Understanding the Bioconversion of *Quercus baronii* Wood during the Artificial Cultivation of *Lentinus edodes*

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To reuse waste wood bioresources and determine the factors required for the growth of *Lentinus edodes*, *Quercus baronii* wood bioconversion during the artificial cultivation of *L. edodes* was characterized by X-ray diffraction (XRD), TG, FT-IR, and TD-GC-MS. Mycelia were observed to grow in wood if cellulose was sufficiently degraded and wood extractives were adequately retained. *L. edodes* grew in wood if the extractives, cellulose, hemicellulose, and lignin maintained a stable quality ratio. Mycelium and *L. edodes* grew in samples with high cellulose crystallinity. FT-IR spectra showed that *L. edodes* grew as the intensity of absorbance associated with unconjugated C=O stretching decreased. TG curves suggested that the samples with lower weight loss were suitable for mycelium, but those with higher weight loss were suitable for *L. edodes*. TD-GC-MS indicated that the samples containing more phenol derivatives and less acetic acid were suitable for mycelium; the opposite trends were observed for *L. edodes*.

Keywords: Bioconversion; Quercus baronii wood; Artificial cultivation; Lentinus edodes; Mycelium

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INTRODUCTION

Lentinula edodes, a fungus native to East Asia, has long been used as an herbal agent in traditional medicine (Miles and Chang 2004). *L. edodes* is rich in ergosterol and produces vitamin D2 by bioconversion (Ko *et al*. 2008; Lee *et al*. 2009). Previously, it was thought that *L. edodes* influenced the immune system, possessed antibacterial properties, reduced platelet aggregation, and possessed other anti-disease properties (Nakano *et al*. 1999; Oba *et al*. 2009; Bisen *et al*. 2010). Sadly, none of these effects has been proven with sufficient scientific evidence. Recently, *L. edodes*, which was valued not only for its nutritional value but also for its potential therapeutic applications, has become the first medicinal macrofungus to enter the realm of modern biotechnology (Bisen *et al*. 2010; Welbaum 2015). *L. edodes* is used medicinally for disease treatments including depressed immune function, cancer, fungal infections, frequent flu and colds, infectious diseases, bronchial inflammation, heart disease, hyperlipidemia, hypertension, diabetes, hepatitis, and urinary inconsistencies (Tochikura *et al*. 1989; Tsujinaka *et al*. 1990; Gordon *et al*. 1998; Kim *et al*. 1999; Nakano *et al*. 1999; Odani *et al*. 1999; Cowawintaweewat *et al*. 2006; Nimura *et al*. 2006; Terakawa *et al*. 2008; Yang *et al*. 2008; Oba *et al*. 2009; Turner and Chaudhary 2009; Wang *et al*. 2009; Jiang *et al*. 2013; Kim *et al*. 2014). Antibiotic, anti-carcinogenic, and antiviral compounds have been isolated from intracellular and

extracellular extracts of *L. edodes*, including lentinan, lectins, and eritadenine (Hirasawa *et al*. 1999; Hazama *et al*. 2009; Isoda *et al*. 2009; Kataoka *et al*. 2009; Shimizu *et al*. 2009; Bisen *et al*. 2010). Hence, this macrofungus shows great potential in the most important areas of applied biotechnology.

L. edodes was traditionally cultivated on dead hardwood logs but has been transferred into large-scale commercial cultivation in the United States (Leatham 1982) and all over the world (Hang and Hayes 1978). The annual yield of *L. edodes* is 100,000 tons globally, with 80% of the product from artificial cultivation in China. Commercially, *L. edodes* was typically grown in conditions similar to their natural environment on either artificial substrate or hardwood logs, such as oak, whereas *L. edodes* is generally commercially cultivated on oak wood particles. Research studies have mainly concentrated on its pharmacodynamics, cultivation conditions, and culinary uses (Dhillon and Chahal 1978; Miller and Jong 1987; Bhatti *et al*. 1987; Royse *et al*. 1990; Krishnamoorthy 1997; Palomo *et al*. 1998; Chang 1999; Philippoussis *et al*. 2001; Zhang *et al*. 2002; Obodai *et al*. 2003; Permana *et al*. 2004; Jiang *et al*. 2013; Kholoud *et al*. 2014; Kim *et al*. 2014), whereas little attention has been paid to wood biodegradation. Profiling wood chips could help growers optimize their production media and reduce production costs (Royse *et al*. 2001).

L. edodes extractives contain antibacterial substances (Yamamoto *et al*. 1997; Hirasawa *et al*. 1999; Wu *et al*. 2007). However, oak wood extractives can be inhibitory to the growth of *L. edodes* (Leatham and Griffin 1984), and oak wood must be pretreated before *L. edodes* cultivation. *L. edodes* produces lignocellulolytic enzymes during solid-state and submerged fermentation of various plant raw materials (Elisashvili *et al*. 2008). It also produces cellulolytic enzymes, including hemicellulases, ligninolytic enzymes, glucoamylase, pectinase, acid protease, cell wall lytic enzymes (laminarinase, 1,4-β-d-glucosidase, β-*N*-acetyl-d-glucosaminidase, α-d-galactosidase, β-d-mannosidase), acid phosphatase, and laccase (Leatham 1985). *L. edodes* is an important wood lignin-degrading fungus (Leatham 1986). It is implicated that degradation of the lignin occurs during the growth of *L. edodes* (Barry *et al*. 1998). The overall effect of *L. edodes* on oak is similar to that of many white-rot fungi, which simultaneously degrade all cell wall components (Vane *et al*. 2003; Vane 2003). Unfortunately, cases of shiitake dermatitis have been recorded (Hérault *et al*. 2010; Boels *et al*. 2014), and inexplicable cases have become more prevalent among mushroom growers in China. The biodegradation of wood by *L. edodes* is not well understood, along with its potential for reuse and environmental safety issues during cultivation of *L. edodes*. The aim of this study was to recognize the mushroom bioconversion and reveal the potential environmental safety hazards. *Quercus baronii* (*Quercus baronii* Skan var. Baronii) wood was firstly prepared during *L. edodes* growth, and its chemical structure was examined and analyzed by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), thermogravimetric analysis (TGA), and thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS).

