Original article

Pyrolysis molecule of Torreya grandis bark for potential biomedicine

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A B S T R A C T

Torreya grandis is a unique tree species in China. Although full use has been made of the timber, the processing and utilization of the bark has not been effective. In order to explore a new way to utilize the bark of Torreya grandis, a powder of T. grandis bark was prepared and analyzed qualitatively and quantitatively. Differential scanning calorimetry (TG) and pyrolysis gas chromatography-mass spectrometry (PY-GC/MS) revealed many bioactive components in the bark of T. grandis, such as acetic acid, 2-methoxy-4-vinyl phenol, D-mannose, and furfural. These substances have potential broad applications in the chemical industry, biomedicine, and food additives. The chemical constituents of the bark of T. grandis suggest a theoretical basis for the future development and utilization of the bark of T. grandis.

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1. Introduction

The tree Torreya grandis grows as high as 25 m, with a diameter at breast height of 65 cm, and is mainly found in southern Jiangsu, Zhejiang, northern Fujian, southern Anhui and Daibie Mountains, Northern Jiangsu, and other mountains below 1400 m in altitude (Zhu et al., 2015). In the valley of the shade, the trees grow well, due to a warm and humid environment, with winter temperature of −15 °C without freezing damage (Li et al., 2014). The tree grows for 200 years old, it is usually propagated with seeds, with a high germination rate, generally up to 80% (Zeng et al., 2014).

Meanwhile Torreya seeds can be used to make oil, edible oil, lubricants, and wax. The acetic acid linaloid and rose oil contained in Torreya seeds are raw materials for the refinement of high-grade aromatics (Ni and Shi, 2014; Shi et al., 2009). The Torreya tree has a neat crown and rich foliage (Liu, 2018; Zong et al., 2018).

Big trees are planted alone as shade trees at the edge of lawn, or around buildings. They have strong anti-pollution ability and adapt to the urban ecological environment. They are widely used in greening, industrial areas, and have high economic value (Saeed et al., 2010; Chen et al., 2006). Torreya bark is pale yellow gray, dark gray, or grayish brown, with irregular longitudinal cracks. It is thick skinned on the outside layer of the tree (Wang et al., 2002).

Torreya grandis is an endemic tree in China, and its wood has many functions. Due to the lack of development and utilization of high value-added products, most T. grandis bark is used as firewood. We extracted the T. grandis bark as powder. Differential scanning calorimetry (TG) and pyrolysis gas chromatography-mass spectrometry (PY-GC/MS) were used to study the pyrolysis reaction of the bark of Torreya grandis during heating and the types of high temperature catalytic cracking products in order to provide a new method for the utilization of high-grade resources of Chinese Torreya bark.

2. Material and methods

2.1. Experimental materials

Torreya samples were collected from the Xixia Forest District in Henan Province. The bark was processed into powder of 40–60 meshes by a pulverizer, followed by baking at 55 °C under a vacuum of 0.01 MPa to dryness for use (Wang et al., 2018).
2.2. TG analysis

The Torreya grandis bark was analyzed by thermogravimetry (TGA Q50 V20.8 Build 34). The nitrogen release rate was 60 mL/min. The temperature program of TG started at 30 °C and rose to 300 °C at a rate of 5 °C/min (Duan et al., 2018).

2.3. Py-GC/MS analysis

Py-gas chromatography (GC)/mass spectrometry (MS) triple system, Py using Frontier’s PY-2020iS cracker, GC/MS Agilent 5975C/6890N GC–MS (Ge et al., 2017; Li et al., 2015). Gas chromatography conditions: The column was a DB-5 MS (30 m × 0.25 mm × 0.25 μm) elastic silica capillary column manufactured by Agilent Company (Peng et al., 2017). The carrier gas was helium, inlet temperature is 250 °C; column ascending conditions: 50–300 °C at 10 °C/min, 30:1 split injection (Peng et al., 2016a, 2016b). Mass spectrometry conditions: ionization mode El, electron energy 70 eV, He flow rate 1 ml/min, scanning mass range 35–550 AMU (m/z) (Peng et al., 2016a, 2016b).

