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Identification of Organic and Inorganic Compounds as Sustainable Bioproducts in *Eucalyptus camaldulensis, Salix alba, Albizia julibrissin* Wood and Bark Extractives by Analytical Instruments

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Abstract

Forest products as a renewable, environmentally friendly with no health problems are the available alternative due to reduction oil reserves. In this study, organic and mineral compounds of Eucalyptus (*Eucalyptus camaldulensis*), willow (*Salix alba*) and silk tree (*Albizia julibrissin*) wood and bark extractives were evaluated. The crude acetone extract of these compounds was analyzed and identified by gas chromatography-mass spectroscopy (GC-MS). Finally, 131 organic compounds in Eucalyptus, Willow, and Silk tree wood and bark extractives were identified which 12 organic compounds were common in most samples. Some of these extractive compounds are very valuable and expensive. A wide range of chemical compounds in extractives of these three species can lead to manufacturing sustainable bioproducts in many industries such as pharmaceutical, cosmetics, fuel, packaging, textile and chemical industries. These compounds were bis(2-ethylhexyl) phthalate, γ-sitosterol, cyclohexane, α-amyrin, inositol, 9,12-octadecadienoic acid، hexadecadienoic acid, 1,2-benzenedicarboxylic acid, 2-pentanon, decane, hexadecane, tetradecane and octadecadienoic acid. Bis(2-ethylhexyl) phthalate is identified as a valuable and useful material in the main part of Eucalyptus, Willow, and Silk tree wood and bark extractives. Bis(2-ethylhexyl) phthalate is identified as the major component of Willow and silk wood and bark extractives and also the main part of Eucalyptus bark extractives. Whereas, the principal amount of Eucalyptus wood extractives was 2-pentanon. In addition, Mn, Zn, and Fe were the main part of Eucalyptus, Willow, and Silk tree bark extractives, respectively.

Keywords: *Eucalyptus camaldulensis; Salix alba; Albizia julibrissin*; Extractives; Bioproducts

Introduction

Nowadays the use of both renewable and environmentally friendly resources seem necessary as alternative raw materials instead of fossil fuels, oil derivatives and other non-renewable resources in the pharmaceutical, cosmetics, fuel, packaging, textile and chemical industries [1]. For example, 8% of the world's oil is consumed in plastic production each year (4% of feedstocks and 4% to produce power for manufacturing process) [2]. The biological resources that are natural, renewable, biodegradable [3], non-toxic [4], and non-carcinogenic [5] are preferred for manufacturing sustainable bioproducts. There are two biological sources including edible and inedible products for manufacturing bioproducts. The first one includes starch, sugar, corn, potatoes, soybeans, wheat, rice which is overlap with human and animal food sources, thus it consumptions will increase food prices [6]. Hence, the increasing use of the second source of non-food products such as inedible genetically modified plant, and both agriculture and food industry waste, because of lower cost is applicable for bioproducts development [7]. Agriculture waste and inedible genetically modified plant like forest resources are moving toward bioproducts manufacturing according to printing paper lower demand [2]. The use of trees extractives can be the first step in biorefinery with the increasing replacement of forest resources instead of oil derivatives and other fossil fuels [8]. Wide, diverse, and valuable trees extractives' compounds which generally involve organic (terpenoids, steroids, fats, waxes, phenolics) and inorganic compounds are important in the process of biological treatment since the extraction capacity can bring so much value added to the industry. In addition, currently, the demand for biopolymers, biofuels, bioplastics and minerals are increasing due to eco-friendly industries. A wide variety of chemical compounds that found in the trees wood and bark are easily extractable by organic and aqueous gentle solvents [9]. *Eucalyptus camaldulensis*, the river red gum, is a tree of the genus Eucalyptus and one of around 800 species within the genus. It is a plantation species in many parts of the world but is native to Australia, where it has the most widespread natural distribution of Eucalyptus in Australia [10], especially beside inland water courses. Although it was first described from a cultivated plant growing in the garden of the Camaldoli religious order in Naples, Italy [11]. The tree has a large, dense crown of leaves that the base of the bole can be covered with rough, reddish-brown bark [12]. In an investigation of Eucalyptus (*Eucalyptus globulus* Labill.) honey and flower organic extractives to the identification of botanical marker compounds [13]. Eucalyptus honey is characterized by 2-hydroxy-5-methyl-3-hexanone and 3-hydroxy-5-methyl-3-hexanone, as well as exo-2-hydroxycineole and an unknown norisoprenoid. Aside from, acetone, nonanal, methyl nonanoate, and dehydrovomifoliol were present in higher concentrations. Also, in Eucalyptus flower extracts, norisoprenoids were the most abundant compounds, all of which were also present in the honey samples. 3-Oxo-aionone comprised half of the total amount, followed by eucalyptol. Salix (Babylon willow or weeping willow) is a species of willow which is native to dry areas of northern China, nevertheless cultivated for years elsewhere in Asia, also to reach