EXPERIMENTAL

The bioconversion scheme of *Q. baronii* wood during *L. edodes* growth was established as shown in Fig. 1.

Fig. 1. Wood bioconversions during the artificial cultivation of *L. edodes*

Materials

Q. baronii wood was collected from Tongbaishan Forest, Zhumadian, China, and crushed into particles (sample XG0). The mycelium of *L. edodes* was industrial grade (Biyang Dadi Industry Co., Ltd., Zhumadian, China). Ethanol, benzene, acetic acid, H_2O_2, and KOH used in experiments were analytical grade reagents (Hunan Chemical Reagent Factory, Changsha, China).

Methods

Bioconversion process

XG0 particles (1.0 ton) were steamed for 60 h to ensure further decomposition, and then 2 kg portions were packed into plastic bags and tied with rope. These bags were drilled and inoculated with *L. edodes* mycelium. Inoculated XG0 particles were stored in a confined space under high humidity for 140 days. *L. edodes* mycelium survived in some samples (XG2) and died in others (XG1). After small fruiting bodies of *L. edodes* had grown, XG2 samples were placed in a plastic shed with ventilation and sunlight during the day and no ventilation at night. The small fruiting bodies lived in some samples (XG4) and died in others (XG3). After the XG4 samples had raised *L. edodes* fruiting bodies five times, these samples were classified as waste wood (XG5).

Component determination

The 40- to 60-mesh wood powder was dried to 0% moisture content, and 5 g (weighed to an accuracy of 0.1 mg) were weighed and placed in a cotton bag tied with cotton thread and extracted with ethanol-benzene solution (2:1 v/v) at 85 to 90 °C for 6 h. The extracted flour was dried to 0% moisture content and weighed to calculate the extractives content. To determine the hemicellulose content, the extracted flour was treated in 17.5% KOH solution at room temperature for 24 h (1:5 v/v). The KOH-extracted flour was filtered, washed five times with 0.5% acetic acid, dried to 0% moisture content, and weighed. To determine the lignin content, the KOH-extracted flour was treated in acetic acid-H_2O_2 solution (1:5 v/v) at room temperature for 36 h. The treated flour was filtered, washed five times with water, dried to 0% moisture content, and weighed. Two parallel samples were used.

Thermogravimetric analysis

For TG analysis, 5 to 7 mg of each powdered sample was used. TG curves were recorded from room temperature to 800 °C on a Pyris 6 thermogravimetric analyzer (Perkin

Elmer, Waltham, MA, USA) using a carrier gas (N_2) velocity of 40 mL/min and a heating rate of 20 °C/min.

FT-IR analysis

FT-IR spectra were obtained on an IR100 spectrophotometer (Shimadzu, Tokyo, Japan) using KBr discs containing 1% finely ground sample (Peng *et al*. 2014a; Xue *et al*. 2014).

XRD analysis

After sample preparation, the samples were examined using an XD-2 diffractometer (Beijing General Instrument Co., Ltd., Beijing, China) with Cu radiation (λ = 1.5406 nm), 36 kV voltage, and 20 mA current. The 2θ value was scanned continuously with a linkage scanning system (rotary half-cone 2θ) from 5° to 42°, at a scanning velocity of 2°/min and a scan step of 0.01°. A graphite crystal monochromator was used, with slit device widths of DS = 1°, SS = 1°, and RS = 0.3 mm (Peng *et al*. 2014b).

TD-GC-MS analysis

For each sample, 5 g was placed in the sample tubes of a Master TD thermal desorber (DANI Instruments S.p.A., Cologno Monzese, Italy, and the sample tubes were purged with 120 °C He for 30 min with the following conditions: trap adsorption temperature, 120 °C; trap resolution temperature, 130 °C; valve temperature, 130 °C; and transmission line temperature, 130 °C. The volatiles were desorbed for 15 min and analyzed by an online linked gas chromatograph/mass spectrometer (GC/MS; models 6890N and 5795C, Agilent Technologies, Santa Clara, CA, USA), which was linked to a mass selective detector. An elastic quartz capillary column (DB-5MS; 30 m × 0.25 mm × 0.25 μm) coated with a neutral phase (cross-linked 5% phenyl methyl silicone) was used. The carrier gas was helium, and the injection port temperature was 280 °C. The GC temperature program was as follows: from room temperature to 45 °C for 3 min, increased at 8 °C/min to 120 °C, increased 20 °C/min to 300 °C, and 300 °C for 5 min. The split injection ratio was 30:1. The MS program scanned over a range of 29 to 500 AMU (m/z) at an ionizing voltage of 70 eV. The flow velocity of the He carrier gas was 1.2 mL/min. The ion source temperature was 230 °C, and the quadropole temperature was 150 °C (Peng *et al*. 2012).

