth roots and nitriles (11.9%), and phenols (10%) for water hyacinth stems and leaves. The Py-GC-MS results in the research of Calixto *et al.* (2021) indicated that phenols, furans, and C1-C4 oxygenated compounds are the main pyrolysis products of corn stover, bean pods, sugarcane bagasse, and pineapple crown leaves.

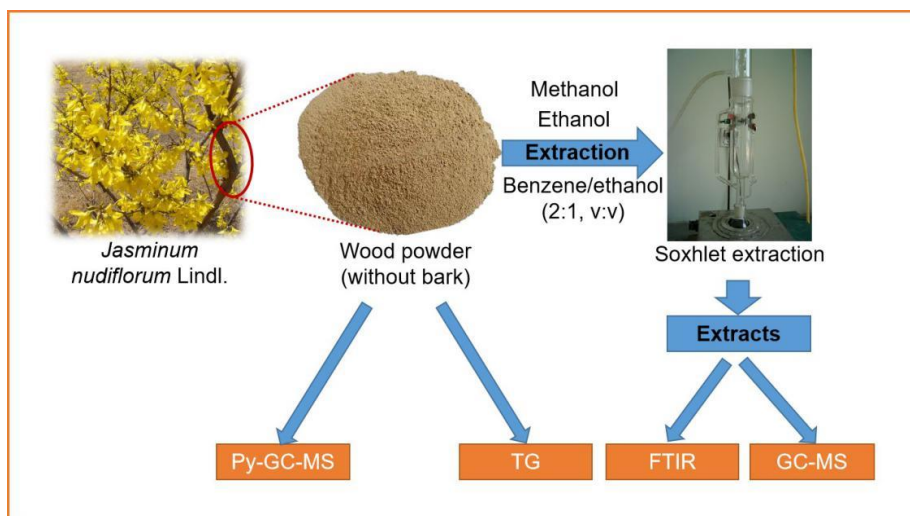


Fig. 1. Experimental flow chart

In this study, the authors used methanol, ethanol, and benzene/ethanol (2:1, v:v) to extract the chemical components of JNL wood (without bark) separately. In addition, the components of JNL wood and the characteristics of its extracts were analyzed by Fourier transform-infrared spectroscopy (FTIR), GC-MS, Py-GC-MS, and thermogravimetric techniques (Fig. 1). This study provides useful information on the chemical composition, pyrolysis characteristics, and potential medicinal utilization of JNL wood. Moreover, it is of great value to provide the basis for sustainable development of high value-added applications of JNL wood.

EXPERIMENTAL

Materials and Reagents

The wood (without bark) of JNL was provided by the biotechnology laboratory of the College of Forestry, Henan Agricultural University (Zhengzhou, China). After drying at 40 °C, the wood was powdered by a plant disintegrator (FZ102, Tanjing Taisite Ins. Corp., Tanjing, China). Then, the powdered wood was sieved to pass through a 0.074-mm AS200 sieving instrument and stored in desiccators for further experiments of GC-MS, FTIR, Py-GC-MS, and TG analyses.

All reagents were purchased from Sigma Chemical Co. (St. Louis, MO, USA). All organic solvents used were high performance liquid chromatography grade, and inorganic chemicals were analytical grade or better.

Methods

JNL wood extraction

The JNL wood was extracted by methanol, ethanol, and benzene/ethanol (2:1, v:v) separately based on the methods of Gu *et al.* (2021). Briefly, 10.0 g of the JNL wood samples were mixed separately with methanol, ethanol and benzene/ethanol (2:1, v:v) at a solid-liquid ratio of 1:20. After 12 h of immersion at 25 °C, the mixed solutions were fully extracted by Soxhlet extraction for 5 h at 70 °C. After being filtrated rapidly with filter paper that had previously been immersed into ethanol for 24 h, the extracts were evaporated at 45 °C under a vacuum of 0.01 MPa and concentrated to 20 mL. Then, the extracts were kept into sealed reagent bottles at 4 °C for the following determination. The extraction yields of methanol, ethanol, and benzene/ethanol (2:1, v:v) in this study were 3.41%, 2.27%, and 4.06%, respectively.

FTIR analysis of the JNL wood extracts

According to the research of Wang *et al.* (2020), the three extract samples were dripped onto the KBr tablet, and the FTIR spectra of the tablets were recorded with an IR AFFINITY-1 spectrophotometer (Shimadzu, Kyoto, Japan) over a wavenumber range of 400 to 4000 cm^{-1} and scanned 32 times.

GC-MS analysis of the JNL wood extracts

The chemical components present in the extract samples were analyzed by a GC-MS instrument (Agilent 7890B-5977A; Agilent Technologies Inc., Santa Clara, CA, USA) equipped with a column of HP-5MS (30 m \times 250 μm \times 0.25 μm). The carrier gas

used was high purity helium (99.99%) at a constant flow rate of 1 mL min⁻¹. The split ratio was 2:1. The temperature program of the GC started at 50 °C, rose to 250 °C at a rate of 8 °C min⁻¹, and then rose to 300 °C at a rate of 5 °C min⁻¹.

The program of MS was scanned over the range 30 to 600 AMU (*m/z*), the ionization voltage was 70 eV, and the ionization current was 150 μA for electron ionization (EI). The ion source and the quadrupole temperature were set at 230 and 150 °C, respectively (Liu *et al.* 2017).

TG analysis of JNL wood

The samples of JNL wood were pyrolyzed using a TG analyzer (TGA Q50 V20.8 Build 34; TA Instruments, New Castle, DE, USA.) Initial sample mass of 3.03 mg was placed in a ceramic TG crucible. The analysis temperature was performed at 30 °C, and then increased to 300 °C (ensure more useful organic compositions in the JNL wood are obtained during pyrolysis process) at a linear heating rate of 5 °C min⁻¹. High-purity nitrogen with a flow rate of 100 mL min⁻¹ was used as the carrier gas. The TG experiments were performed in triplicate, and the average results were used for plotting weight-derivative weight (deriv. weight, % °C⁻¹, weight loss of sample per percent against temperature). The empty crucible clamp was treated as a reference.

Py-GC-MS analysis of JNL wood

The samples of JNL wood were pyrolyzed in a pyrolysis apparatus (PY-2020iS; Frontier Co., Ltd., Japan). The carrier gas was high purity helium, and the pyrolysis temperature was from room temperature to 300 °C at a heating rate of 20 °C ms⁻¹. Pyrolysis products were analyzed by GC-MS (CDS5000-Agilent 7890B-5977A ISQ; Agilent Technologies Inc., Santa Clara, CA, USA), which was carried out with a HP-5MS column coated with a neutral phase (60 m × 250 μm i.d., 0.25 μm film thickness, Agilent Technologies Inc., Santa Clara, CA, USA). Helium at a constant flow rate (1.0 mL min⁻¹) was used as carrier gas, and the injection valve temperature was set at 300 °C. The temperature program of GC began at 40 °C and increased to 200 °C at the rate of 10 °C min⁻¹, followed by a split injection at ratio of 60:1 (v:v). The program of MS was scanned over the 35 to 550 AMU (*m/z*), with an ionizing voltage of 70 eV and an ionization current of 150 μA of electron ionization (Gu *et al.* 2021).