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Europe and southwest Asia it's being traded along the Silk Road [14]. Although Salix has a short life span, between 40 and 75 years, it is a medium- to the large-sized deciduous tree due to growing up to 20-25 m (66-82 ft) tall. In addition, the leaves are light green, alternate, narrow (4-16 cm long and 0.5-2 cm broad), and spirally arranged [15]. *Albizia julibrissin* (Persian silk tree, pink silk tree) is a species of tree in the Fabaceae family that is native to southwestern and eastern Asia. However, the original habitat of the tree is regions from Iran and the Republic of Azerbaijan to China and Korea. It is a small deciduous tree growing to 5-16 m (16-52 ft) tall which has a broad crown of level or arching branches. Furthermore, the bark is dark greenish gray and it will be striped vertically as it gets older, also the leaves are bipinnate (20-45 cm long and 12-25 cm broad) [16]. In an investigation of organic extractives from unifloral chestnut (*Castanea sativa* L.) extraction was performed by ultrasonic aid, and 1-phenylethanol and 2'-aminoacetophenone as two most powerful botanical markers of chestnut honey were identified by gas chromatography-mass spectrometry (GC-MS) analysis [13]. The presence of heptanoic acid, cis-cinnamyl alcohol, and phydroxyacetophenone exclusively in chestnut honey was reported in conclusion. Additionally to those mentioned above, seven compounds were quantified at higher concentrations ($p<0.001$): 2,3,4-trimethylpentane, 2,3,3-trimethylpentane, hexanoic acid, benzyl alcohol, 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one, transpyran linaloxide, and decanoic acid. The organic extractives from whole flowers were predominated by 1-phenylethanol, nonanal, benzyl alcohol, and nonanoic acid. Of the 16 compounds found in the flower extract, 13 were present in the honey as well. The crude methanolic extract of E. globulus stump wood was studied in order to isolate the components responsible for such biological properties [17]. This extract was subjected to bioassay-guided fractionation and the antioxidant and antimicrobial properties of the fractions were then evaluated. The antioxidant activity was assessed by the DPPH scavenging assay and the antimicrobial properties were studied by bioautography and resazurin microtiter methods. The fractions presented considerable capacity to scavenge the DPPH free radicals and to inhibit the growth of bacterial and yeast strains. The results obtained for the fractions were even better than the ones obtained with the crude extract. The GC-MS analysis revealed that the major compounds present in the extract were gallic acid, ellagic acid, citramalic acid and citric acid. In the present work, the crude acetone extractives of Eucalyptus, willow and silk tree in wood and bark were extracted. Organic and mineral compounds were identified and evaluated by Gas chromatography-mass spectrometry (GC-MS) analysis and atomic absorption spectrometry.

Materials and Methods

Samples, plant materials and reagents

Three species consist of Eucalyptus, Willow and Silk tree was randomly collected from Caspian Hyrcanian forest (Nowshahr, Iran).

BSTFA [bis (trimethylsilyl) trifluoroacetamide], TMCS (trimethylchlorosilane) and pyridine were purchased from Merck Company (Germany). All of the chemical reagents were of analytical grade.

Apparatus

Analysis of extractives was performed using an Agilent HP 6890 Gas Chromatograph (Agilent technology, USA), equipped with an Agilent 5973 mass detector at 70 eV, transfer line 320 and Ms source 220. The column was HP-5MS capillary column (SGE, 30 m, 0.25 mm i.d., 0.25 µm film thickness) and helium was used as carrier gas at 1 mL/min rate. The injector temperature, Ms transfer line and Ms source were 220°C, 320°C and 220°C. In all analysis, 1 µL of the extract was injected with split mode (1:20). The oven temperature program was raised from 60°C to 260°C at 6°C/min. All measurements of metals were carried out using a model Varian AA-1275 flame atomic absorption spectrometer with a deuterium background corrector. Hollow cathode lamps were operated at 5 mA as the light source. The wavelength was set at 217 nm with 1 nm spectral band pass.

Samples preparation

Sample preparation was performed according to TAPPI standard T257 cm-85 [18]. Briefly, wood and bark samples were prepared both from freshly and dried cut wood. Samples were left to dry under ambient conditions. The dried wood and bark samples (moisture content 8%) were chopped into small parts with a special knife and powdered with a hammer mill. The wood and bark powder (particle size between 0.05 and 0.4 mm) were stored in closed glass jars at room temperature.

Extraction process

Extractives from three species were extracted according to TAPPI standard T204 cm-97 [18]. The extraction test was carried out using Soxhlet extractors according to TAPPI standard T204 om-88 (1988) [18]. Wood and bark samples (10 g) were extracted using acetone (150 ml) for 8 h. The acetone extracts were evaporated and dried extractive samples were kept in glass bottles at approximately -18°C until future experiment.

Briefly, about 1 mg of the solid sample obtained from extraction was mixed with 30 mL of BSTFA [bis (trimethylsilyl) trifluoroacetamide]+1% TMCS (trimethylchlorosilane) reagent and about 15 mL of pyridine inside a tube test in order to identify components of each extract. Samples were kept in a water bath at 70°C for an hour and analyzed by GC-MS. The extractive content was calculated as follows:

$$Extractables\% = We - WbWp \times 100$$

Where We is oven-dry weight of extract (g), Wp is oven-dry weight of wood or pulp (g) and Wb is oven-dry weight of blank residue (g).

Metallic elements

Metallic elements were extracted according to TAPPI standard T211 om-93 [18]. Firstly, the empty crucible was cleaned and ignited in a muffle furnace at 525 ± 25°C for 30-60 minutes. Then it was cooled slightly and put in a desiccator, containing indicating-grade anhydrous alumina. After cooling, weigh the ignited crucible on the analytical balance to the nearest 0.1 mg. Each of ash samples was completely dissolved in nitric acid for 2 h and filtered by Whatman 1001-090 Grade 1 Qualitative Filter Paper, 9 cm, Pore Size: 11 µm. Subsequently, they were washed with 20 mL distilled water. Finally, the existence and the number of minerals including Cu, Fe, Zn, Ni, Mn, K, Mg, Co, and Cd were evaluated using atomic absorption spectrometry.