RESULTS AND DISCUSSION

Analysis of Chemical Composition

Q. baronii wood, a solid and rot-resistant timber, contains protein, carbohydrate, fat, and other components. It is particularly rich in starch, tannin, and other nutrients and very suitable for planting various edible mushrooms including *L. edodes*, and *Armillaria*. *Q. baronii* wood needs to be fully degraded so that *L. edodes* can absorb low molecular weight nutrients that promote mycelium growth. Steaming is an effective method of wood degradation. When *Q. baronii* wood was degraded by steam for 60 h, it was suitable for cultivation of *L. edodes* mycelium. If *Q. baronii* wood was inadequately steamed, *L. edodes* mycelium would not live through the entire life cycle and produce fruiting bodies. *Q. baronii* wood contained four chemical constituents (extractives, cellulose, hemicellulose, and lignin). These chemical constituents would be changed during the growth of *L. edodes*

(Table 1). The extractives, cellulose, hemicellulose, and lignin contents of *Q. baronii* wood were 3.09, 20.40, 22.86, and 53.64%, respectively. During 100 °C water vapor treatment, some wood extractives were evaporated, volatilized, and degraded, Cellulose and hemicellulose were hydrolyzed and degraded, but limited changes occurred for lignin content. Table 1 shows that *L. edodes* mycelium did not grow in *Q. baronii* wood if cellulose was insufficiently degraded and wood extractives were excessively lost, whereas *L. edodes* mycelium grew in *Q. baronii* wood if cellulose was sufficiently degraded and wood extractives were adequately retained. *L. edodes* mycelium gradually multiplied and rotted the wood, and the *Q. baronii* wood continued to biodegrade. After *L. edodes* was cultivated five times, cellulose content degraded from 53.64 to 15.56%. Extractives and lignin contents remained basically unchanged, but hemicellulose content increased from 20.40 to 56.10%. When extractives, cellulose, hemicellulose, and lignin contents were maintained at a relatively stable ratio of 8.72, 25.30, 21.29, and 44.70%, *L. edodes* mycelium and *L. edodes* fruiting bodies could grow normally.

Table 1. Chemical Composition of Wood during *L. edodes* Cultivation

Sample	Extractives (%)	Hemicellulose (%)	Lignin (%)	Cellulose (%)
XG0	3.09	20.40	22.86	53.64
XG1	2.66	23.80	21.65	51.88
XG2	8.72	25.30	21.29	44.70
XG3	6.73	47.50	19.62	26.15
XG4	8.50	26.20	21.14	44.16
XG5	7.38	56.10	20.96	15.56

XRD Analysis

During the steaming of wood and the growth of *L. edodes* mycelium and fruiting bodies, the cellulose in wood was degraded, which changed the wood structure. XRD diffraction was used to measure cellulose crystallinity in the six wood samples obtained during *L. edodes* cultivation (Fig. 2). I_{002} was the intensity of the peak at $2\theta = 22°$ in the crystal region, and I_{am} was the diffracted intensity of the peak at $2\theta = 18°$ in the amorphous region. The relative crystallinity C_r was calculated by Eq. 1:

$$C_r\ (\%) = (I_{002} - I_{am})/I_{002} \times 100 \quad (1)$$

The I_{am}, I_{002}, and C_r values are shown in Table 2. These results showed that the amorphous cellulose increased after steaming, and then it decreased during the growth of mycelium and *L. edodes*. I_{am} and I_{002} were both more than 0, indicating that the remaining cellulose residue was not completely biodegraded during the growth of mycelium and *L. edodes*. After steaming, crystal cellulose swelled and the crystalline structure was destroyed. Hydroxyl (−OH) groups in carbohydrates were desorbed, allowing fungal mycelium to bond with the wood and survive. Mycelium did not survive in the XG1 sample because the crystalline structure was not been adequately broken down. During mycelium growth, water evaporated from the wood, and increased intramolecular hydrogen bonding. *L. edodes* survived in the XG3 sample because of high cellulose crystallinity due to significant water loss. After *L. edodes* was cultivated and picked five times, cellulose crystallinity was 17.63%, and cellulose content was 15.56%. Though *L. edodes* was expected to survive and produce fruiting bodies, the mycelium and nutrient contents were

both reduced, and production was abandoned at this stage because the *L. edodes* yield was too low in practice.