RESULTS AND DISCUSSION

FTIR Analysis of JNL Wood Extracts

The technology of FTIR is rapid and sensitive to confirm the presence of chemical bonds and functional groups in samples (Suksuwan *et al.* 2015). FTIR is usually used as a qualitative technique. The specific absorbance bands in FTIR spectra provide direct molecular-level information allowing investigation of molecular structure and conformations (Movasaghi *et al.* 2008). Moreover, FTIR could be also used as a semi-quantitative indirect measure of the variation of functional groups through the analysis of second derivative curves (Koch *et al.* 1998). In this experiment, the FTIR spectra of methanol, ethanol, and benzene/ethanol extracts from JNL wood were recorded in the 400 to 4000 cm⁻¹ region (Fig. 2).

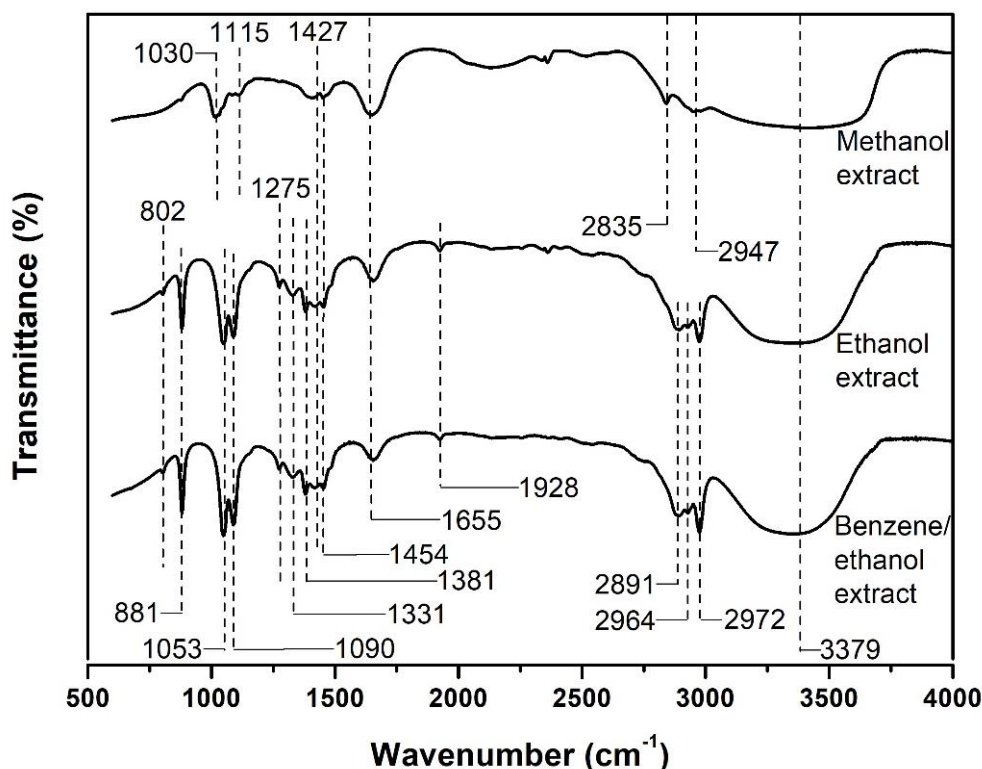


Fig. 2. Infrared spectra of methanol, ethanol, and benzene/ethanol extracts from JNL wood

As shown in Fig. 2, the spectra of the three extracts were similar in appearance and various functional groups were observed. A broad band near 3379 cm^{-1} indicates the stretching vibrations of intermolecular OH (Lourençon *et al.* 2015). A group of absorbance peaks at 2835 to 2972 cm^{-1} was assigned mainly to the symmetric and asymmetric stretching vibrations of CH in alkanes. CH_2 and CH_3 bending vibrations are present at 1331 to 1454 cm^{-1} (Liu *et al.* 2013; Alekhina *et al.* 2015). The peak at 1655 cm^{-1} corresponded to C=C and C=O stretching, which originated from ester acids and aromatic components (Cruz *et al.* 2016). A small absorbance peak at 802 to 1257 cm^{-1} was related to the vibrations of C-C, C-O, and C-H in organic components (Gu *et al.* 2015). These results indicated that the similar chemical compounds present in the three extracts of JNL wood may contain phenols, polysaccharides, alcohols, acids, ketones, and ethers.

In contrast, some absorption peaks were not observed in the methanol extracts but existed in the ethanol and benzene/ethanol extracts (Fig. 2). For example, the obvious peak at 881 cm^{-1} and the small peak at 802 cm^{-1} (Fig. 2) were assigned to lone aryl C-H wag and two-adjacent aryl C-H wags of the aromatic components, respectively. A small absorption peak at 1257 cm^{-1} was related to the vibration of C-O-C and OH of polysaccharides. It indicated that some organic compounds can be extracted with ethanol and benzene/ethanol but not by methanol. This is probably because that some absorbance peaks may have not been detected because the chemical bonds were unstable or condensed during the extraction process with high temperature (Liu *et al.* 2017).

GC-MS Analysis of the JNL Wood Extracts

The methanol, ethanol, and benzene/ethanol extracts of JNL wood were analyzed by GC-MS to further characterize the chemical components of the extracts. The GC-MS chromatograms of the three kinds of extracts are shown in Figs. 3 through 5. The relative content of each product was calculated from the summed areas normalization of the peaks. According to Gu *et al.* (2021), the retention times and mass spectra of the extracts were compared with the GC-MS mass spectra from the National Institute Standard and Technology (NIST) library and published literatures to assign the components. The confidence was set at 80% in this study. The relative contents of the constituents higher than 2.50% were accepted as the main components (Table 1).

Fifty peaks were detected, and 47 compounds were identified in the methanol extract of JNL wood. The methanol extract of JNL wood was rich in secondary metabolites of inositol, which is important in plant biochemistry and physiology (Loewus and Murthy 2000; Stevenson *et al.* 2000). This result was different from the previous studies in which secoiridoids and saccharides were found to be the main components in the methanol extract of JNL leaf and bark, respectively (Takenaka *et al.* 2000; Gu *et al.* 2021).

In the ethanol extract of JNL wood, 30 peaks were detected and 22 compounds were identified and phenol was the main constituent in this extract (Table 1). This is notably different from the methanol extract of JNL bark, in which saccharide is the main component (Gu *et al.* 2021). Pourmorad *et al.* (2006) reported that the phenolic compounds are potent in radical scavenging for plants. It can be inferred that the ethanol extract of JNL wood has antioxidant capacity.

A total of 76 peaks were detected, and 76 compounds were identified in the benzene/ethanol extract of JNL wood. Alcohol, particularly 1-hexanol, 2-ethyl-, was the major component in the extract (Table 1). This result was consistent with the main constituent in the benzene/ethanol extract of JNL bark (Gu *et al.* 2021).