The ash content was calculated as follows:

$$Ash\% = (A \times 100)/B$$

Where A is weight of ash (g) and B is weight of test specimen moisture-free (g).

Characterization of the organic compounds (OCs) in species

A GC diagram was used to obtain abundance, retention time of each compound, calculation of quartz index and Adams table in order to compounds identification. For final confirmation, Kovats retention index for each compound was compared with Kovats retention indexes for references. The structure of organic molecules was identified by retention time ratio [19]. This index is calculated by the following equation:

$$KI=[100]_n+100[((\log(T_{rx})-\log(T_{rx})))/(\log(T_{rn}+1)-\log(T_{rn}))]$$

Where KI is retention index, n is the normal carbon number, Trx, Trn, Trn+1 are the retention time of unknown composition, retention time of lighter hydrocarbon before unknown composition and retention time of heavier hydrocarbons after unknown composition, respectively. Compositions in each essence and the amount of them were determined by Adams table after calculating the retention index from each ingredient of the essence and comparing mass spectra of unknown and standard compositions.

Results and Discussion

Measurement of ash, extractives, and metallic elements in eucalyptus, willow and silk trees wood and bark

Ash, extractive percent, and metallic elements were calculated in the same method in three species. The results (Table 1) showed that the highest and the lowest extractive percent are 5.43% and 2.6% in Silk tree bark and Eucalyptus wood, respectively. Extractives are different in various species; also bark extractives are usually higher the wood. The greatest and the lowest amount of ash were 15.16% and 0.33% in Willow bark and Eucalyptus wood, respectively. Minerals in the bark are much more than the wood, for preserving wood against mechanical damage [20]. The maximum and minimum Fe amounts were measure 5.184 in Silk tree bark and 0.601 in willow wood. Fe is the vital nutrient for organisms because of playing a critical role in metabolic processes such as the synthesis of DNA, respiration, and photosynthesis [21]. Cu was analyzed in three species Silk, Willow, Eucalyptus bark and wood which maximum amount was 0.179 in Silk bark and minimum amount was 0.028 in Eucalyptus. Cu effects on growth, development, photosynthesis and plant protein production in trees [22]. Zn was in Willow bark and Eucalyptus wood. The amount of Mn in Eucalyptus bark and wood were measured 5.184 vs. 1.004 ppm, 0.179 vs. 0.028 ppm, 3.465 vs. 0.271 ppm, and 5.466 vs. 0.705 ppm, respectively. Mn plays a key role in many physiological processes, especially photosynthesis and oxygen production [23]. Zn as an essential trace element plays a metabolic role including carbohydrates, proteins and reproductive metabolism processes in plants [24]. Ni was found just in Silk tree wood and bark 0.484 vs. 0.536 ppm, respectively. Ni is the last essential element in plants that is classified for plant growth [25], the involvement in iron metabolism (Ni deficiency induces iron reduction) cause Ni an important element [25]. Also, Ni leads to better absorption of Fe and urea by the plant and cause improve efficiency [26]. Metal ions are usually the operating part of enzymes that act as the catalyst in biosynthesis [20]. Mg is needed for many physiological processes in plants, particularly chlorophyll production because it is an essential constituent of chlorophyll and also it causes a higher concentration of soluble protein concentration in leaf and root [27]. In the cytoplasm, K has an important role in providing the correct ionic environment for metabolic processes [28].

Extractives from *Eucalyptus camaldulensis* (wood and bark)

Generally, 18 and 13 components were identified by GC-MS (Figure 1) in Eucalyptus wood and bark, in order. That the most important of these components are 2-Pentanone, bis(2-ethylhexyl) phthalate, and disiloxane in Eucalyptus wood,1,2 benzenedicarboxylic acid, hexadecadienoic acid, and tetradecane in Eucalyptus bark. Among all important components 2-pentanonein Eucalyptus wood and bis(2-ethylhexyl) phthalate in Eucalyptus bark are the maximum amount of components and vice versa ethyl octanoate and octadecane are the lowest amount of components in Eucalyptus wood and bark, respectively (Table 2).

Extractives from *Salix alba* (wood and bark)

Generally, 31 and 13 components were identified by GC-MS (Figure 1) in Willow wood and bark, respectively. That the most important of these components are bis(2-ethylhexyl) phthalate, ethyl octanoate, tridecane, and dodecane in Willow wood, 1,2 benzenedicarboxylic acid, styrene, dodecane, 2-ethylhexanol in Willow bark. Among all important components bis(2-ethylhexyl) phthalate is the maximum amount of component in Willow wood and bark and vice versa 2-ethylhexanol and octadecane are the lowest amount of components in Willow wood and bark, respectively. Bis(2-Atylhexyl) phthalate is the major component in Willow, because other components include less than 5% totally (Table 2).