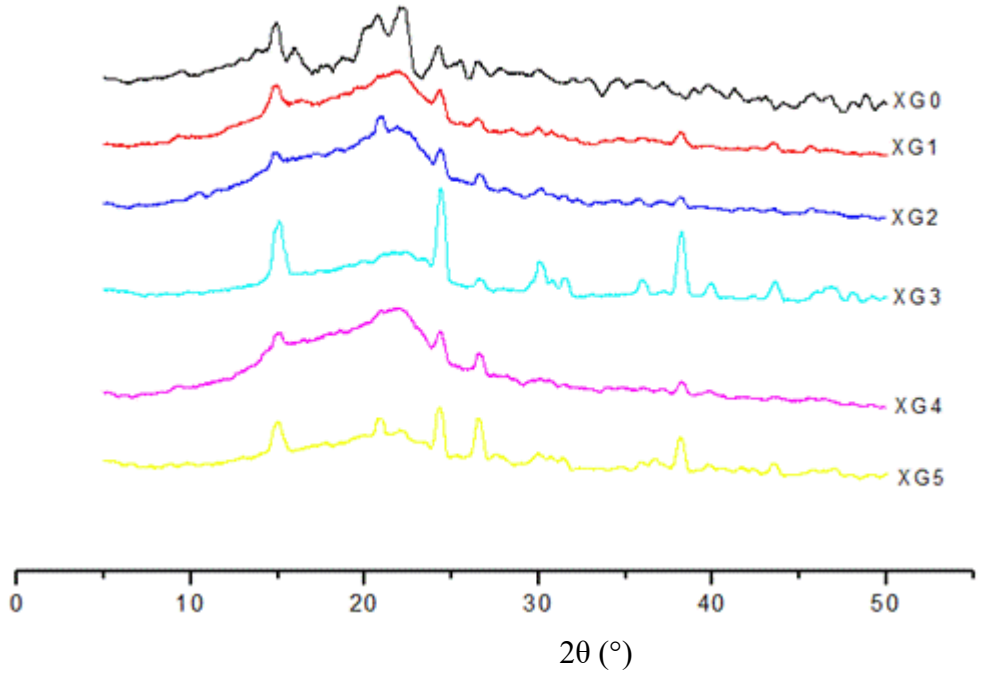


Fig. 2. XRD curves of natural, steamed, and biodegraded wood

Table 2. Crystallinity of Natural, Steamed, and Biodegraded Wood

Sample	XG0	XG1	XG2	XG3	XG4	XG5
I_{am} (cps)	167	375	562	222	472	257
I_{002} (cps)	479	556	583	319	611	312
C_r (%)	65.14	32.55	3.60	30.41	22.75	17.63

FT-IR Analysis

After wood steaming and mycelium inoculation, *Q. baronii* wood would be fractured and degraded. FT-IR spectra were used to investigate the structural groups of *Q. baronii* wood and its biodegradation products (Fig. 3). The peaks at 3420, 2930, 1720, 1620, 1540, 1400, 1320, 1200, 1150, and 1050 to 1120 cm^{-1} were assigned to O–H stretching, –C–H stretching, unconjugated C=O stretching, conjugated C=O or C=C stretching, C–C stretching in ring, CH_2 bending, CH_3 bending, C=O stretching, and C–O stretching, respectively (Aggarwal *et al*. 2003; Kwon *et al*. 2013). All spectra showed similar patterns except with different intensities. The most typical bands (1600, 1510, and 1460 cm^{-1}) represented the aromatic regions of lignin (Yuan *et al*. 2011; Wen *et al*. 2014). After steam treatment and biodegradation, the lignin peak at 1600 cm^{-1} disappeared, and the two others were reduced, suggesting that lignin was biodegraded during *L. edodes* growth. After steaming, the peaks at 3420, 2920, 1620, 1540, 1450, 1400, and 1320 cm^{-1} first decreased and then increased, whereas the peaks at 1510, 1150, and 1050 to 1120 cm^{-1} decreased. The absorption peaks of unconjugated C=O stretching increased in XG1 and decreased in XG2. After biodegradation, almost all peaks first increased and then decreased; the absorption peaks of unconjugated C=O stretching increased in XG3 and XG5 and decreased in XG4. Mycelium and *L. edodes* did not survive as the absorption

peaks of unconjugated C=O stretch increased, but grew as the absorption peaks of unconjugated C=O stretch decreased.