3. Results and analysis

3.1. Behavior of the Torreya grandis bark during heating

In order to study the thermal decomposition of the bark of Torreya grandis, we conducted a TGA test on the samples (Fig. 1). The TGA analysis of the bark of Torreya grandis revealed that the weightlessness process of pyrolysis process can be divided into three stages. The first stage is the evaporation stage of water, which is 23–90 °C. At this stage, the weight loss of the sample is very small, and may be caused by the loss of moisture in the sample (Debbarma et al., 2018). The second stage is between 90 °C and 175 °C, which is the transition phase of the preheating solution. The differential curve of this stage is relatively flat, indicating that the pyrolysis rate is relatively stable, and the sample begins to show obvious weight loss (Lans and Vodovotz, 2018). Weightlessness is mainly due to a small amount of polymer depolymerization and recombination in the sample. The third stage is between 175 °C and 300 °C. Torreya grandis bark rapidly decomposes and produces a large amount of volatile gas, resulting in weightlessness (Raba et al., 2018). The three stages have different kinetic parameters and reaction mechanisms, and the final bark residual mass of T. grandis is 76.29%. During the whole process, the bark heat weight of Torreya grandis was only about 23%, the weight loss was small, the mass change was small, and the speed was low. The thermal decomposition process of the bark of Torreya grandis under 300 °C was analyzed by TG experiment, which provided a reference for the thermal decomposition of the bark of Torreya grandis under certain conditions. That is to say, in order to ensure that the organic matter content in the bark of Torreya grandis does not lose much during heat treatment, the temperature should be controlled below 90 °C in order to make full use of the bark of Torreya grandis (Wu et al., 2018).

3.2. Identification of pyrolysis products of Torreya grandis bark

For further study, PY-GC/MS experiments were carried out. Under the above experimental conditions, the pyrolysis gas of Torreya grandis bark was analyzed by on-line GS/MS (Francisco et al., 2011). The chromatographic ion chromatogram and mass spectrometry data were obtained (Fig. 2). Based on the total ion current plot, the microprocessor configured by GC–MS used area normalization to calculate the relative percentages of peak areas (Vielhauer et al., 2011; Mehrabian et al., 2015). The NIST standard library was used to search mass spectrometry data automatically of each peak by electronic computer (Lin et al., 2018; Okamoto et al., 2018). The chromatograms of each peak were compared with manual spectrum analysis and the published relevant mass spectrometry data (Kim et al., 2018a, 2018b). Torreya grandis bark pyrolysis products of the main chemical composition were compared (Fang et al., 2018). 225 peaks were found in the gas chromatogram of pyrolysis products, which were analyzed by MS and literature review, 205 compounds were identified (Table 1). Some of these substances were analysed briefly below.

Acetone (3.12%) is an important raw material for organic synthesis, used in the production of epoxy resin, polycarbonate, plexiglass, and other solvents, and used as extractant and diluent (Zhang et al., 2018a, 2018b). In the pharmaceutical industry, it is one of the raw materials of vitamin C and anesthetic sophora, and is also used as a vitamin and hormone production process extractant. Acetone is one of the raw materials for the synthesis of pyrethroid in pesticide industry (Fedorovich et al., 2018; Yang et al., 2018).