Extractives from *Albizia julibrissin* (wood and bark)

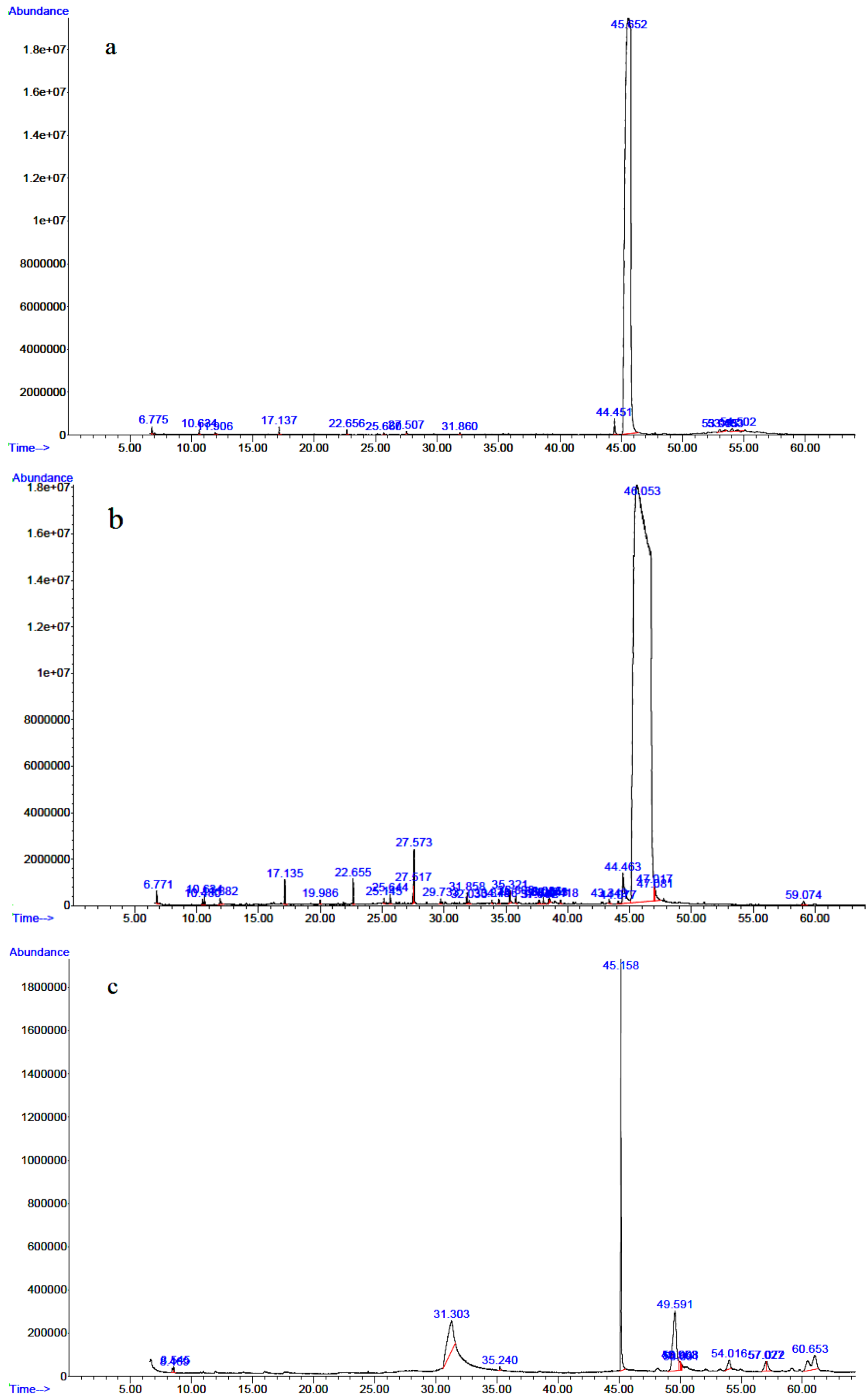
Generally, 43 and 13 components were identified by GC-MS (Figure 1) in Silk tree wood and bark, respectively. That the most important of these components are bis(2-ethylhexyl) phthalate, inositol,9,12 octadecadienoic acid, hexadecadienoic acid, and 1,2 benzenedicarboxylic acid in Silk tree wood, bis(2-ethylhexyl) phthalate, γ-sitosterol, inositol, cyclohexane, and α-amyrin in Silk tree bark. Among all important components bis(2-ethylhexyl) phthalate in Silk tree wood and bark is the maximum amount of component and vice versa decane in Silk tree wood and disiloxane in Silk tree bark are the lowest amount of components. Whereas bis(2-ethylhexyl) phthalate in Silk tree bark is higher than the other components. Also, the amount of γ -sitosterol, inositol, and cyclohexane in Silk tree wood are almost the same (Table 2).

Comparison of *Eucalyptus camaldulensis*, *Salix alba* and *Albizia julibrissin*

A number of compounds (Table 2) and also organic compounds GC-MS (Figure 1) of Eucalyptus, Willow and Silk tree wood and bark extractives were measured. Moreover, important compounds of those species were compared with each other in Figure 2.