The spectral data show that the benzene/ethanol extract presented the most compounds, while the least compounds were found in the ethanol extract, which was consistent with the yields of the three extracts. This was because solvent choice is vital for the extracted compounds and the extraction efficiency Cowan (1999). In addition, the major components and the contents of each extract from JNL wood were completely different with those from JNL bark (Gu *et al.* 2021), which suggests different chemical structures of JNL wood and bark.

Based on the functional groups and peak areas, the compounds identified in the methanol, ethanol, and benzene/ethanol extracts of JNL wood can be classified as esters, acids, aldehydes, phenols, alcohols, ketones, inositol, furfural, alkanes, saccharides, and glycosides. Among the identified compounds, some of them are bioactive and used in medicines. For example, clindamycin, inositol, scopoletin, cinnamaldehyde, cyclotetrasiloxane, furanone, ester, steroids, and terpenoid substances that possess antimicrobial activity and are widely used to treat inflammatory diseases (Bharathy *et al.* 2012; Keskin *et al.* 2012; Sheela and Uthayakumari 2013; Anupama *et al.* 2014; Hameed *et al.* 2015; Angel *et al.* 2016; Narayanan *et al.* 2017). Specifically, 3,5-dimethoxy-4-hydroxycinnamaldehyde and ethyl iso-allocholate have been used as anticancer, anesthetic, antiulcer antiviral, and hypoglycemic drugs (Daffodil *et al.* 2012). Scopoletin inhibits thyroid function and prevents hyperglycemia without hepatotoxicity (Panda and Kar 2006).