2, 3-Butanedione (0.49%) is mainly used to make food flavors (Kastier et al., 2018). It is the main flavor of cream, and can also
| No. | Retention time (min) | Relative content (%) | Compounds name |
|-----|---------------------|----------------------|----------------|
| 1   | 3.71                | 0.06                 | 2-Propenamide  |
| 2   | 4.09                | 14.86                | Ethyne, fluoro-|
| 3   | 4.25                | 6.37                 | Carbon dioxide|
| 4   | 4.54                | 0.22                 | Methylamine, N,N-dimethyl-|
| 5   | 4.70                | 3.12                 | Acetone        |
| 6   | 5.13                | 0.10                 | 2-Propan-1-ol  |
| 7   | 5.20                | 0.21                 | 2-Propan-1-ol, 2-methyl-|
| 8   | 5.24                | 0.54                 | Acetaldehyde, hydroxy-|
| 9   | 5.46                | 0.49                 | 2,3-Butanedione|
| 10  | 5.70                | 1.56                 | Furan, 2-methyl-|
| 11  | 5.80                | 0.93                 | Acetic acid    |
| 12  | 5.98                | 2.72                 | Acetic acid    |
| 13  | 6.47                | 0.35                 | Butanal, 3-methyl-|
| 14  | 6.60                | 1.83                 | 2-Propanone, 1-hydroxy-|
| 15  | 7.10                | 0.16                 | Acetic acid, sodium salt|
| 16  | 7.21                | 0.23                 | Heptane        |
| 17  | 7.39                | 0.22                 | 1,2-Ethanediol |
| 18  | 7.55                | 0.41                 | Furan, 2,5-dimethyl-|
| 19  | 7.74                | 0.53                 | Propanoic acid |
| 20  | 7.95                | 0.07                 | 3-Methylpyridazine|
| 21  | 8.01                | 0.08                 | Butyric acid hydrate|
| 22  | 8.40                | 0.26                 | 1H-Pyrole, 1-methyl-|
| 23  | 8.61                | 0.21                 | Pyridine       |
| 24  | 8.75                | 0.52                 | Pyrrole        |
| 25  | 8.98                | 0.06                 | Butanenitrile, 2,3-dioxo-, dioxime, O,O'-diacetyl-|
| 26  | 9.06                | 0.17                 | 2-Propanone, 1-hydroxy-|
| 27  | 9.12                | 0.82                 | Toluene        |
| 28  | 9.46                | 0.16                 | Acetylacetone  |
| 29  | 9.60                | 0.46                 | Propanoic acid, 2-oxo-, methyl ester|
| 30  | 9.76                | 0.20                 | 1,2-Cyclopentadien, trans-|
| 31  | 9.93                | 0.58                 | 3-Amino-s-triazole|
| 32  | 10.39               | 0.05                 | 3-Furaldehyde  |
| 33  | 10.46               | 0.06                 | Methanesulfonic acid, methyl ester |
| 34  | 10.71               | 0.09                 | Ethanol, 2-(2-aminoethyl)amino-|
| 35  | 10.76               | 0.07                 | 4-Aminopyridine|
| 36  | 10.92               | 0.07                 | Butanenitrile, 4-oxo-|
| 37  | 11.02               | 0.76                 | Furfural       |
| 38  | 11.08               | 0.34                 | 2-Cyclopenten-1-one|
| 39  | 11.22               | 0.23                 | 1H-Pyrole, 3-methyl-|
| 40  | 11.52               | 0.11                 | 1H-Pyrole, 3-methyl-|
| 41  | 11.69               | 0.43                 | 2-Furanmethanol|
| 42  | 12.00               | 0.11                 | Ethylbenzene   |
| 43  | 12.08               | 0.33                 | 2-Propanone, 1-(acetoxy)-|
| 44  | 12.19               | 0.15                 | 1,2-Cyclopentanediene|
| 45  | 12.25               | 0.14                 | p-Xylene       |
| 46  | 12.69               | 0.13                 | 4-Cyclopentene-1,3-dione|
| 47  | 12.86               | 0.08                 | 1-Nonene       |
| 48  | 12.96               | 0.14                 | Bicyclo[4.2.0]octa-1,3,5-triene|
| 49  | 13.04               | 0.11                 | Propanedioic acid, propyl-|
| 50  | 13.46               | 0.12                 | 2-Cyclopenten-1-one, 2-methyl-|
