DOI : [http://doi.org/10.22438/jeb/40/3\(SI\)/Sp-17](http://doi.org/10.22438/jeb/40/3(SI)/Sp-17)

Bioactive constituents and biodrugs from *Euphorbia tirucalli* stene

Paper received: 17. 04. 2018

Revised received: 14. 11.2018

Accepted: 03.01. 2019

Authors Info

S. Dong¹, H. Bi², D. Zheng², Y. Li²,
Y. Zhao² and W. Peng^{2*}

¹The Scientific Research Institution,
Henan Xiaolin National Nature
Reserve Administration Bureau,
SanMen Xia-472 500, China

²School of Forestry, Henan
Agricultural University, Zhengzhou
450002, Henan, China

*Corresponding Author Email :
pengwanxi@163.com

Edited by

Prof. Muhammad Aqeel Ashraf

Reviewed by

Dr. Jialong Wen
Dr. Lam Su Shiung

Abstract

Aim: *Euphorbia tirucalli* L. is an evergreen succulent shrub that possess ecological value because it can prevent water-soil loss, and it is also an energy plant of economic value. This study was carried out to evaluate the bio active constituents and bio drugs from the stem of *Euphorbia tirucalli*.

Methodology: Four techniques were analyzed for estimating the chemical components of *E. tirucalli*. Fourier Transform Infrared Spectroscopy (FT-IR), Gas Chromatography-Mass Spectrometry (GC-MS), Pyrolysis-Gas Chromatography-Mass Spectrometry (GC-MS), and thermogravimetric (TG) technologies were carried out to detect and analyze the chemical composition from the stem of *Euphorbia tirucalli*.

Results: Gas chromatography-mass spectrometry and pyrolysis-gas chromatography-mass spectrometry included β -lactose; 1-O-heptylhexitol; 3,5-dihydroxy-6-methyl-2,3-dihydro-4H-pyran-4-one; γ -sitosterol; 2-ethylhexanol; vitamin E; dl-alanine; hydroxyacetone; syringol; and 1,2,4-cyclopentanetrione as the main chemical constituents of *E. tirucalli* stem.

Interpretation: These constituents can be applied in food, medicine and industrial manufacturing.

Keywords: Bioactive constituents, Biodrugs, *Euphorbia tirucalli*, FT-IR analysis, Priodrugs

Citation: Dong, S., H. Bi, D. Zheng, Y. Li, Y. Zhao and W. Peng: Bioactive constituents and biodrugs from *Euphorbia tirucalli* Stene. *J. Environ. Biol.*, **40**, 524-535 (2019).

Introduction

Euphorbia tirucalli is a succulent shrub that is called Sticks on Fire or Red Pencil Tree/Pencil cactus. It is native to African Mediterranean coast, and the plant has now spread to semi-arid tropical climates in Hong Kong, Taiwan's Penghu Islands, Hainan, the United States, Malaysia and India. It has the advantages of drought resistance, salt tolerance and wind resistance, and is often used as beautification tree and windbreak at seaside (Chang et al., 2005; Elsayed, 2017). Most of the native habitat of *E. tirucalli* in Africa belong to dry environment. To reduce transpiration, the leaves of *E. tirucalli* fall off earlier, and therefore, most plants are leafless. *E. tirucalli* is a strong drought resistant plant. It can be used for afforestation and soil protection for preventing water-soil loss, and is ecologically valuable. It is also a hydrocarbon plant whose latex can be converted into gasoline, and thus, there is a great potential for large-scale development of the plant. Because of its high yield and low cost compared to other energy plants, some countries and regions have used it as key energy plant for development. However, there is also a bottleneck that there is a great demand for the latex of the plant that can only be used when it is ripe. The entire *E. tirucalli* plant contains a toxic latex that can cause strong irritation. The latex of this plant causes skin inflammation, redness and swelling, pustules, pain and itching. The sap of this plant has been associated with the risk of developing Burkitt's lymphoma. However, the sap also exhibits valuable pharmacological activities, such as antimicrobial and antiparasitic. It has been used to treat cough, rheumatism, and even cancer and other maladies (Silva et al., 2007; Hastilestari et al., 2013; Khaleghian et al., 2011; Hanaflah et al., 2017; Usman et al., 2017).

The current destruction of Earth's ecology and the environment has forced us to consider the relationship between humans and nature. Therefore, it has become necessary to explore the resources available in nature. The aim of this study was to detect the chemical components present in *E. tirucalli* using Fourier transform-infrared spectroscopy, thermogravimetric analysis, gas chromatography-mass spectrometry and pyrolysis-gas chromatography-mass spectrometry and to collect and briefly analyze the effects of these components.