Species	Et (%)	ASH (%)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Fe (ppm)	Ni (ppm)	K (ppm)	Mg (ppm)	Cd (ppm)	Co (ppm)
Willow Wood	4.05	1.26	1.234	0.122	2.564	0.601	0	< 0.7	< 0.7	0	0
Willow bark	4.87	15.16	2.523	0.103	3.465	1.281	0	< 0.7	< 0.7	0	0
Silk wood	3.98	0.8	0.821	0.047	1.108	0.851	0.484	< 0.7	< 0.7	0	0
Silk bark	5.43	6.3	1.846	0.179	1.841	5.184	0.536	< 0.7	< 0.7	0	0
Eucalyptus wood	2.6	0.33	0.705	0.028	0.271	1.004	0	< 0.7	< 0.7	0	0
Eucalyptus bark	2.78	4.83	5.466	0.028	0.376	1.087	0	< 0.7	< 0.7	0	0
Extractives: Et											

Table 1: The proportion of ash, extractives, and metallic elements in the Eucalyptus, Willow and Silk trees wood and bark.


a
Abundance
Time-->
45.652
44.451
6.775
17.137
22.656
31.860
b
Abundance
Time-->
46.053
27.573
44.463
17.135
22.655
6.771
19.986
59.074
c
Abundance
Time-->
45.158
49.591
31.303
35.240
54.016
60.653

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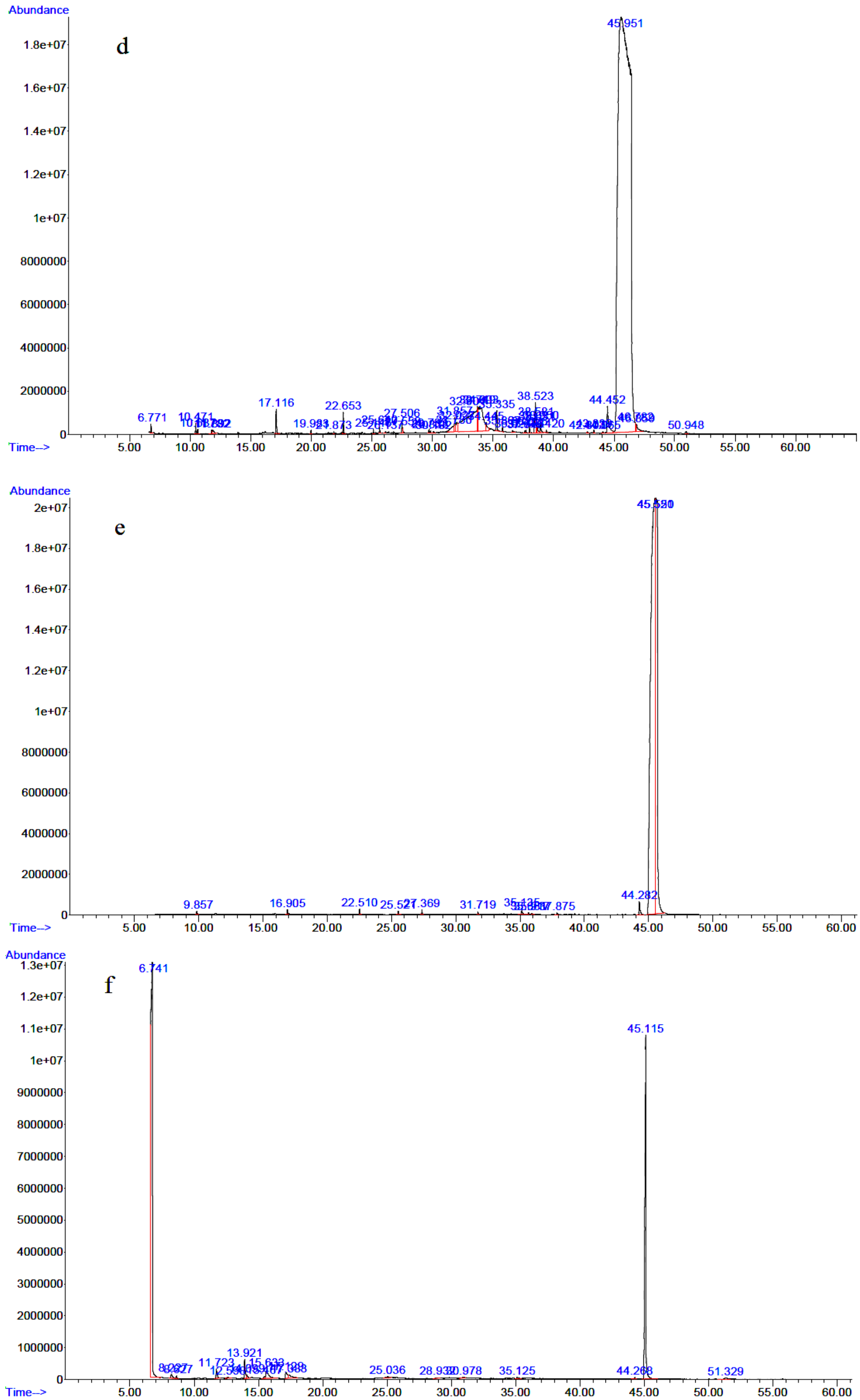

Figure 1: Organic compounds GC-MS in willow bark (a), Willow wood (b), Silk tree bark (c), Silk tree wood (d), Eucalyptus bark (e), Eucalyptus wood (f).