| 51  | 13.58               | 0.12                 | Ethanone, 1-(2-furanyl)-|
| 52  | 13.68               | 0.34                 | 2(3H)-Furanone |
| 53  | 13.90               | 0.24                 | Hexane, 3,3,4-trimethyl-|
| 54  | 14.08               | 0.65                 | 2-Cyclopenten-1-one, 2-hydroxy-|
| 55  | 14.52               | 0.07                 | 2(3H)-Furanone, 5-methyl-|
| 56  | 14.58               | 0.09                 | 2,5-Furandione, 3-methyl-|
| 57  | 14.79               | 0.07                 | Dihydro-3-methylene-5-methyl-2-furanone |
| 58  | 15.05               | 0.08                 | Pentanoic acid, 4-methyl-|
| 59  | 15.17               | 0.13                 | trans-1-Ethoxy-1-butene |
| 60  | 15.30               | 0.29                 | 2-Furanacarboxaldehyde, 5-methyl-|
| 61  | 15.42               | 0.25                 | 2-Cyclopenten-1-one, 3-methyl-|
| 62  | 15.82               | 1.23                 | Phenol         |
| 63  | 16.11               | 0.19                 | Heptanoic acid |
| 64  | 16.14               | 0.07                 | 1-Decene       |
| 65  | 16.28               | 0.04                 | Glycerin       |
| 66  | 16.31               | 0.03                 | Diglycerol     |
| 67  | 16.36               | 0.16                 | 1H-1,2,4-Triazol-3-amine, 1-ethyl-|
| 68  | 16.48               | 0.23                 | 2-Methyliminohydroxy-1,3-oxazine|
| 69  | 17.04               | 0.11                 | 4(1H)-Pyrimidinone, 6-hydroxy-|
| 70  | 17.22               | 0.17                 | 2-Cyclohexen-1-one|
| 71  | 17.32               | 0.09                 | Hexane, 2,5-dimethyl-|
| 72  | 17.51               | 0.48                 | 2-Cyclopenten-1-one, 2-hydroxy-3-methyl-|
| 73  | 17.88               | 0.33                 | 2-Cyclopenten-1-one, 2,3-dimethyl-|
| No. | Retention time (min) | Relative content (%) | Compounds name |
|-----|----------------------|----------------------|----------------|
| 74  | 18.14                | 0.52                 | 1,3-Dioxol-2-one, 4,5-dimethyl- |
| 75  | 18.22                | 0.15                 | Phenol, 2-methyl- |
| 76  | 18.40                | 0.09                 | Benzene, n-butyl- |
| 77  | 18.64                | 0.09                 | Furaneol |
| 78  | 18.74                | 0.06                 | Acetophenone |
| 79  | 18.83                | 0.87                 | p-Cresol |
| 80  | 18.94                | 0.18                 | 6-Heptenoic acid |
| 81  | 19.01                | 0.13                 | Heptanoic acid |
| 82  | 19.10                | 0.41                 | Heptanoic acid |
| 83  | 19.20                | 0.09                 | Furfuryl hydroxymethyl ketone |
| 84  | 19.29                | 0.19                 | 3-Acetoxydodecanone |
| 85  | 19.39                | 0.98                 | Phenol, 2-methoxy- |
| 86  | 19.54                | 0.34                 | 2-Butanamine, 3-methyl- |
| 87  | 19.60                | 0.19                 | Furan, 2-methyl- |
| 88  | 19.73                | 0.20                 | 1-Cyclopropane-carbonitrile, 1-aminoo- |
| 89  | 19.97                | 0.22                 | Benzo[1,2-$d$]furan, 2-methyl- |
| 90  | 20.09                | 0.18                 | Maltol |
| 91  | 20.20                | 0.14                 | 2H-Pyran-3(4H)-one, dihydro-6-methoxy- |
| 92  | 20.24                | 0.09                 | 2-Cyclopenten-1-one, 3-ethyl-2-hydroxy- |
| 93  | 20.38                | 0.17                 | 2-Pentenoic acid, 4-hydroxy- |
| 94  | 20.57                | 0.08                 | Phenol, 3-ethyl- |
| 95  | 20.64                | 0.05                 | 2-Propanamine, N-methyl-N-nitroso- |
| 96  | 20.72                | 0.07                 | Benzyl nitrile |
| 97  | 20.88                | 0.63                 | 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methoxy- |
| 98  | 20.97                | 0.08                 | 2H-Pyran-2-one, tetrahydro- |
| 99  | 21.06                | 0.04                 | Cyclopropa[j]indene, 1,1a,6,6a-tetrahydro- |