Materials and Methods

E. tirucalli wood (without bark) was collected from the National Forest Park in Lingbao (Sanmenxia) City, Henan Province, China. Lingbao city is located between 110°21'-111°11'E, latitude 34°07'-34°44'N. It belongs to sub-humid warm temperate continental monsoon climate. The annual average temperature is 14.5°C, and the annual precipitation is 600 mm.

E. tirucalli was extracted using multiple solvents. First, the peeled *E. tirucalli* plant parts were placed in micro plant grinding machine to obtain wood powder. Then, after extraction with the

solvents and suction filtration, the leaching liquor was concentrated in a rotary evaporator. *E. tirucalli* liquors were labelled according to the type of solvent used: the methanol solvent was labelled L₁, ethanol solvent as L₂, and the mixed solvent of ethanol and benzene as L₃, respectively.

FT-IR analysis : Leaching liquors were used for FT-IR analysis. The salt table composed of polished KBr and because of its fragility and solubility in water, the leaching liquor to be tested was evaporated to dryness before testing. The range of spectrum was set at 400cm⁻¹-4000cm⁻¹.

GC-MS analysis : Material for GC/MS analysis leaching liquor, L₁ and L₂ was used. High purity helium gas was used as carrier gas. The flow velocity of helium was 1.0 ml min⁻¹, and the split ratio was 20:1. The chromatographic column used was a HP-5MS (30 m×250 μm×0.25 μm). The GC temperature program was set at 50 °C, further increase the temperature to 250 °C at 8 °C·min⁻¹ and then increasing to 300 °C at 5 °C min⁻¹. The MS program scanning range was 30-600 amu (m z⁻¹), with an ionization voltage of 70 eV, and ionization current of 150 μA for electron ionization. The quadrupole temperature and ion source temperature were set at 150 °C and 230 °C, respectively.

Py-GC-MS analysis : Py-GC/MS analysis was performed on *E. tirucalli* wood powder using a pyrolysis temperature of 500 °C, heating rate of 20 °C ms⁻¹, and pyrolysis time of 15 sec. The temperature of transfer line for pyrolysis products and the injection valve was set at 300°C. A TR-5MS chromatographic capillary column was used (30 m×0.25 mm×0.25 μm). High purity helium was used as carrier gas, with shunting mode; the flow velocity of helium was 50.0 ml min⁻¹, and the split ratio was 1:60. The GC temperature program was set 40°C, for 2 min, and increased to 120 °C at 5°C·min⁻¹. The temperature was increased to 200 °C at 10 °C·min⁻¹, and maintained for 15 min. The ion source temperature was 280°C, with a scanning range of 28-500 amu (m z⁻¹).

Thermogravimetric : Thermogravimetric was performed using *E. tirucalli* wood powder. Nitrogen gas was used with a flow velocity of 60 ml min⁻¹. The initial temperature was 30 °C and increased to 250 °C at 5 °C min⁻¹.

Results and Discussion

Fig. 1 shows that the transmittance of mixed solvent of ethanol and benzene was highest, although it resulted in the lowest peak resolution, which indicates that the chemical components of *E. tirucalli* was more efficiently detected during FT-IR analysis when methanol or ethanol was used for extraction. When the mixed solvent of ethanol and benzene was used, FT-IR spectrometry was not able to detect variety of absorption peaks from *E. tirucalli* leaching liquor, which may be due to the solvent effects, where by interaction between sample molecules and solvent molecules led to changes in the vibration frequency and

Fig. 1 : FT-IR spectra of *E. tirucalli* leaching liquors with different extraction solvents.

Table 1 : Analytical results of FT-IR data for *E. tirucalli* leaching liquor composed of different extraction solvents

Absorption peak (cm ⁻¹)			Absorption peak attribution
L ₁	L ₂	L ₃	
3382	3353	3361	O-H Stretching vibration
2947/2835	2974/2893	2974/2897	C-H Stretching vibration
1655	1655	-	C=C Stretching vibration
1450/1414	1454/1421/1380	-	C-H Bending vibration; CH ₂ , CH ₃ Asymmetric bending vibration
-	1330	-	S-ring, 5-substituted G-ring
1113/1028	1090/1049	1088/1049	C-H Aromatic surface bending
-	881	-	Anomeric carbon vibrational frequency

vibration intensity of sample molecules. Other experimental analyses performed mixture solvent of ethanol and benzene was used as leaching liquor, the FT-IR results were not very prominent (Jiang *et al.*, 2017; Chen *et al.*, 2017).