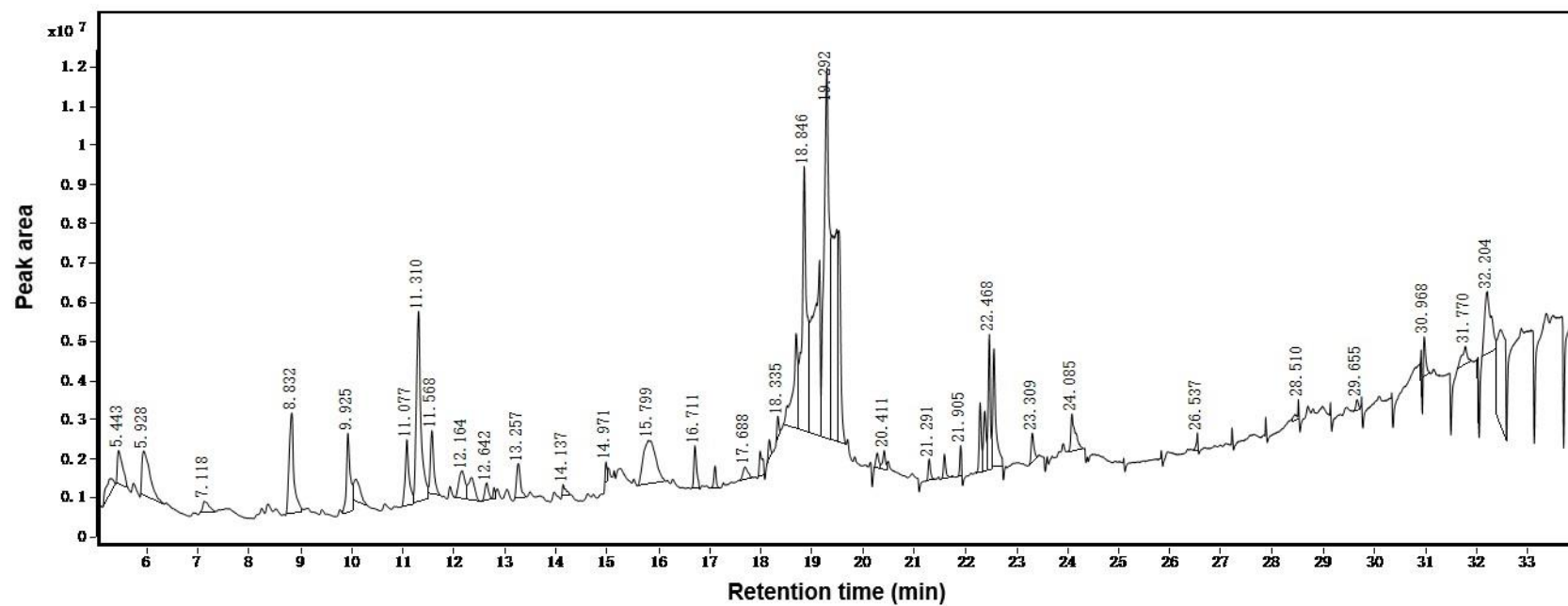


Fig. 3. Total ion chromatogram of methanol extract from JNL wood

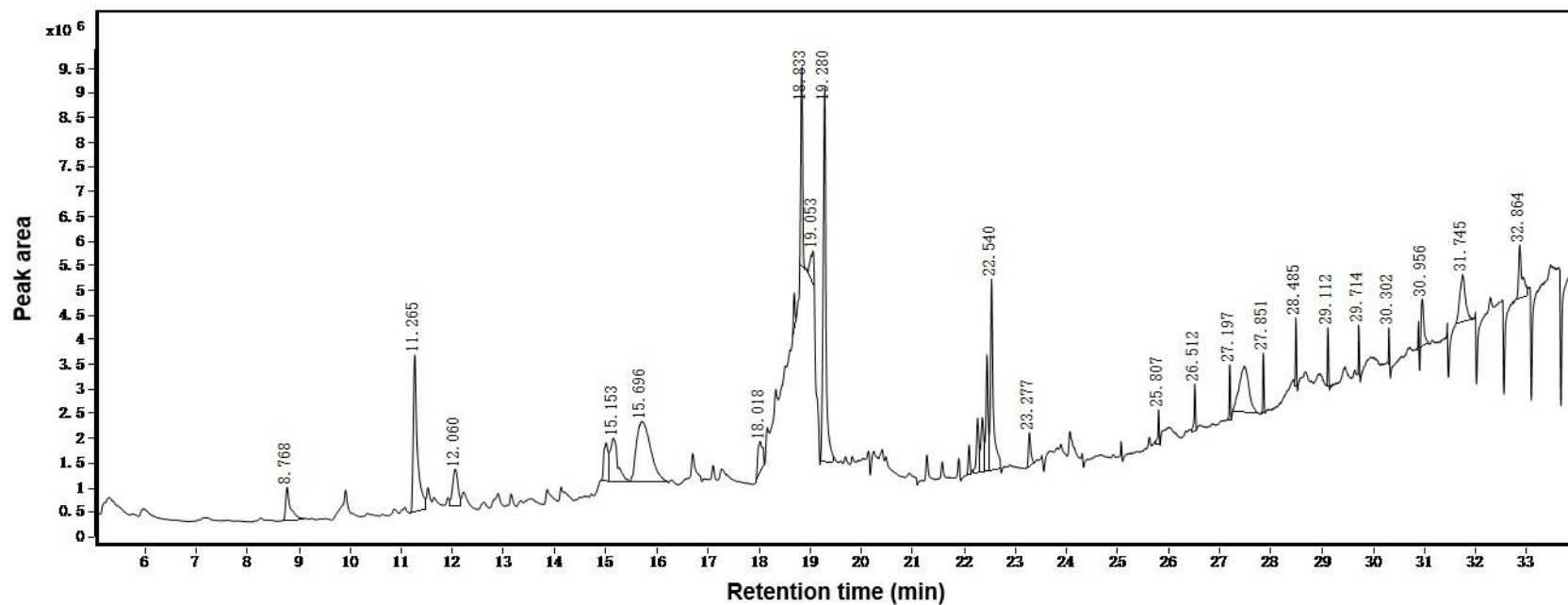


Fig. 4. Total ion chromatogram of ethanol extract from JNL wood

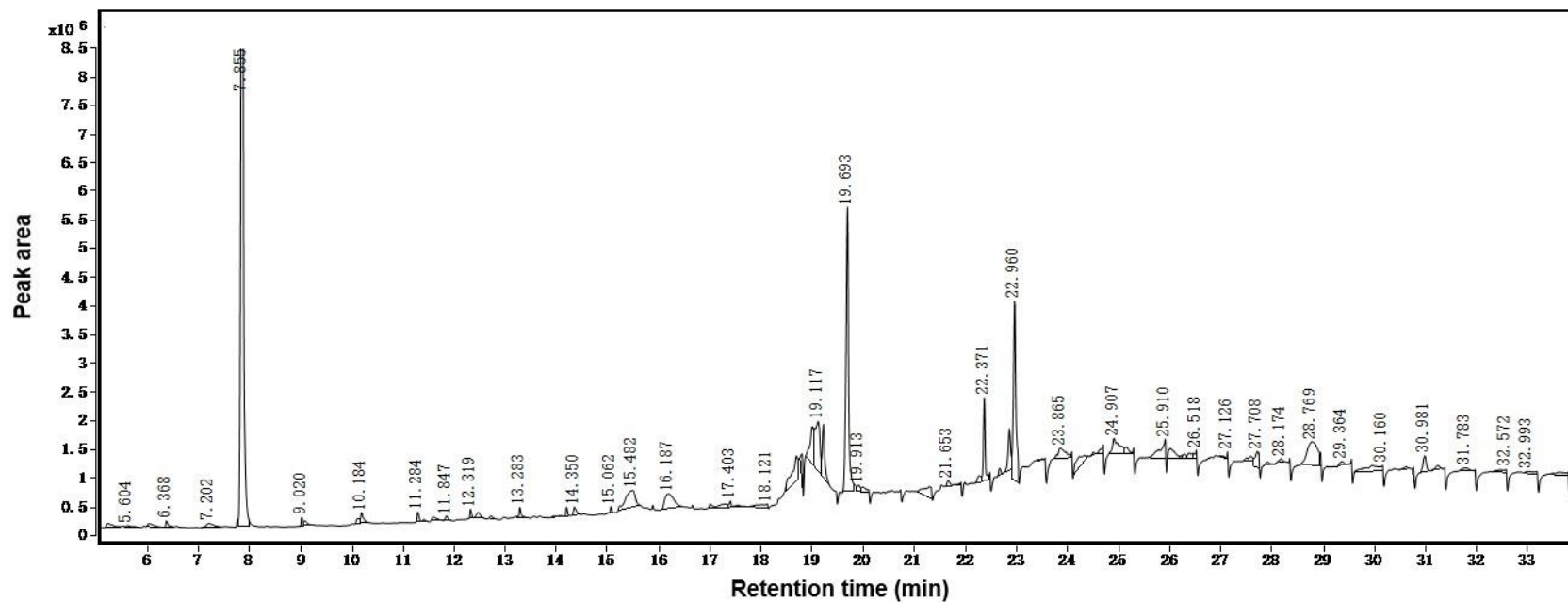


Fig. 5. Total ion chromatogram of benzene/ethanol extract from JNL wood

Table 1. Main Components of Methanol, Ethanol, and Benzene/Ethanol Extracts of JNL Wood by GC-MS ($\geq 2.50\%$)

Extraction Solvent	RT ^a (min)	RC ^b (%)	Component Names
Methanol	18.85	22.70	Scyllo-Inositol, 1-C-methyl-
	19.15	21.24	Myo-Inositol, 4-C-methyl-
	29.66	6.73	Cyclotetrasiloxane, octamethyl-
	11.31	6.19	5-Hydroxymethylfurfural
	15.80	3.79	D-Allose
	18.34	3.60	.Alpha.-methyl mannofuranoside
	8.83	3.34	D-Alanine, N-propargyloxycarbonyl-, and isohexyl ester
	21.59	3.00	Trans-sinapyl alcohol
	32.20	2.85	Benzoic acid, 4-methyl-2-trimethylsilyloxy-, and trimethylsilyl ester
	10.07	2.61	Isosorbide dinitrate
	5.93	2.50	Dihydroxyacetone
Ethanol	19.28	15.60	(E)-4-(3-Hydroxyprop-1-en-1-yl)-2-methoxyphenol
	15.70	12.83	.Beta.-D-glucopyranose, 1,6-anhydro-
	11.27	9.53	5-Hydroxymethylfurfural
	22.54	7.90	Trans-sinapyl alcohol
	15.00	7.29	Sucrose
	30.88	4.15	Cyclotetrasiloxane, octamethyl-
	22.45	3.91	3,5-Dimethoxy-4-hydroxycinnamaldehyde
	12.06	2.91	Butyl 2-acetoxyacetate
	18.02	2.90	Scyllo-inositol, 1-C-methyl-
	32.86	2.86	Cyclotrisiloxane, hexamethyl-
Benzene/ Ethanol	7.86	34.74	1-Hexanol, 2-ethyl-
	28.77	18.51	1H-Cyclopropa[3,4]benz[1,2-e]azulene-5,7b,9,9a-tetrol, 1a,1b,4,4a,5,7a,8,9-octahydro-3-(hydroxymethyl)-1,1,6,8-tetramethyl-, 5,9,9a-triacetate, and [1aR-(1a.alpha.,1b.beta.,4a.beta.,5.beta.,7a.alpha.,7b.alpha.,8.alpha.,9.beta.,9a.alpha.)]-
	22.96	12.82	1H-2,8a-Methanocyclopenta[a]cyclopropa[e]cyclodecen-11-one, 1a,2,5,5a,6,9,10,10a-octahydro-5,5a,6-trihydroxy-1,4-bis(hydroxymethyl)-1,7,9-trimethyl-, [1S-(1.alpha.,1a.alpha.,2.alpha.,5.beta.,5a.beta.,6.beta.,8a.alpha.,9.alpha.,10a.alpha.)]-
	19.69	11.12	(E)-4-(3-Hydroxyprop-1-en-1-yl)-2-methoxyphenol
	19.12	5.73	.Beta.-D-glucopyranose, 4-O-.beta.-D-galactopyranosyl-
	18.70	2.86	Octaethylene glycol monododecyl ether
	15.48	2.53	9-Octadecenoic acid, (2-phenyl-1,3-dioxolan-4-yl)methyl ester, trans-