| 100 | 21.18                | 0.14                 | 1-Methyl-3-piperidinemethanol |
| 101 | 21.28                | 0.18                 | Phenol, 4-ethyl- |
| 102 | 21.35                | 0.28                 | Cyclopentane, 2-methyl-1-methylethylene-3-[(1-methylthyl)enyl]- |
| 103 | 21.41                | 0.08                 | 2-Isopropyl-3-methoxy-cyclopropanecarboxylic acid, methyl ester |
| 104 | 21.54                | 0.86                 | Octanoic acid, silver(1+) salt |
| 105 | 21.58                | 0.82                 | 1,3-Dioxane-5-methanol, 5-ethyl- |
| 106 | 21.82                | 0.13                 | Cyclododecanone |
| 107 | 21.87                | 0.16                 | 4-Hydroxy-N-methyl-piperidine |
| 108 | 21.94                | 0.17                 | 4H-Pyran-4-one, 3,5-dihydroxy-2-methyl- |
| 109 | 22.00                | 1.54                 | Croscrofuran |
| 110 | 22.06                | 1.22                 | Catechol |
| 111 | 22.39                | 0.11                 | 1,4:3,6-Dianhydro-alpha-d-glucopyranose |
| 112 | 22.44                | 0.42                 | Benzo[1,2-$d$]furan, 2,3-dihydro- |
| 113 | 22.54                | 0.06                 | 1H-Benzimidazole, 2-ethyl- |
| 114 | 22.63                | 0.14                 | m-Guaiafol |
| 115 | 22.71                | 0.17                 | 5-Hydroxymethylfurural |
| 116 | 22.79                | 0.19                 | 2,6,10-Dodecatetraen-1-yl, 3,7,11-trimethyl-, (Z,E)- |
| 117 | 22.89                | 0.11                 | Cyclopentan-1-yl, 4-isopropyldiene-2-methyl- |
| 118 | 23.04                | 0.06                 | Benzyldiene-l-ornithine |
| 119 | 23.18                | 0.07                 | Phenol, 4-(2-propynyl)- |
| 120 | 23.26                | 0.05                 | 1,3-Cyclopentadiene, 5,5-dimethyl-2-propynyl- |
| 121 | 23.35                | 0.18                 | trans-2-Dodecen-1-ol, trifluoracetate |
| 122 | 23.38                | 0.23                 | 1,2-Benzenediol, 3-methyl- |
| 123 | 23.47                | 0.39                 | 1,2-Benzenediol, 3-methoxy- |
| 124 | 23.62                | 0.27                 | Hydroquinone |
| 125 | 23.71                | 0.10                 | 1-(Dimethylamino)pyrrole |
| 126 | 23.77                | 0.66                 | Phenol, 4-ethyl-2-methoxy- |
| 127 | 23.84                | 0.23                 | 1-Tridecane |
| 128 | 23.93                | 0.55                 | 1,2-Benzenediol, 4-methyl- |
| 129 | 23.98                | 0.18                 | Tridecane |
| 130 | 24.12                | 0.28                 | Indole |
| 131 | 24.26                | 0.39                 | 2-Allylphenol |
| 132 | 24.34                | 0.13                 | 2,6-Octadiene, 2,6-dimethyl- |
| 133 | 24.44                | 0.98                 | 2-Methoxy-4-vinylphenol |
| 134 | 24.64                | 0.12                 | 1,4-Benzenediol, 2-methyl- |
| 135 | 24.76                | 0.26                 | Biphenylene, 1,2,3,6,7,8,8a,8b-octahydro-, trans- |
| 136 | 24.79                | 0.21                 | Phenol, 4-(2-propynyl)- |
| 137 | 24.88                | 0.16                 | 2,4-Diaminophenol |
| 138 | 24.96                | 0.11                 | N-(2,6-Dimethyl-phenyl)-2-(2-methyl-5-nitro-imidazol-1-yl)-acetamide |
| 139 | 25.04                | 0.44                 | 9-Decenoic acid |
| 140 | 25.16                | 0.48                 | Eugenol |
| 141 | 25.20                | 0.15                 | Hexyl 8-methyl-2-enone |
| 142 | 25.26                | 0.14                 | (6R)-7a-Hydroxy-3,6-dimethyl-5,6,7,7a-tetrahydrobenzofuran-2(4H)-one |
| 143 | 25.33                | 0.26                 | Phenol, 2-methoxy-4-[(methoxymethyl)- |
| 144 | 25.43                | 0.25                 | 1H-Indene, 2-butyryl-6-hexyloctahydro- |
| 145 | 25.54                | 0.75                 | 1-Tetradecene |
| 146 | 25.66                | 0.69                 | 3,4-Altrosan |
| 147 | 25.73                | 0.35                 | Indole, 3-methyl- |