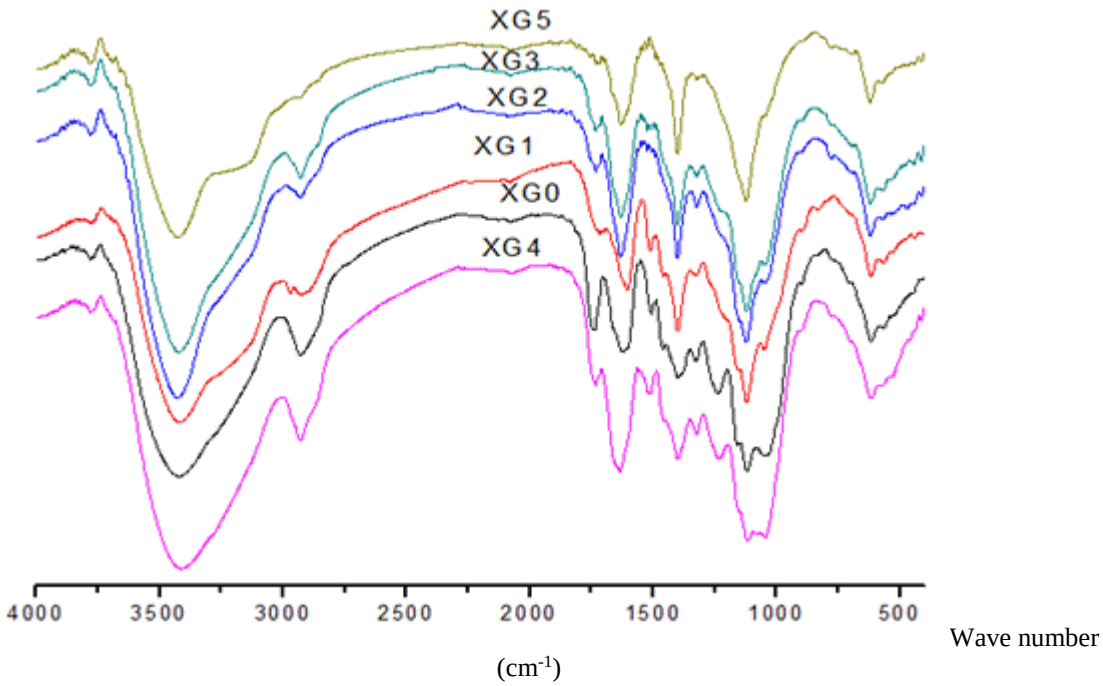


Fig. 3. FT-IR spectra of natural, steamed, and biodegraded wood

TG Analysis

During the artificial cultivation of *L. edodes*, *Q. baronii* wood was degraded by steam and mycelium. The extractives and macromolecules of wood were transformed into lower molecular weight compounds, which were characterized by TGA and DTG (Fig. 4). TGA showed weight changes in a controlled atmosphere with variations in temperature. Under a hot N_2, *Q. baronii* wood reacted via oxidation, reduction, hydration, dehydration, and decomposition, leading to weight loss. The XG0, XG1, XG2, XG3, XG4, and XG5 samples were investigated by TGA between room temperature and 804 °C. The thermal degradation of three samples proceeded over a wide temperature range (100 to 804 °C; Fig. 4; Tables 3). The thermal stability of samples was almost the same at less than 50% weight loss, but there were obvious differences for weight losses greater than 70%. The samples with higher thermal stability were more suitable for the growth of mycelium and *L. edodes*. Similar to the extractives results, the samples with lower weight loss were suitable for the growth of mycelium, but those with higher weight loss were suitable for the growth of *L. edodes* fruiting bodies (Table 4).

The DTG curves presented the weight loss rates, and DTG_{max} was the maximum thermal degradation rate, which estimated the degree of thermal degradation (Gedemer 1974). The DTG_{max} values were 374, 390, 379, 383, 390, and 365 °C for the XG0, XG1, XG2, XG3, XG4, and XG5 samples, respectively. The temperature of DTG_{max} decreased with increased hemicellulose content (Yang *et al*. 2006). Similar to the trends in hemicellulose content, the samples with higher hemicellulose content were suitable for mycelium growth, but those with lower hemicellulose content were suitable *L. edodes* fruiting bodies.