RT^a: Retention time; RC^b: Relative content

Isosorbide dinitrate is effective for slowing or preventing the progression of heart failure (Taylor *et al.* 2004). 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- has an anti-cancer effect (Ban *et al.* 2007). DL-Arabinose has anti-tumor and antiviral activity (Hadi *et al.* 2016; Sosa *et al.* 2016). d-Mannose is effective for recurrent urinary tract infections (Kranjčec *et al.* 2014), and 7-methyl-Z-tetradecen-1-ol acetate can help with coughing (Lou *et al.* 2018). 5-hydroxymethylfurfural is reported to be a promising candidate for therapy of sickle cell disease (Rosatella *et al.* 2011). Acetamide N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butyryl]- and 11,13-dihydroxy-tetradec-5-ynoic acid, methyl ester are new chemical compounds (Idan *et al.* 2015; Hussein *et al.* 2016,) and their effects need further research.

Thus, it appears that JNL wood is a potentially useful resource in the medical field. The highest total content of bioactive components was found in the methanol extract compared with the other two extracts. Therefore, the appropriate solvent can be chosen for extraction according to the need for different components. The authors' results suggest that the methanol extract possessed the best prospects for development.

TG Analysis of JNL Wood

The pyrolysis processes of JNL wood from 30 to 300 °C at a linear heating rate of 5 °C min⁻¹ were studied by TG analysis. The changes in wood weight and the derivative weight curves are shown in Fig. 6. The thermal degradation stages, weight loss, peak temperature and the corresponding residual weight of JNL wood in TG analysis are shown in Table 2. Based on the curve, there were two obvious stages of thermal loss in the wood (Fig. 6, Table 2). The first stage occurred up to 75 °C with a weight loss of 8.58%, and the maximum weight loss rate, which was shown in the first peak at 39.4 °C, occurred in this stage (Fig. 6, Table 2). According to some reports, this stage is responsible for the drying process, and the weight loss represents removal of moisture and light volatile matter (Liu *et al.* 2013; Mishra and Mohanty 2018). The decrease in weight (8.58%) indicated high content of moisture and small molecules in the wood. The curve between 75 and 200 °C was relatively flat, indicating possible occurrence of a small amount of polymer depolymerization and recombination in the sample (Gu *et al.* 2021).

The second stage of weight loss was 31.2% occurring in the temperature range of 200 to 300 °C (Fig. 6, Table 2). It was clear that the decomposition temperature for the wood biomass was about 200 °C, which was delayed compared with some reported plants with similar moisture content (Sait *et al.* 2012). There was a peak around 300 °C in the derivative weight curve (Fig. 6, Table 2), showing that the weight loss rate was fastest at this temperature. According to some reports, this stage is called the active pyrolytic zone, and weight loss is mainly due to decomposition of organic constituents (such as hemicellulose, cellulose, and lignin) into volatiles (Sait *et al.* 2012; Mishra and Mohanty 2018). In general, hemicellulose and cellulose (180 to 450 °C) are highly reactive and burn at a lower temperature than lignin, which has quite a broad burning range of 250 to 700 °C (Mishra and Mohanty 2018). The thermo-chemical decomposition route followed by a biomass is given as extract, cellulose, hemicelluloses, and lignin or char (Sait *et al.* 2012). At this stage, the weight has changed noticeably, which may be caused by remarkable chemical changes, such as macromolecules pyrolyzed into smaller more volatile molecules. In addition, the heating temperature in this study was set below 300 °C, which was far from carbonization temperature. Therefore, many volatile components can be

obtained in the range 200 to 300 °C to make full use of JNL wood (Mishra and Mohanty 2018).

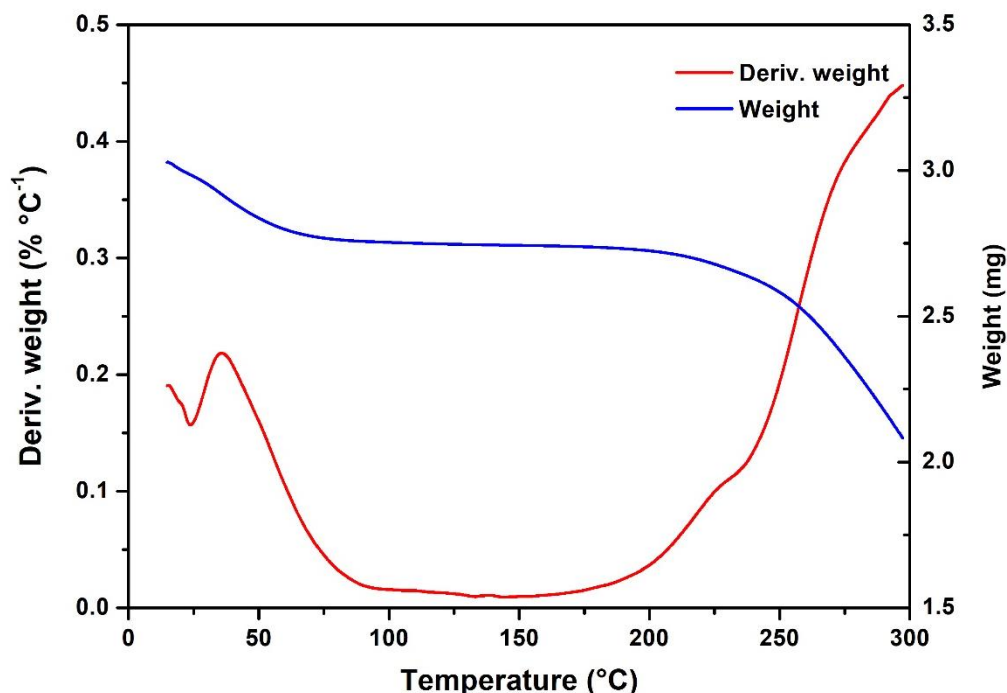


Fig. 6. Weight-derivative weight curves of JNL wood during pyrolysis at a heating rate of 5 °C min⁻¹

Table 2. TG Analysis of JNL Wood during Pyrolysis

	Weight loss (%)	Peak temperature (°C)	Peak temperature residual weight (mg)
The first stage (<75 °C)	8.58	39.4	2.89
The second stage (200-300 °C)	31.22	300	2.08

Py-GC-MS Analysis of JNL Wood

The pyrolysis temperature of the JNL wood sample was set at 300 °C, and the pyrolyzates were detected by GC-MS. The total ion chromatograms of pyrolyzates are shown in Fig. 7, and the results of pyrolyzates are listed in Table S1. A total of 203 peaks were detected, and 203 chemical compounds were identified. Among these chemical compounds, the main pyrolysis products from JNL wood were: acetaldehyde, hydroxy- (6.85%), acetic acid (6.63%), beta-D-glucopyranose, 1,6-anhydro- (3.41%), 4-(1-hydroxyallyl)-2-methoxyphenol (2.78%), methyl glyoxal (2.43%), acetic acid, methyl ester (2.23%), 2,4,7(1H, 3H, 8H)-pteridinetriene (2.22%), and ethylene oxide (2.12%).