(continued on next page)
| No. | Retention time (min) | Relative content (%) | Compounds name |
|-----|---------------------|----------------------|----------------|
| 148 | 25.80               | 0.36                 | 1,4-Benzenediol, 2-methoxy- |
| 149 | 25.90               | 0.95                 | Vanillin |
| 150 | 25.99               | 0.26                 | trans-Isoeugenol |
| 151 | 26.13               | 0.33                 | Benzoic acid, 3-hydroxy-, methyl ester |
| 152 | 26.18               | 0.17                 | 4’-a-Methyl-8’-methylidene-decahydro-2‘H-dispiro[2.3.2.2.3]benzo[2.3-b][furan]-2’-one |
| 153 | 26.24               | 0.25                 | Cyclopentanol, 2-cyclopentylidene- |
| 154 | 26.44               | 0.21                 | Benzenemethanol, alpha,4-dimethyl- |
| 155 | 26.54               | 0.44                 | Z,Z-2,13-Octadecadien-1-ol |
| 156 | 26.63               | 1.09                 | trans-Isoeugenol |
| 157 | 26.71               | 0.41                 | E-9-Tetradecenoic acid |
| 158 | 26.83               | 0.39                 | 2-Isopropyl-5,6-dimethyl-1,3-oxathiane |
| 159 | 26.90               | 0.33                 | 1,5-Dodecadiene |
| 160 | 26.97               | 0.21                 | 1,5-Dodecadiene |
| 161 | 27.07               | 0.45                 | 1-Octadecene |
| 162 | 27.18               | 0.27                 | Pentadecane |
| 163 | 27.28               | 0.76                 | Apocynin |
| 164 | 27.41               | 1.03                 | 1-Chloroecospane |
| 165 | 27.47               | 1.56                 | 10-Methyltricyclo[4.3.1.1(2,5)]undecan-10-ol |
| 166 | 27.66               | 0.21                 | Cyclohexane, (3-chloro-1-propynyl)- |
| 167 | 27.83               | 0.14                 | 3-Penten-2-one, 3-bromo-4-methyl- |
| 168 | 27.89               | 0.20                 | 2-Furamethanamine |
| 169 | 27.97               | 0.28                 | 2-Propanone, 1-(4-hydroxy-3-methoxyphenyl)- |
| 170 | 28.07               | 0.17                 | (1-Methoxy-1-methylbut-2-enyl)benzene |
| 171 | 28.18               | 0.42                 | Dodecenoic acid |
| 172 | 28.25               | 0.20                 | Oleic Acid |
| 173 | 28.33               | 0.45                 | 4-(2,2,6,6-tetramethyl-3,5-dihydro-2H-pyran-2-yl)benzene |
| 174 | 28.46               | 0.17                 | 4-Methyl-2,5-dimethoxybenzaldehyde |
| 175 | 28.52               | 0.14                 | 4(1H)-Isobenzofuranone, hexahydro-3a,7a-dimethyl, cis(+/-)- |
| 176 | 28.58               | 0.12                 | 1,5-Dodecadiene |
| 177 | 28.61               | 0.10                 | 5-Butyl-1,3-oxathiolan-2-one |
| 178 | 28.69               | 0.69                 | Cetene |
| 179 | 28.81               | 0.08                 | 1-Octadecane |
| 180 | 28.86               | 0.10                 | 10-Methyltricyclo[4.3.1.1(2,5)]undecan-10-ol |
| 181 | 28.94               | 0.12                 | Cyclohexane, (3-chloro-1-propynyl)- |
| 182 | 29.16               | 0.09                 | 3-Penten-2-one, 3-bromo-4-methyl- |
| 183 | 29.55               | 0.21                 | n-Hexadecanoic acid |
| 184 | 29.65               | 0.33                 | Melezitose |
| 185 | 29.70               | 0.14                 | Estra-1,3,5(10)-trien-17.beta.-ol |
| 186 | 29.81               | 0.32                 | Estra-1,3,5(10)-trien-17.beta.-ol |
| 187 | 29.93               | 0.17                 | n-Hexadecanoic acid |
| 188 | 30.08               | 0.52                 | Benzene propanol, 4-hydroxy-3-methoxy- |
| 189 | 30.21               | 0.50                 | 6-tert-Butyl-2,4-dimethylphenol |
| 190 | 30.30               | 0.46                 | 1(5-Dimethylthyl)pyrazin-2-yl-ethan-1-one |
| 191 | 30.49               | 0.09                 | 2-Chloropropionic acid, hexadecyl ester |
| 192 | 30.59               | 0.26                 | 1-Heptadecene |
| 193 | 30.74               | 0.14                 | 2-Hydroxy-1,10-trimethyl-6,9-epoxydecalin |
| 194 | 30.81               | 0.06                 | Decanoic acid, 3-methyl- |
| 195 | 30.86               | 0.11                 | 2-Trimethylsilyl-1,3-dithiane |
| 196 | 30.95               | 0.32                 | tert-Butyldimethylsilyl 23-acetoxy-3,6,9,12,15,18,21-heptaoxatricosan-1-oate |
| 197 | 31.71               | 0.19                 | Thiazole[5,4-f]quinoline |
| 198 | 31.98               | 0.72                 | beta-(4-Hydroxy-3-methoxyphenyl)propionic acid |
| 199 | 32.09               | 0.54                 | 4-(1E)-3-Hydroxy-1-propenyl)-2-methoxyphenol |
| 200 | 32.14               | 0.25                 | Tetradecanoic acid |
| 201 | 32.51               | 0.08                 | 1H-Pyrazole-4-carbaldehyde, 3-(3-hydroxyphenyl)- |
| 202 | 32.68               | 0.28                 | 9-Embosenone, (E)- |
| 203 | 32.85               | 0.48                 | 9-Octadecen-1-ol, (E)- |
| 204 | 33.02               | 1.12                 | 1-Octadecane |
| 205 | 33.19               | 0.18                 | Octadecane |
| 206 | 33.98               | 0.11                 | 10-Methyltricyclo[4.3.1.1(2,5)]undecan-10-ol |
| 207 | 34.09               | 0.23                 | 4-Hydroxy-7-methyl-phenyl[4,3-b]pyran-2,5-dione |
| 208 | 34.44               | 0.21                 | Cyclohexane, 2,2-dimethyl-5-(3- methoxyxiranyl)-, [2.2.0]3,3.alpha.,( +,-)- |
| 209 | 34.66               | 0.46                 | 5-(4-Methoxyphenyl)thiazol-2-ylamine |
| 210 | 34.86               | 0.12                 | Cyclopentadecanone, 2-hydroxy- |
| 211 | 35.08               | 0.50                 | Pentadecanoic acid |
| 212 | 35.32               | 0.07                 | Octadecanoic acid |
| 213 | 35.39               | 0.06                 | Octadecanoic acid |
| 214 | 35.82               | 0.17                 | Cycloptadecanone |
| 215 | 36.24               | 0.18                 | 1-Octadecene |
| 216 | 36.36               | 0.05                 | Pyrimidine-5-carbonitrile, 3,4-dihydro-6-(dimethylaminophenyl)-2-mercapto-4-oxo- |
| 217 | 36.47               | 0.14                 | Octadecane, 1-chloro- |
| 218 | 37.30               | 0.11                 | 9-Hexadecenoic acid, methyl ester, (Z)- |
| 219 | 38.89               | 0.87                 | Hexadecenoic acid, Z-11- |
| 220 | 39.04               | 0.47                 | Cyclopentadecanone, 2-hydroxy- |
be used in milk, cheese, and other fragrances (Sirois et al., 2018; Fechter-Leggett et al., 2018). It can also be used in cosmetic fresh fruit flavors and as gelatin hardener and photographic binder (Jedlicka et al., 2018).