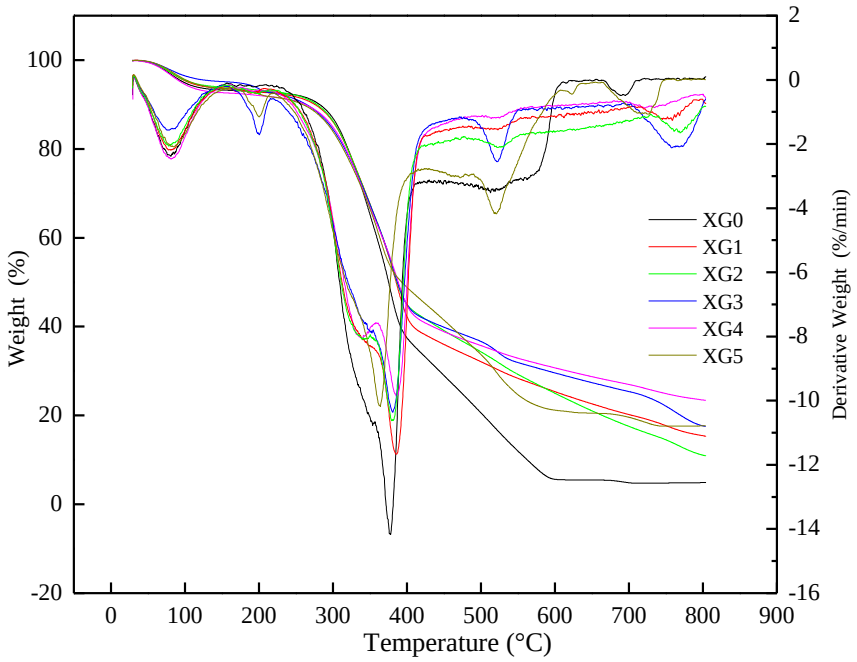


Fig. 4. TGA/DTG thermal curves of natural, steamed, and biodegraded wood

Table 3. Temperature and Weight Loss of Different Wood Samples

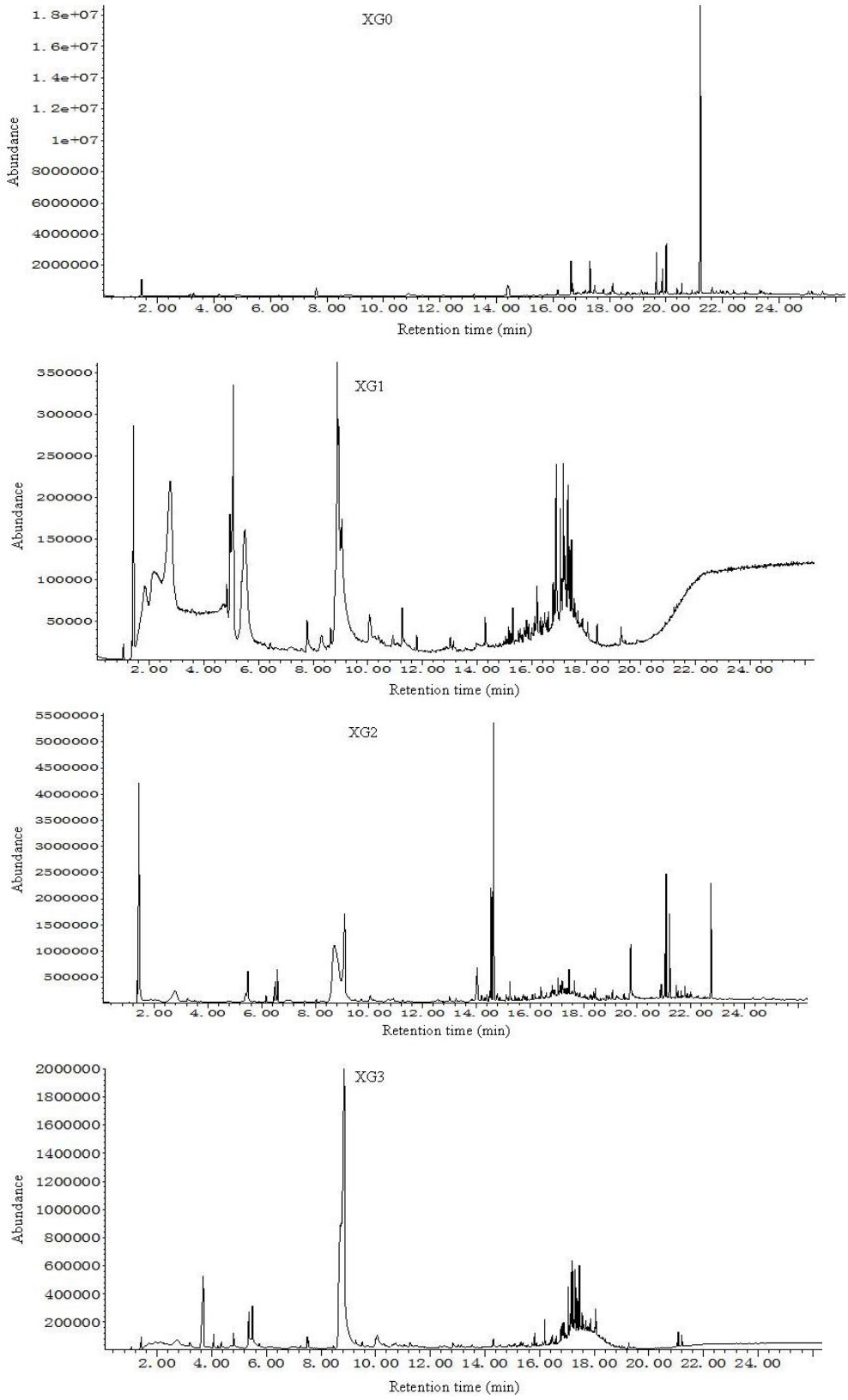
	Temperature (°C)					
Weight Loss (%)	XG0	XG1	XG2	XG3	XG4	XG5
10	282	275	278	264	262	259
30	341	344	344	343	342	341
50	375	385	386	386	388	392
70	443	526	541	590	617	519

Table 4. Weight Loss and Temperatures of Different Wood Samples

	Weight Loss (%)					
Temperature (°C)	XG0	XG1	XG2	XG3	XG4	XG5
804	95.11	84.69	89.09	82.46	76.61	82.34
100	5.11	4.64	4.52	3.57	5.45	4.38
120	6.19	5.74	5.51	4.35	6.71	5.61

TD-GC-MS Analysis on Wood during the Artificial Cultivation of *L. edodes*

According to the above bioconversion during the artificial cultivation of *L. edodes*, different wood samples were obtained. The total ion chromatograms of these six samples obtained by TD-GC-MS are shown in Fig. 5. The relative content of each component was counted by area normalization. Subsequent analysis of the MS data using the NIST standard MS map (Cong and Li 2003; Peng *et al*. 2012; Peng *et al*. 2015) identified the individual components (Tables 5 through 10).


XG0
Abundance
Retention time (min)
XG1
Abundance
Retention time (min)
XG2
Abundance
Retention time (min)
XG3
Abundance
Retention time (min)