According to functional groups, these compounds were classified as aldehydes, organic acids, phenols, esters, ketones, alkanes, and heterocyclic chemicals. Moreover, a large amount of valuable medicinal components were detected, such as n-hexadecanoic

acid, which is an anti-inflammatory compound (Aparna *et al.* 2012). The cinnamaldehyde compound (3,5-dimethoxy-4-hydroxycinnamaldehyde) is widely used to synthesize various drugs, which has antimicrobial, anti-inflammatory, anticancer, anesthetic, antiulcer, antiviral, and hypoglycemic effects (Vadivel and Gopalakrishnan 2011). Benzene 1,2,3-trimethoxy-5-methyl- is an important chemical intermediate for intelligent stimulant medicine, such as idebenone (Kitajima *et al.* 1988). In addition, 6-azacytosine is a biologically active compound for antineurotic preparations of low toxicity and has immunotropic properties (Alekseeva *et al.* 1994). In conclusion, there were quite a few components in the pyrolysis products of JNL wood that are widely used in medicine. This suggests that JNL wood has potential for high-value applications in the field of pharmacy.

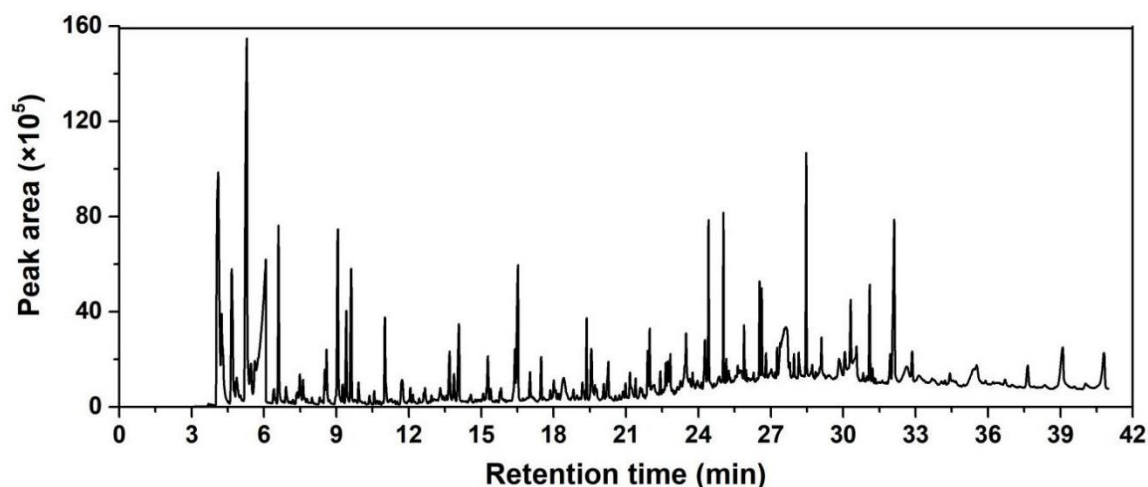


Fig. 7. Total ion chromatograms of pyrolyzates from JNL wood by Py-GC-MS

From the analysis results of GC-MS, TG, and Py-GC-MS, it is clearly shown that many components can be obtained from the extracts and pyrolyzates of JNL wood. Moreover, some components, such as 3,5-dimethoxy-4-hydroxycinnamaldehyde, ethyl iso-allocholate, scopoletin, isosorbide dinitrate, d-mannose, n-hexadecanoic acid, *etc.* can be used as medicines to combat various kinds of diseases. Thus, JNL wood is a potentially useful resource in the medical field. However, isolation and purification of the effective components to make full use of JNL wood are still a long ways away.

CONCLUSIONS

1. A total of 47, 22, and 76 compounds were identified in the ethanol, methanol, and benzene/ethanol extracts of JNL wood, respectively. The main components were esters, alcohols, ethers, fatty acids, phenols, and hydrocarbons.
2. A total of 203 peaks were detected and 203 chemical compounds were identified in the pyrolyzates at 300 °C of JNL wood. The main components were aldehydes, organic acids, phenols, esters, ketones, and alkanes.
3. Many kinds of identified compounds, such as ethyl iso-allocholate, scopoletin, isosorbide dinitrate, and idebenone, are bioactive compounds with medicinal value.

4. The TG analysis of the JNL wood resulted in two obvious stages of thermal loss for removal of moisture (up to 75 °C) and decomposition of the organic constituents (200 to 300 °C).
5. This research learned the chemical composition, pyrolysis characteristics, and potential medicinal utilization of JNL wood, which provides the scientific basis for the JNL wood to become a resource with high application value.

ACKNOWLEDGMENTS

This work was supported by the National Natural Science Foundation of China (41701360) and Henan province science and technology research project (202102310608, 212102110109).

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Article submitted: August 11, 2021; Peer review completed: November 14, 2021;
Revised version received and accepted: February 12, 2022; Published: March 15, 2022.
DOI: 10.15376/biores.17.2.2525-2546

APPENDIX (Supplementary Information)

Table S1. Py-GC-MS Analysis of the JNL Wood

No.	R.T. ^a (min)	R.C. ^b (%)	Component Names	No.	R.T. ^a (min)	R.C. ^b (%)	Component Names
1	3.70	0.03	2-Propenamide	103	22.12	0.27	Catechol
2	4.11	5.78	Carbon dioxide	104	22.17	0.25	Catechol
3	4.25	2.12	Ethylene oxide	105	22.43	0.27	Benzofuran, 2,3-dihydro-
4	4.67	2.43	Methyl glyoxal	106	22.51	0.10	2-Hexene, 1-methoxy-3-methyl-, (E)-
5	4.87	0.65	Formic acid	107	22.58	0.08	1,8-Dioxacyclohexadecane-2,10-dione, 5,6:12,13-diepoxy-8,16-dimethyl-
6	5.01	0.04	Formic acid	108	22.65	0.34	trans-2,3-Epoxydecane
7	5.03	0.11	1,3-Cyclopentadiene	109	22.73	0.52	5-Hydroxymethylfurfural
8	5.29	6.85	Acetaldehyde, hydroxy-	110	22.84	0.51	1H-Imidazole, 1-acetyl-
9	5.46	0.81	2,3-Butanedione	111	23.03	0.06	cis-7,cis-11-Hexadecadien-1-yl acetate
10	5.62	0.79	Azetidine	112	23.13	0.17	2-Furanmethanamine, tetrahydro-N-[(tetrahydro- 2-furanyl)methyl]-
11	6.08	6.63	Acetic acid	113	23.26	0.35	Piperazine, 1,4-dimethyl-
12	6.41	0.18	2-Butenal	114	23.49	1.48	1,2-Benzenediol, 3-methoxy-
13	6.49	0.05	Methacrolein	115	23.64	0.33	2H-Furo[2,3-b]pyrrole-2,5(3H)-dione, tetrahydro- 3a,6a-dimethyl-, cis-
14	6.61	1.72	2-Propanone, 1-hydroxy-	116	23.76	0.25	Phenol, 4-ethyl-2-methoxy-
15	6.92	0.26	Methyl formate	117	23.80	0.19	2-Oxo-1-methyl-3-isopropylpyrazine
16	7.20	0.05	2,3-Pentanedione	118	23.96	0.37	1,2-Benzenediol, 4-methyl-
17	7.38	0.20	1,2-Ethanediol	119	24.13	0.20	Cyclooctanone, 5-(acetyloxy)-
18	7.49	0.46	3-Buten-1-amine, N,N-diethyl-	120	24.28	0.93	Ethane, isothiocyanato-
19	7.62	0.26	Methyl methacrylate	121	24.36	0.12	1-Methoxy-3-(2-hydroxyethyl)nonane
20	7.70	0.07	1-Butaneboronic acid	122	24.43	1.34	2-Methoxy-4-vinylphenol
21	7.79	0.06	2-Butenoyl chloride	123	24.66	0.14	Ethyl cyclobutanecarboxylate
22	7.99	0.07	Propanoic acid, 2-oxo-, methyl ester	124	24.85	0.43	Oxiraneacetic acid, 2-(methoxycarbonyl)-, methyl ester, (+-)-