Furan, 2-methyl-(1.75%) is used to produce vitamin B1, chloroquine phosphate, and promethazine phosphate (Carrasco et al., 2018). It is also a good solvent for the synthesis of pyrethroid pesticides and flavors and fragrances (Li et al., 2018). It is the raw material of allyl ketone, the pyrethroid and pyrethroid intermediate, while 2- methyl furan has anesthetic effects (Dohade and Dhepe, 2018).

Acetic acid (3.64%) can be used as acidifier, pickling agent, flavoring agent, spice (Spaepen et al., 2010), and is also a good antimicrobial agent, mainly attributed to its ability to reduce pH below the pH required for optimum microbial growth (Xie et al., 2018). Acetic acid is the earliest and most widely used sour agent in China (Kregel et al., 2018). It is mainly used in compound seasoning, wax preparation, canned food, cheese, and jelly (Omoniyi and Dupont, 2018). The third generation of commercial beverages is made of vinegar as sour agent, supplemented by natural nutrition and health products (Chen et al., 2018; Philippe et al., 2018).

Propionic acid (0.53%) is an important chemicals, and it is also the intermediate of many other fine chemicals (Bodul et al., 2018). It is mainly used as food and feed additives, followed by home medicine, rare herbs, medicine, and spices (Belgrano et al., 2018; Nazareth et al., 2018). In terms of grain and feed additives, the application of propionic acid is significant and consumption is growing rapidly (Kim et al., 2018a, 2018b).

Toluene (0.82%) is widely used as a solvent and high octane gasoline additive, and is also an important raw material in the organic chemical industry (Chu et al., 2018; Xia et al., 2018). A series of intermediates derived from it are widely used in the production of fine chemicals such as dyes, pharmaceuticals, pesticides, propellants and explosives, additives, spices, and in the synthetic materials industry (Zhang et al., 2018a, 2018b; Liu et al., 2018a, 2018b).

n-Hexadecanoic acid (1.91%) has a special aroma and, and is a raw material for food additives such as fatty acid glycerides, fatty acid sorbitol anhydride esters, and sugar esters (Moreno et al., 2006). It is also the raw material for producing candles, soap, grease, softeners, and synthetic detergents (Song et al., 2008).

1-Octadecene (1.75%) is used in organic synthesis to produce surfactants, spices, palmites, dyes, and polymers (Pandey et al., 2018). Vanillin (0.95%) is a good perfume for obtaining powder and bean fragrance (Priefert et al., 2001). It can be widely used in almost all types of fragrance, such as violet, grass orchid, sunflower, and Oriental fragrance. It is also widely used in food such as vanilla bean, cream chocolate, toffee, flavoring biscuits, pastries, sweets and drinks, and tobacco flavors (Broadhurst and Jones, 2010). It is used in the analytical chemistry to test protein nitrophenylene, three benzene and tannic acid. In the pharmaceutical industry, it has uses in the production of hypnotive drugs methyl dopa, catechol drugs dopa, as well as betaine and dichlorofen (Frings et al., 1972).