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	Compound	Willow Flower extract (%)		Silk Flower extract (%)		Eucalyptus Flower extract (%)	
		Wood	Bark	Wood	Bark	Wood	Bark
1	bis(2-ethylhexyl) phthalate (DEHP)	97.46	98.68	89.28	28.81	33.66	97.72
2	γ-Sitosterol	_	_	_	26.76	_	_
3	Cyclohexane	_	_	_	10.95	_	_
4	α -Amyrin	_	_	_	2.74	_	_
5	Inositol	_	_	7.2	22.46	_	_
6	9,12 Octadecadienoic acid (linoleic acid)	_	_	0.69	_	_	_
7	Hexadecanoic acid (Palmitinic acid)	0.18	_	0.58	_	_	0.19
8	2-Pentanone or methyl propyl ketone (MPK)	_	_	_	_	57.41	_
9	1,2-benzenedicarboxylic acid	0.14	0.57	0.27	_	_	0.48
10	Ethyl octanoate (ethyl caprylate)	_	_	_	_	2.01	_
11	Styrene	_	0.19	_	_	_	_
12	2-Ethylhexanol	0.12	0.10	_	_	_	_
13	Disiloxane	_	_	_	0.47	0.78	_
14	Decane	_	0.09	0.13	_	_	0.07
15	Octadecane	_	0.04	0.2	_	_	0.05
16	Hexadecane (cetane)	_	0.04		_	_	0.09
17	Dodecane	_	0.15	0.26	_	_	0.08
18	Tetradecane	_	0.10	0.17	_	_	0.11
19	Octadecadienoic acid (Stearic acid)	_	_	0.14	_	_	_
20	Tridecane	0.21	_	_	_	_	_

Table 2: The amount of components in Eucalyptus, Willow and Silk tree wood and bark.

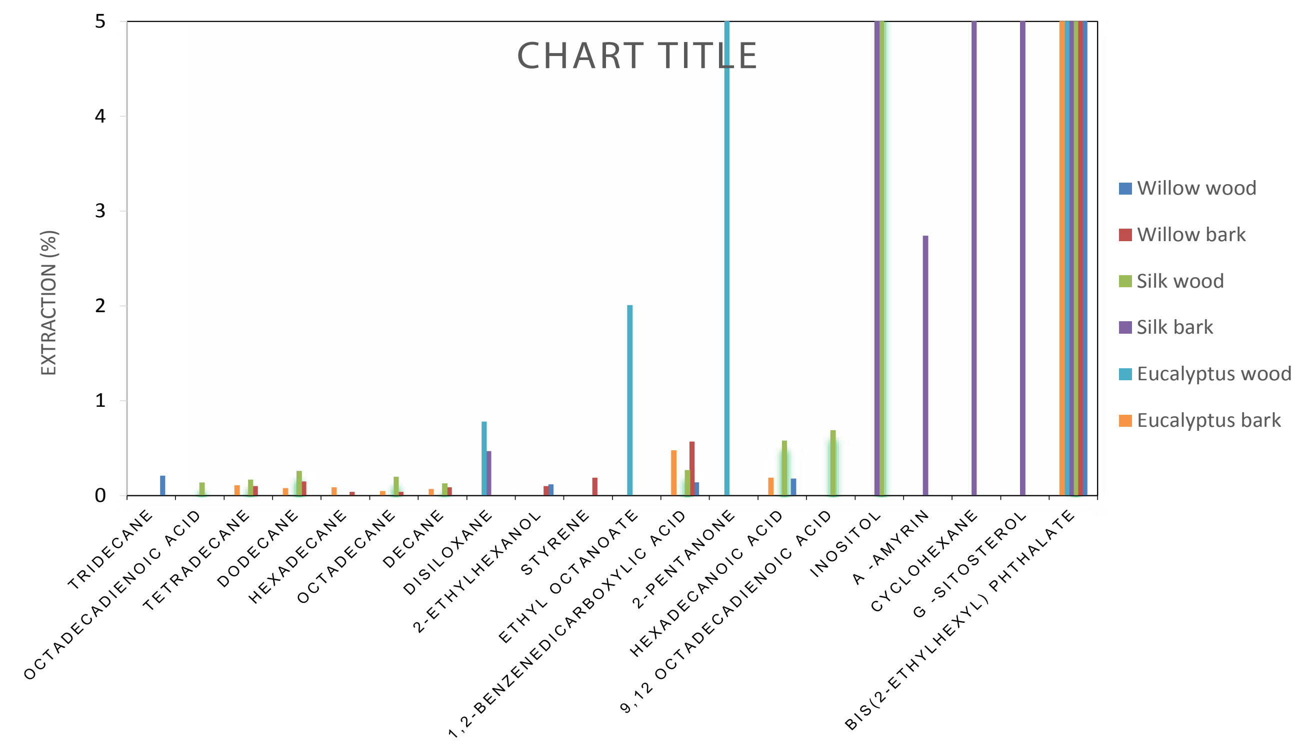

Figure 2: Comparison of Eucalyptus camaldulensis, Salix babylonica and Albizia julibrissin wood and bark important compounds.

Samples of the most important compounds structure from Eucalyptus, Willow and Silk tree wood and bark extractives are shown in Figure 3.