As shown in Table 1, when the wave numbers were 3361 cm⁻¹, 2897-2974 cm⁻¹ and 1088-1049 cm⁻¹, L₃ had absorption peaks denoting O-H stretching vibration, C-H stretching vibration and C-H aromatic surface bending, respectively. L₁ and L₂ had same absorption peaks at similar wave number. In addition, at 1655 cm⁻¹, L₁ and L₂ exhibited C=C stretching vibrations; L₁ and L₂ exhibited C-H bending vibrations and CH₂, CH₃ asymmetric bending vibrations at 1450 cm⁻¹, 1414 cm⁻¹ and 1454 cm⁻¹, 1421 cm⁻¹, 1380 cm⁻¹, respectively. At 1330 cm⁻¹, L₂ exhibited an S-ring, 5-substituted G-ring, and anomeric carbon vibrational frequency

at 881 cm⁻¹. Above all, the chemical components of *E. tirucalli* were cellulose, hemicelluloses, lignin, alcohols, phenols, fatty acids and hydrocarbon compounds (Li *et al.*, 2015; Rozainy *et al.*, 2017).

To clarify the chemical components in *E. tirucalli*, GC/MS and Py-GC/MS was also conducted. The GC/MS analysis of *E. tirucalli* methanol leaching liquor showed 56 peaks detected, and 26 types of chemical components were identified. The main components were β -lactose (22.32%), 1-O-heptylhexitol (12.13%), 3,5-dihydroxy-6-methyl-2,3-dihydro-4H-pyran-4-one (7.57%), 3,7,11,15,18-pentaoxa-2,19-disilaicosane, 2,2,19,19-tetramethyl- (7.38%), melezitose (5.64%), 5-hydroxymethylfurfural (5.14%), maltol (4.46%), 2-furanmethanol (3.97%), desulphosinigrin (2.47%), DL-arabinose (2.07%), 2-

Table 2 : GC/MS analysis of methanol extraction of *E. tirucalli*

PK	RT (min)	PeakArea(%)	Composition
1	5.20	2.07	DL-Arabinose
2	5.39	3.97	2-Furanmethanol
3	5.66	2.04	2-Nitro-1-buten-3-ol
4	5.78	1.31	3-Pyrroline, 1-nitroso-
5	6.02	5.60	DL-Arabinose
6	6.36	0.86	DL-Arabinose
7	6.66	0.13	DL-Arabinose
8	6.86	0.36	(2E)-3-(2-Amino-1H-imidazol-5-yl)acrylic acid
9	7.06	1.29	2-Propyl-tetrahydropyran-3-ol
10	7.40	0.44	N ⁶ -Formyllysine
11	8.24	0.97	DL-Arabinose
12	8.50	0.41	Furaneol
13	8.96	4.46	Maltol
14	9.44	0.46	5-Methylpyrimidine-4,6-diol
15	9.90	0.54	β-Lactose
16	10.05	7.57	3,5-Dihydroxy-6-methyl-2,3-dihydro-4H-pyran-4-one
17	10.31	0.52	β-Lactose
18	10.62	0.27	Methyl 6-oxoheptanoate
19	10.75	0.55	5-Methoxyuridine
20	11.28	0.70	Melezitose
21	11.44	5.14	5-Hydroxymethylfurfural
22	11.73	1.53	Melezitose
23	12.57	1.38	Melezitose
24	12.81	0.27	Melezitose
25	12.86	0.22	Melezitose
26	13.01	0.68	Melezitose
27	13.48	0.52	2-Oxa-7-thiatricyclo [4.3.1.0 ^{3,5}] dec-10-yl acetate
28	14.37	1.56	l-Gala-l-ido-octonic lactone
29	14.73	0.16	1,3-Dihydroxyacetone dimer
30	15.18	0.41	Melezitose
31	15.84	0.45	Melezitose
32	16.33	2.47	Desulphosinigrin
33	16.44	1.44	β-Lactose
34	16.89	0.32	Acetamide, N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butynyl]-
35	17.09	0.14	1,3-Dihydroxyacetone dimer
36	17.82	0.19	β-Lactose
37	18.36	3.91	β-Lactose
38	18.48	2.59	β-Lactose
39	18.89	11.62	β-Lactose
40	19.40	0.65	β-Lactose
41	19.53	4.62	4-(3-Hydroxy-1-propen-1-yl)-2-methoxyphenol
42	19.90	0.86	β-Lactose
43	20.47	0.17	Glycolaldehyde dimer
44	20.61	0.22	Acetamide, N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butynyl]-
45	21.07	0.20	Glycolaldehyde dimer
46	21.63	0.19	β-D-Galactopyranose, 6-O-(trimethylsilyl)-, cyclic 1,2:3,4-bis(methylboronate)
47	21.83	0.14	Acetamide, N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butynyl]-
48	22.13	0.95	β-D-Galactopyranose, 6-O-(trimethylsilyl)-, cyclic 1,2:3,4-bis(methylboronate)
49	22.79	0.83	trans-Sinapyl alcohol
50	22.82	0.80	Acetamide, N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butynyl]-
51	24.02	0.21	2,2,19,19-Tetramethyl-3,6,10,14,18-pentaoxa-2,19-disilaicosane
52	24.40	7.38	3,7,11,15,18-Pentaoxa-2,19-disilaicosane, 2,2,19,19-tetramethyl-
53	24.66	12.13	1-O-Heptylhexitol
54	29.11	0.16	24(R), 25-Dihydroxyvitamin D3
55	33.11	0.66	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa [3,4] benzo[1,2-e] azulene-5,9,9a-triyl triacetate
56	33.96	0.33	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa [3,4] benzo[1,2-e] azulene-5,9,9a-triyl triacetate