Eugenol (0.48%) is the fragrance of the carnation flower, roses, and Xiang Wei (López de Lerma et al., 2018). It can be used as modifer and fixative. It can be perfused with colored perfumed soap, and is used in Xixiang, Costus, Oriental and incense, and also in flavors such as spicy, peppermint, nuts, fruit flavors, dates and other tobacco flavors (Li et al., 2017). Eugenol also has a strong smell of Dianthus odorus, which is the blending basis of Kang and Zhi flavor, and is used in the blending of cosmetics, soap, food, and other flavors. As a local analgesic for dental caries, eugenol has strong bactericidal activity. Ding Zixiang phenol can also be used to produce isoniazid, a specific drug for treating tuberculosis (Wang et al., 2017).

2-Methoxy-4-vinylphenol (2.98%) and phenol, 4-ethyl-2-methoxy-(0.66%) are a food spice prescribed by GB 2760-1996, which can be used as food additives and fragrances (Xu et al., 2016). Catechols (1.22%) are important chemical intermediates, which are used in manufacture antioxidants, special inks, light stabilizers, rubber hardeners, plating additives, skin antisepsics, fungicides, hair dyes, photographic developers, and other important pharmaceutical intermediates (Kawahata et al., 2018). It is also used to manufacture cough, butyl phenol, berberine, and isoproterenol (Roychoudhury et al., 2018). It can also be used for the production of 4-tert-butyl catechol as an inhibitor for styrene, butadiene and vinyl chloride (Yuzugullu Karakus et al., 2018).

Phenol, 2-methoxy-(1.98%) is mainly used to make coffee, vanilla, smoked tobacco and tobacco flavor (Hijas and Kumar, 2018; Zagorchev et al., 2018). It produces calcium guaiacol sulfate in medicine, vanillin and artificial musk in perfume industry (Oliveira et al., 2018). P-Cresol (0.87%) is an intermediate for the production of antioxidant additive 2, 6-tert-butyl-4-methylphenol and P hydroxybenzaldehyde (Saito et al., 2018; Dou et al., 2004). It is also an important basic raw material for the production of Trimethylamine and the dye dicyanobutel sulfonic acid. It is also an intermediate of the fungicide methyl parquat, the insecticide Fenvalerate and ethemethrin (Muraledharan et al., 2018; Liu et al., 2018a, 2018b). 1,3-Dioxol-2-one,4,5-dimethyl- (0.52%) can be used as an intermediate of olmesartan for antihypertensive drugs (Gao et al., 2018). Heptanoic acid (0.73%) are mainly used in the production of heptate esters as perfumes, safe glass polyvinyl butyral plasticizer esters, alkyl resin stabilizers can also be used as intermediates, as well as the production of polyol esters for synthetic lubricants (Coleman et al., 2018; Saren et al., 2018; Cui et al., 2017).

### 4. Conclusions and discussion

TGA in the bark of *Torreya grandis* can be divided into three stages: the first stage is mainly water evaporation, the second stage is caused by a small amount of polymer depolymerization and recombination, the third stage is mainly caused by the rapid decomposition of substances in the bark of *Torreya grandis* and a large number of volatile gases, resulting in weight loss.

The pyrolysis results showed that 205 substances were detected from 225 peaks. 1,3-Dioxol-2-one,4,5-dimethyl- can be used as an intermediate of olmesartan for antihypertensive drugs. 6-tert-Butyl-2,4-dimethylphenol acids can be used as antioxidants in polymeric resins and aviation fuels, and they are also very important pharmaceutical intermediates, as an inhibitor in MMA, UV

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| No. | Retention time (min) | Relative content (%) | Compounds name |
|-----|----------------------|----------------------|----------------|
| 221 | 39.22                | 1.53                 | n-Hexadecanoic acid |
| 222 | 39.62                | 0.17                 | Dibutyl phthalate |
| 223 | 39.86                | 0.09                 | Cyclopentadecanone, 2-hydroxy- |
| 224 | 40.39                | 0.58                 | 1,19-Eicosadiene |
| 225 | 40.70                | 0.68                 | Cycloeciosane |
light-solid monomer, and resin and unsaturated resin, especially at high temperature. n-Hexadecanoic acid can be used as precipitating agents, chemical reagents and waterproofing agents, and are raw materials for making other food additives.

From the above studies, we can see that the effective components of Torreya bark have many functions, which are embodied in medicine, chemistry, food, and other aspects. Therefore, the bark of Torreya grandis is a resource with good application prospects, and has broad potential for sustainable utilization of forest bio-mass resources.

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