Industrial applications

Eucalyptus, Willow and Silk tree wood and bark extractives can be consumed in the fields of pharmaceutical, cosmetics, fuel, packaging, textile and chemicals (Table 3). For instance, α-amyrin, inositol, 9,12 octadecadienoic acid, and hexadecadienoic acid in drugs manufacturing both for diseases treatment such as diabetic, hyperlipidemic, anxiety, depressant, inflammatory and improving the health through breaking down of fats, gene expression, improving lipid profile, declining HDL, increasing lipoprotein, moisture retentive, control of insulin secretion, reducing the severity and progressing of skin lesions

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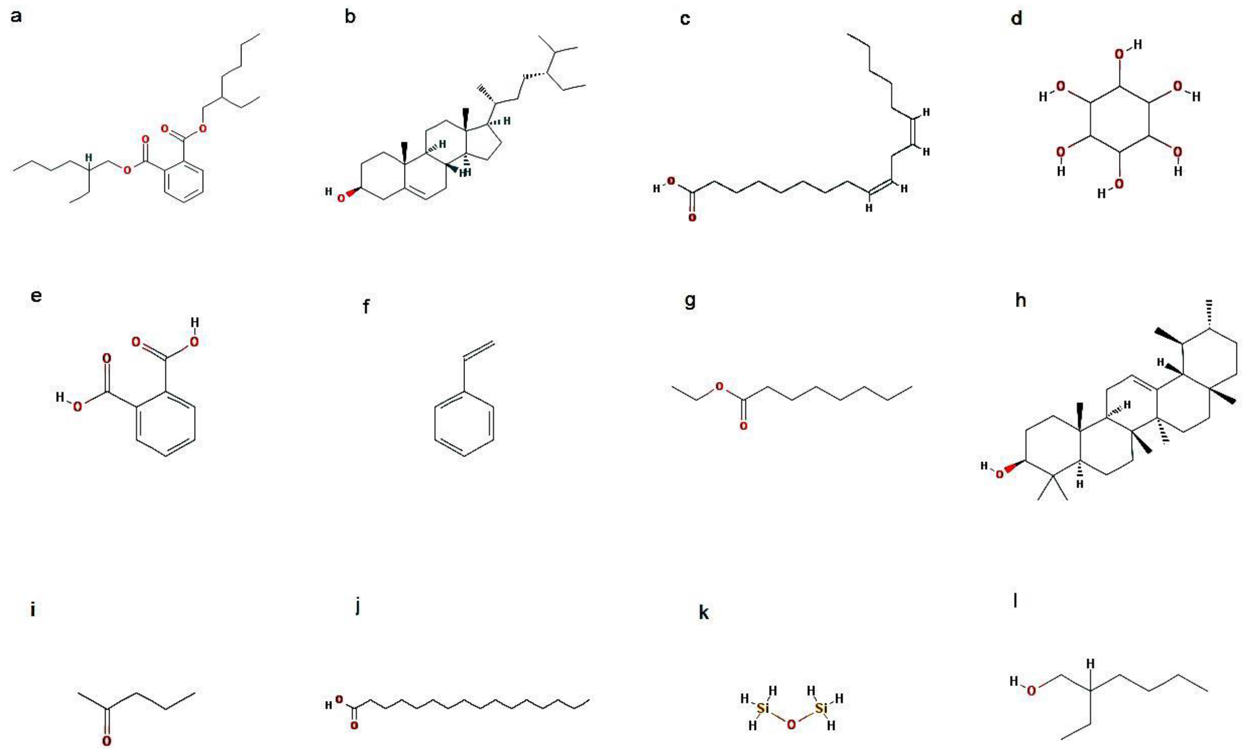

Figure 3: Bis(2-ethylhexyl) phthalate (a), γ-sitosterol (b), 9, 12-Octadecadienoic acid (c), Inositol (d), 1,2 Benzenedicarboxylic acid (Phthalic acid) (e), Styrene (f), Ethyl octanoate (g), α-Amyrin (h), 2-Pentanone (i), Hexadecanoic acid (j), Disiloxane (k), 2-Ethylhexanol (l).

	Compound	Molecular formula	Molecular weight (g/mol)	RT (min)	KI	Products
1	bis(2-ethylhexyl) phthalate (DEHP)	$C_{24}H_{38}O_4$	390.6	45.52	2578	Plasticizer
2	γ-Sitosterol	$C_{29}H_{50}O$	414.71	4959	2783	Antidiabetic, Antihyperlipidemic
3	Cyclohexane	C_6H_{12}	84.162	6065	3089	Nylon
4	α -Amyrin	$C_{30}H_{50}O$	426.729	54.01	2932	Anxiolytic and Antidepressant, Anti-inflammatory
5	Inositol	$C_6H_{12}O_6$	180.156	31.30	1738	Antidepressant, Breakdown of fats, Gene expression
6	9,12 Octadecadienoic acid (linoleic acid)	$C_{18}H_{32}O_2$	280.4455	38.52	2150	improved lipid profile, declines in HDL and increases in lipoprotein, Quick-drying oils, Anti-inflammatory, acne reductive, and moisture retentive
7	hexadecadienoic acid (Palmitic acid)	$C_{16}H_{28}O_2$	252.398	35.32	1976	Antioxidant, Control of insulin secretion, Cosmetics and personal-care products
8	2-Pentanone or methyl propyl ketone (MPK)	$C_5H_{10}O$	86.134	6.74	851	Paint additives and coating additives, Intermediates
9	1,2 Benzenedicarboxylic acid (Phthalic acid)	$C_8H_6O_4$	166.132	47.01	2663	Plasticizers
10	Ethyl octanoate (ethyl caprylate)	$C_{10}H_{20}O_2$	172.268	15.63	1150	Supercritical extraction
11	Styrene	C_8H_8	104.152	6.77	852	Polystyrene, Intermediate to produce copolymers
12	2-Ethylhexanol	$C_8H_{18}O$	130.231	11.90	1031	Diester bis(2 ethylhexyl) phthalate (DEHP) as a plasticizer
13	Disiloxane	H_6OSi_2	78.217	8.54	926	Ingredient for cosmetics formulations
14	Decane	$C_{18}H_{38}$	254.502	10.47	987	Fabric, Textile, and Leather Products
15	Octadecane	$C_{18}H_{38}$	254.502	31.86	1801	Fabric, Textile, and Leather Products
16	Hexadecane (cetane)	$C_{16}H_{34}$	226.448	27.50	1601	Fuels and fuel additives, Fabric, Textile, and Leather Products
17	Dodecane	$C_{12}H_{26}$	170.34	17.11	1200	Lubricants and Greases, Solvent, distillation chaser, and scintillator component
18	Tetradecane	$C_{14}H_{30}$	198.394	22.65	1401	Intermediates, Lubricants and lubricant additives, Fuels and fuel additives, Paint additives, Coating additives , Plasticizers
19	Octadecadienoic acid (Stearic acid)	$C_{18}H_{36}O_2$	284.484	38.95	2174	lessened the severity and progression of skin lesions chemically-induced burns, Intermediate, Fuels and fuel additives, Finishing agents, Anti-adhesive agents, Filler
20	Tridecane	$C_{13}H_{28}$	184.367	22.65	1401	Intermediates