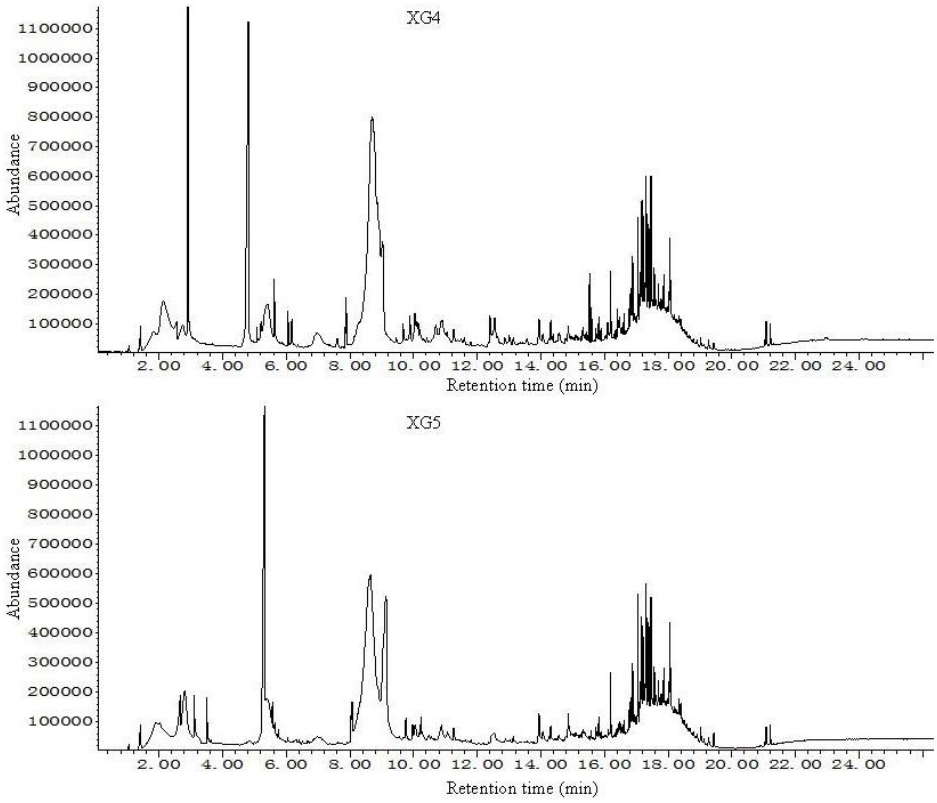


Fig. 5. Total ion chromatograms of natural, steamed, and biodegraded wood

Table 5. TD-GC-MS Analysis of Wood

Retention Time(min)	Peak Area (%)	Component
3.182	0.44	2,3-Butanediol
7.630	2.06	α-Pinene
10.883	0.45	2-Methoxy-phenol
13.201	0.33	4,6,6-Trimethyl-bicyclo[3.1.1]hept-3-en-2-one
16.180	1.06	Butylated hydroxytoluene
16.642	5.30	1,1'-(1,3-Propanediyl)bis-benzene
16.810	0.41	Eicosane
17.041	0.56	Cedrol
17.104	0.58	2,6,10,14-Tetramethyl-hexadecane
17.146	0.95	(2r-cis)-α,α,4a,8-Tetramethyl-1,2,3,4,4a, 5,6,7-octahydro-2-naphthalenemethanol
17.251	1.16	1,1'-(1,3-Propanediyl)bis-benzene
17.481	2.64	7 -Phenyl-bicyclo[4.2.1]nona-2,4,7-triene
17.796	0.98	Octadecamethyl-cyclononasiloxane
18.016	0.35	2,5- Dichloro-2,5-cyclohexadiene-1,4-dione
18.090	2.70	1,4-Diphenyl-1,3-butadiene
18.216	0.95	1,1'-(1,3-Butadienylidene)bis-benzene
18.415	0.67	1,1'-(1-Methyl-2-butynyli dene)bis-benzene
18.835	0.18	(1-Methylenebutyl)-benzene
19.328	0.45	2,4-Bis[(trimethylsi lyl)oxy]-benzoic acid, trimethylsilyl ester
20.922	0.86	1,2-Diphenyl-2-propen-1-one
22.034	0.60	Hippuric acid n,o-d-methyl derivative
22.381	0.53	Terephthalic acid, di(2-ethylhexyl) ester

Table 6. TD-GC-MS Analysis of the XG1 Sample

Retention Time (min)	Peak Area (%)	Component
1.43	2.99	Carbon dioxide
2.773	31.39	Benzene
5.070	10.74	Acetic acid
5.501	12.61	Furfural
8.889	16.47	Phenol
9.047	8.01	Phenol
16.904	4.82	Cis-1-ethylideneoctahydro-7 a-methyl-1H-indene
17.167	7.25	[1R-(1α,7β,8a.a lpha.)]-1,2,3,5,6,7,8,8a-Octa hydro-1,8a-dimethyl-7-(1-methyleth enyl)-naphthalene
17.324	5.72	(1Z,3aα,7aβ)-1-Ethylideneoctahydro-7 a-methyl-1H-indene

Table 7. TD-GC-MS Analysis of the XG2 Sample

Retention Time (min)	Peak Area (%)	Component
1.430	12.07	Unidentified substances
2.784	3.25	Benzene
5.490	2.46	Acetic acid
6.508	1.24	[R-(R*,R*)]-2,3-Butanediol
6.592	1.19	[R-(R*,R*)]-2,3-Butanediol
8.721	20.86	Phenol
9.099	11.34	Phenol
14.040	3.09	Phthalic anhydride
14.565	4.92	1,3-Diisocyanato-2-methyl-benzene
14.649	10.02	2,4-Diisocyanato-1-methyl-benzene
14.785	0.76	2-Undecenal
15.257	0.78	1,3-Dihydro-5-methyl-2H-benzimidazol-2-one
15.761	0.81	Megestrol acetate
16.107	0.32	(R,R)-(+)-3,3,4-Trimethyl-4-p-tolyl-cyclopentanol
16.191	0.39	2,6-Bis(1,1-dimethylethyl)-phenol
16.842	2.03	Caryophyllene
17.051	3.89	Cedrol
17.460	1.42	2,6,10,14-Tetramethyl-pentadecane
17.660	1.52	1-Benzyl-2-bromo-cyclopropane
19.758	3.23	6-Octadecenoic acid
20.912	0.86	Propofol
21.090	4.74	α-Acetamidocinnamic acid
21.216	2.64	1-Benzyl-3,3-dimethyl-2 -phenyl-azetidine
21.468	0.84	1,2-Benzenedicarboxylic acid, mono (2-ethylhexyl) ester
21.783	0.84	1-Phenyl-3(1-phenylethylamino)but- 2-en-1-one
21.982	0.58	2-Amino-5-phenyl-3,4-furandicarbon itrile
22.758	3.93	(all- E)-2,6,10,15,19,23-hexamethyl- 2,6,10,14,18,22-Tetracosahexane