23	8.31	0.09	2-Butenoyl chloride	125	24.88	0.22	Estra-1,3,5(10)-trien-17.beta.-ol
24	8.41	0.03	2-Butenoic acid, (E)-	126	24.97	0.11	Estra-1,3,5(10)-trien-17.beta.-ol
25	8.53	0.34	2-Butenal, 2-methyl-	127	25.04	1.30	Phenol, 2,6-dimethoxy-
26	8.60	0.57	1,4-Pentadien-3-one	128	25.16	0.29	Phenol, 2-methoxy-3-(2-propenyl)-
27	9.06	2.23	Acetic acid, methyl ester	129	25.21	0.09	Estra-1,3,5(10)-trien-17.beta.-ol
28	9.26	0.20	2-Butenal, 2-methyl-, (E)-	130	25.26	0.28	Phenol, 3,4-dimethoxy-
29	9.42	1.06	Succinaldehyde	131	25.32	0.16	3,5-Dimethylthiophenol, S-pentafluoropropionyl-
30	9.62	1.60	Propanoic acid, 2-oxo-, methyl ester	132	25.54	0.38	9-Hexadecenoic acid, methyl ester, (Z)-
31	9.77	0.09	O-Methylisourea	133	25.63	0.40	Pyrazole-5-carboxylic acid, 3-methyl-
32	9.92	0.26	4H-1,2,4-Triazol-4-amine	134	25.68	0.07	1,3,5-Benzenetriol
33	10.37	0.11	3-Furaldehyde	135	25.73	0.37	Oleic Acid
34	10.57	0.14	2(5H)-Furanone, 3-methyl-	136	25.80	0.28	3-Hydroxy-3-methylbicyclo[3.3.1]nonane-2,4-dione
35	10.69	0.06	2-Furanmethanol, tetrahydro-	137	25.90	0.64	Vanillin
36	10.80	0.03	4H-1,2,4-Triazol-3-amine, 4-methyl-	138	25.98	0.22	Phenol, 2-methoxy-4-(1-propenyl)-
37	10.91	0.02	Propanenitrile, 3-(1-methylethoxy)-	139	26.07	0.39	9,9-Dimethoxybicyclo[3.3.1]nona-2,4-dione
38	11.02	0.99	Furfural	140	26.23	0.21	Oxacyclotetradecan-2-one
39	11.21	0.07	4-Cyclopentene-1,3-dione	141	26.29	0.24	9-Acetoxyxnonanal
40	11.28	0.09	2-Butanone, 3-methyl-	142	26.44	0.19	Cyclohexanone, 2,5-dimethyl-2-(1-methylethenyl)-
41	11.52	0.04	1-Butanol, 2-nitro-	143	26.54	0.93	3,5-Dimethoxy-4-hydroxytoluene
42	11.72	0.57	1H-Imidazole, 4,5-dihydro-2,4-dimethyl-	144	26.63	1.15	trans-Isoeugenol
43	11.96	0.03	Propanoic acid, 2-hydroxyethyl ester	145	26.80	0.54	Phenol, 2-methoxy-4-propyl-
44	12.00	0.03	1-Pentanol, 3,4-dimethyl-	146	26.97	0.30	Isobutyl 8-methylnon-6-enoate
45	12.07	0.16	1,2-Ethandiol, diacetate	147	27.03	0.60	2-Dodecen-1-yl(-)succinic anhydride
46	12.18	0.11	2(3H)-Furanone, 5-methyl-	148	27.18	0.22	4,4-Dimethyladamantan-2-ol
47	12.43	0.07	4-Cyclopentene-1,3-dione	149	27.27	0.47	Apocynin
48	12.63	0.11	3-Butyn-2-ol	150	27.39	0.71	.beta.-D-Glucopyranose, 1,6-anhydro-
49	12.68	0.17	Cyclopent-4-ene-1,3-dione	151	27.51	1.16	.beta.-D-Glucopyranose, 1,6-anhydro-
50	12.94	0.09	Styrene	152	27.56	0.69	D-Allose
51	13.06	0.05	Carbonic acid, dimethyl ester	153	27.60	0.41	D-Allose