Table 3: Identified compounds in Eucalyptus, Willow, and Silk tree wood and bark extractives in order to assess sustainable bioproducts.

chemically-induced burn. In addition, bis(2-ethylhexyl) phthalate, hexadecadienoic acid, and disiloxane as additives in cosmetics. Furthermore, cyclohexane, 9, 12-octadecadienoic acid, styrene, dodecane, and tetradecane as chemical substances in production of nylon, quick-drying oils, polystyrene, lubricants, greases, paint additives, coating additives, finishing agents, anti-adhesive agents, and filler. Moreover, 2-pentanone, styrene, tetradecane, octadecadienoic acid, and tridecaneas intermediate for production of final products. Therewith, decane, hexadecane, tetradecane, 9,12 octadecadienoic acid are as biofuels and fuel derivatives. Lastly, octadecane, hexadecane, 9,12 octadecadienoic acid can be consumed in the textile industry for production of textiles and leather. Since the tree is a renewable source its extractive can be used forever as a source of infinite and environmentally friendly in the relevant industries.

Compounds frequency in other species

There are species that have been studied to identify extractive compounds. Among them, some compounds are similar to this study. For example, bis(2-ethylhexyl) phthalate in *Populus nigra* wood [21], Elm wood [29], Bamboo [30], γ-Sitosterol in Masson Pine wood [31], Elder pine wood and bark [32], α-Amyrin in Phyllostachys heterocycla wood [33], Inositol in Japanese alder wood [34], 9,12 Octadecadienoic acid in *Pinus sylvestris* wood and bark [35], hexadecadienoic acid in *Populus nigra* wood, Phyllostachys heterocycla wood [36], *Pinus sylvestris* wood and bark, abies alba wood and bark, Larix wood and bark [31], Elder pine wood [37], 2-Pentanone in Phyllostachys heterocycla wood [36], 1,2 Benzenedicarboxylic acid in *Populus nigra* wood, Elm wood [37], *Pinus massoniana* wood [38], Ethyl octanoate in oak wood [39], Styrene in Pine bark, Oak bark [40], Elder pine wood and bark [32], Decane, Dodecane and Tetradecane in Elm wood [37], Octadecane and Hexadecane in Pnw, black locust wood [41], Octadecadienoic acid in *Pinus massoniana* wood [38], Elder pine wood and bark [32], and Tridecane in *Pinus massoniana* wood [38].

Conclusions

In this study extractive percent, ash and metallic elements were obtained for three species (Eucalyptus, Willow and Silk tree). According to the results, 131 organic compounds in Eucalyptus, Willow and Silk tree wood and bark extractives were identified by GC-MS analysis. The wide range of chemical organic compounds can lead to various manufacturing products. As a result, three species woods and barks contain important and great value added substances. The most important compounds for manufacturing pharmaceutical, cosmetics, fuel, packaging, textile and chemical products that have the largest share of extractives are bis(2-ethylhexyl) phthalate in three species, γ-sitosterol, cyclohexane, α-amyrin, and inositol in Silk tree bark, inositol, 9,12 octadecadienoic acid, and hexadecadienoic acid in Silk tree wood, 1,2-benzenedicarboxylic acid, styrene, and dodecane in Willow bark, 1,2-benzenedicarboxylic acid, hexadecadienoic acid, and tetradecane in Eucalyptus bark, 2-pentanone and ethyl octanoate in Eucalyptus wood. In addition, decane and tetradecane are common in all three species (Eucalyptus and Willow bark, Silk tree wood) among all biofuel components. The results indicate that although both Eucalyptus and Willow extractives include 31 and 44 components, Silk tree wood and bark extractives are more diverse (56 components) rather than the Eucalyptus and Willow, thus, this species can have a wider variety of industrial applications. However, the maximum rate of bis(2-ethylhexyl) phthalate, which known as an expensive and valuable substance, is in Eucalyptus and Willow bark than the Silk tree bark. Therefore, it can be extracted in order to consume in cosmetics and Packaging industry.

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