Table 8. TD-GC-MS Analysis of the XG3 sample

Retention Time (min)	Peak Area (%)	Component
3.686	6.22	Acetic acid
5.501	5.83	2,3-Butanediol
8.847	63.31	Phenol
16.894	2.97	Guaiol
17.051	1.76	Cedrol
17.209	6.42	Agarospirol
17.46	8.09	2,6,10,14-Tetramethyl-pentadecane
17.565	4.10	(E)-1,2,3-Trimethyl-4-pro penyl-naphthalene
18.058	1.28	2,6,10,14-Tetramethyl-hexadecane

Table 9. TD-GC-MS Analysis of the XG4 sample

Retention Time (min)	Peak Area (%)	Component
2.144	8.70	Acetic acid
2.909	3.38	Acetic acid
4.798	9.21	Acetic acid
5.406	5.38	Furfural
5.637	1.09	Propylene Glycol
7.882	0.89	Butyrolactone
8.700	38.28	Phenol
9.026	4.69	Phenol
15.530	1.21	[1S-(1α,3aβ,4α,8aβ)]-Decahydro-4,8, 8-trimethyl-9-methylene-1,4-methanoazulene
16.191	1.7	2,4-Bis(1,1-dimethylethyl)-phenol
17.209	8.51	[1R-(1α,7β,8aα)]-1,2,3,5,6,7,8,8a-Octahydro-1,8a-dimethyl-7-(1-methylethenyl)-naphthalene
17.314	6.94	[2R-(2α,4aα,8aβ)]-2-Naphthalenemethanol, decahydro-α,α,4a-trimethyl-8-methylene-
17.565	3.44	2-(P-tolylmethyl)-p-xylene
17.870	2.95	1,1'-Oxybis-hexadecane
18.058	3.63	2,6,10,14-Tetramethyl-hexadecane

Table 10. TD-GC-MS Analysis of the XG5 sample

Retention Time (min)	Peak Area (%)	Component
2.668	1.81	Benzene
2.815	4.24	Benzene
3.109	1.45	Acetic acid
3.518	0.6	2-bromo-1-chloro-Propane
5.301	13.79	Acetic acid
8.071	1.15	Butyrolactone
8.637	32.88	Phenol
9.13	11.43	Phenol
16.191	1.16	2,4-Bis(1,1-dimethylethyl)-Phenol
16.894	4.65	[1R-(1α,7β,8aα)]- 1,2,3,5,6,7,8,8a-Octa hydro-1,8a-dimethyl-7-(1-methyleth enyl)-naphthalene
17.156	4.4	[1aR-(1aα,3aα,7bα)]-1a,2, 3,3a,4,5,6,7b-Octahydro-1,1,3a,7-tetramethyl-1H-Cyclopropa[a]naphthalene
17.46	9.95	2,6,10,14-Tetramethyl-Pentadecane
17.87	4.78	3-Methyl-heptadecane
18.058	7.72	2,6,10,14-Tetramethyl-Hexadecane

GC-MS analysis showed the molecular distribution of wood and biodegraded samples. The retention times of the different components from wood and biodegraded samples exhibited a particular trend. The molecules with retention times of ≤ 5, ≤ 10, ≤ 15, and > 15 min are listed in Table 11. The samples suitable for the growth of mycelium and *L. edodes* contained volatiles with retention times of > 15 min. The molecular contents of samples are listed in Table 12. The samples that contained more phenol and derivatives and less acetic acid were suitable for mycelium growth. The samples that contained less phenol derivatives and more acetic acid were suitable for *L. edodes* fruiting body growth. However, the biodegraded wood contained a certain amount of benzene, phenol, and their derivatives, which are toxic. The release of toxic volatiles harms the health of farmers during the artificial cultivation of *L. edodes*. Thus, there are potential environmental safety hazards during the artificial cultivation of *L. edodes*.

Table 11. Molecular Relative Content in Different Retention Times (%)

Sample	Retention Time			
	≤ 5 min	≤ 10 min	≤ 15 min	> 15 min
XG0	0.44	2.06	0.78	20.93
XG1	34.38	47.83	0	17.79
XG2	15.32	37.09	18.79	28.82
XG3	6.22	69.14	0	24.62
XG4	21.29	50.33	0	28.38
XG5	8.1	59.25	0	32.66

Table 12. Molecular Content of Samples (%)

Sample	Benzene and its derivatives	Phenol and its derivatives	Acetic Acid	Others
XG0	8.71	3.09	0.00	12.41
XG1	31.39	24.48	10.74	33.39
XG2	19.81	33.43	2.46	44.32
XG3	0	63.31	6.22	30.45
XG4	0	44.67	21.29	34.04
XG5	6.05	45.47	15.24	33.25

CONCLUSIONS

1. During the artificial cultivation of *L. edodes*, the bioconversion of *Q. baronii* wood was characterized by XRD, TGA/DTG, FT-IR, and TD-GC-MS. Mycelium grew in wood if cellulose was sufficiently degraded and wood extractives were adequately retained, whereas *L. edodes* grew in wood if the four components maintained a relatively stable quality ratio.
2. The TD-GC-MS analysis result determined that the samples with more phenol derivatives and less acetic acid were suitable for the growth of mycelium, whereas the ones with less phenol derivatives and more acetic acid were suitable for the growth of *L. edodes*.

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