52	13.07	0.04	1-Propanol, 2-ethoxy-	154	27.64	1.54	.beta.-D-Glucopyranose, 1,6-anhydro-
53	13.31	0.30	2-Butenoic acid, methyl ester, (E)-	155	27.79	0.43	Benzene, 1,2,3-trimethoxy-5-methyl-
54	13.44	0.08	Dihydroxyacetone	156	27.97	0.38	2-Propanone, 1-(4-hydroxy-3-methoxyphenyl)-
55	13.56	0.10	Ethanone, 1-(2-furanyl)-	157	28.16	0.74	Dodecanoic acid
56	13.69	0.69	2(5H)-Furanone	158	28.48	2.22	2,4,7(1H,3H,8H)-Pteridinetriene
57	13.88	0.38	2-Cyclohexen-1-ol	159	28.72	0.82	3,7-Benzofurandiol, 2,3-dihydro-2,2-dimethyl-
58	14.08	1.05	1,2-Cyclopentanedione	160	28.86	0.19	Vanillin, propyl ether
59	14.51	0.04	2(5H)-Furanone, 5-methyl-	161	28.92	0.17	Phenol, 2,6-dimethyl-4-nitroso-
60	14.57	0.10	2,5-Furandione, dihydro-3-methylene-	162	28.98	0.11	Acetamide, 2,2,2-trifluoro-N-(5,6-dihydro-3-cyano-4H-cyclopenta[b]thien-2-yl)-
61	14.76	0.05	Cyclopropanemethanol, .alpha.-methyl-.alpha.-propyl-	163	29.04	0.26	3,1,2-Azaazoniaboratine, 2,2-(1,5-cyclooctanediyl)-4,6-diethyl-2,3-dihydro-5-methyl-
62	14.87	0.03	Tetrahydrofuran-5-on-2-methanol, .alpha.-[.alpha.-methoxy-(tetrahydrofuran-5-on-2-ylmethoxy)]-	164	29.10	0.71	Phenol, 2,6-dimethoxy-4-(2-propenyl)-
63	14.95	0.04	Butanal, 3,3-dimethyl-2-oxo-, hemihydrate	165	29.42	0.44	Z-(13,14-Epoxy)tetradec-11-en-1-ol acetate
64	15.08	0.14	Valeric acid hydrazide	166	29.72	0.10	1H-Benzocyclohepten-7-ol, 2,3,4,4a,5,6,7,8-octahydro-1,1,4a,7-tetramethyl-, cis-
65	15.16	0.03	E-4-Methoxy-2-pentene	167	29.83	0.95	Sulfurous acid, 2-methyl-4-methoxybutyl pentyl ester
66	15.28	0.63	2-Imidazolidinone	168	30.07	0.72	Benzenepropanol, 4-hydroxy-3-methoxy-
67	15.40	0.18	2H-Pyran, 2-(7-dodecynyloxy)tetrahydro-	169	30.15	0.07	Methyl 4-hydroxy-trans-2-hexadecenoate
68	15.78	0.09	4(1H)-Pyrimidinone, 6-methyl-	170	30.18	0.08	Methyl 4-hydroxy-trans-2-hexadecenoate
69	15.82	0.15	Phenol	171	30.31	1.47	Benzaldehyde, 4-hydroxy-3,5-dimethoxy-
70	16.41	0.71	2H-Pyran-2,6(3H)-dione	172	30.41	0.11	Thiophene, tetrahydro-2-methyl-
71	16.53	1.97	2-Methyliminoperhydro-1,3-oxazine	173	30.42	0.09	Cyclohexene, 3R-acetamido-4cis,6cis-bis(acetoxy)-5trans-dimethylamino-
72	16.73	0.05	1,3-Dioxane, 4-methyl-	174	30.55	1.09	4-((1E)-3-Hydroxy-1-propenyl)-2-methoxyphenol
73	16.89	0.10	1H-Pyrrole-2-carboxaldehyde	175	30.83	0.16	3-(2-Methoxy-5-methylphenyl)acrylic acid
74	17.03	0.37	6-Azacytosine	176	31.00	0.14	Tricyclo[5.3.1.1(2,6)]dodecane-11,12-dione, (1.alpha.,2.beta.,6.beta.,7.alpha.)-
75	17.49	0.48	1,2-Cyclopentanedione, 3-methyl-	177	31.10	0.99	(E)-2,6-Dimethoxy-4-(prop-1-en-1-yl)phenol
76	17.59	0.06	Acetoxyacetic acid, but-3-yn-2-yl ester	178	31.22	0.18	1-Butanone, 1-(2,4,6-trihydroxy-3-methylphenyl)-

77	17.87	0.14	Thiazole, 2-ethyl-	179	31.33	0.06	Bicyclo[4.1.0]heptane-7-carbohydrazide, N2-(3-allyl-2-hydroxybenzylideno)-
78	18.01	0.31	2-Hexene, 4-methyl-, (E)-	180	31.96	0.39	Ethanone, 1-(4-hydroxy-3,5-dimethoxyphenyl)-
79	18.10	0.15	1,3-Dioxol-2-one,4,5-dimethyl-	181	32.12	2.78	4-(1-Hydroxyallyl)-2-methoxyphenol
80	18.21	0.09	Phenol, 2-methyl-	182	32.63	1.01	Cyclohexane, 1-(1,5-dimethylhexyl)-4-(4-methylpentyl)-
81	18.42	0.94	(S)-(+)-2',3'-Dideoxyribonolactone	183	32.86	0.49	2-Pentanone, 1-(2,4,6-trihydroxyphenyl)
82	18.83	0.18	Phenol, 3-methyl-	184	33.14	0.38	cis-9-Hexadecenal
83	18.97	0.10	Hept-3-yn-2-one	185	33.69	0.16	Cyclopropaneoctanal, 2-octyl-
84	19.20	0.22	2-Furancarboxylic acid, hydrazide	186	34.07	0.08	2-Dodecen-1-yl(-)succinic anhydride
85	19.26	0.08	2,5-Dimethylfuran-3,4(2H,5H)-dione	187	34.22	0.05	2-Dodecen-1-yl(-)succinic anhydride
86	19.37	0.65	Phenol, 2-methoxy-	188	34.42	0.16	7-Methyl-5-methyl(tetramethylene)silyloxy-3-octyne
87	19.57	0.83	1,3-Propanediamine, N-methyl-	189	34.52	0.01	Oxacyclopentadecan-2-one
88	19.72	0.17	2-Furanmethanol	190	34.56	0.02	Cyclopentadecanone, 2-hydroxy-
89	19.79	0.15	2H-Pyran-2-one, 5,6-dihydro-	191	35.30	0.23	9-Methyl-Z-10-tetradecen-1-ol acetate
90	20.08	0.16	Maltol	192	35.41	0.37	Octadecanoic acid
91	20.27	0.53	2,4(3H,5H)-Furandione, 3-methyl-	193	35.44	0.12	Octadecanoic acid
92	20.56	0.06	4H-Pyran-4-one, 5-hydroxy-2-methyl-	194	35.53	0.64	Octadecanoic acid
93	20.73	0.05	1,2-Pentadiene	195	35.90	0.08	Octadecanoic acid
94	20.88	0.13	2-Furanmethanol, tetrahydro-5-methyl-, trans-	196	36.21	0.03	4'-Phenyl-2-hydroxystilbene
95	20.98	0.17	Cyclopentane	197	36.71	0.11	5-(3-Hydroxypropyl)-2,3-dimethoxyphenol
96	21.17	0.31	Oxalic acid, 4-chlorophenyl tetradecyl ester	198	37.65	0.44	trans-Sinapyl alcohol
97	21.22	0.23	2(3H)-Furanone, dihydro-4-hydroxy-	199	38.36	0.03	2-Heptadecenal
98	21.40	0.20	2,3-Dihydroxybenzaldehyde	200	39.10	1.10	n-Hexadecanoic acid
99	21.60	0.19	Cyclohexanone, 4-ethoxy-	201	39.20	0.01	n-Hexadecanoic acid
100	21.67	0.10	Creosol	202	40.05	0.20	2-Propanone, 1,1-diphenyl-
101	21.90	0.58	Piperidine, 2,6-dimethyl-1-nitroso-	203	40.81	1.07	3,5-Dimethoxy-4-hydroxycinnamaldehyde
102	21.99	0.54	Creosol	RT ^a : Retention time; RC ^b : Relative content; --: nothing detected			