Nitro-1-buten-3-ol (2.04%), l-Gala-l-ido-octonic lactone (1.56%), acetamide, N-methyl-N-[4-(3-hydroxypyrrolidinyl)-2-butyryl]- (1.48%), 3-Pyrroline, 1-nitroso- (1.31%), 2-Propyl-tetrahydropyran-3-ol (1.29%), and alpha.-D-Galactopyranose, 6-O-(trimethylsilyl)-,cyclic 1,2:3,4-bis(methylboronate) (1.14%).

The following chemical components were detected in GC/MS analysis: γ -sitosterol (17.91%), 2-ethylhexanol (15.97%), 5-hydroxymethylfurfural (11.44%), 1-O-heptylhexitol (7.65%), 7b-hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate (7.52%), vitamin E (4.73%), melezitose (4.7%), D-alanine, N-propargyloxycarbonyl-, isohexyl ester (3.95%), butyl isobutyl phthalate (3.36%), dioctyl phthalate (3.31%), 3,5-dihydroxy-6-methyl-2,3-dihydro-4H-pyran-4-one (2.94%), 4-cyclohexene-1,2-diol (2.15%), 3a,6b,8a-trihydroxy-2a-(hydroxymethyl)-

1,1,5,7-tetramethyl-4-oxo-1a,1b,1c,2a,3,3a,4,6a,6b,7,8,8a-dodecahydro-1H-cyclopropa[5',6']benzo[1',2':7,8]azuleno[5,6-b]oxiren-8-yl acetate (2.1%), 2,2,19,19-tetramethyl-3,6,10,14,18-pentaoxa-2,19-disilaicosane (1.44%), 6-acetyl-.beta.-d-mannose (1.33%), β -lactose (1.28%), 4-(3-hydroxy-1-propen-1-yl)-2-methoxyphenol (1.15%) and DL-arabinose (1.13%).

Whereas Py-GC/MS analysis of *E. tirucalli* wood powder detected 234 peaks. The main chemical components identified were dl-alanine (5.65%), hydroxyacetone (5.14%), syringol (3.53%), 1,2,4-cyclopentanetrione (3.53%), 3-(2-pentenyl)-D-allose (3.31%), (E)-2,6-dimethoxy-4-(prop-1-en-1-yl)phenol (2.82%), 1,2-cyclopentanedione (2.27%), furfural (1.89%), glycidol (1.85%), coniferol (1.80%), 2(3H)-furanone, dihydro-4-hydroxy- (1.76%), catechol (1.72%), 2-methoxy-4-vinylphenol (1.69%), acetaldehyde (1.64%), 3,5-dimethoxy-4-

Table 3 : GC/MS analysis of benzene and ethanol extraction of *E. tirucalli*

PK	RT (min)	Peak Area (%)	Composition
1	5.33	2.15	4-Cyclohexene-1,2-diol
2	5.47	0.78	Levogluconenone
3	5.69	0.21	Methyl 12,15-octadecadiynoate
4	6.00	1.13	DL-Arabinose
5	7.17	0.31	Melibiose
6	7.87	15.97	2-Ethylhexanol
7	8.28	0.25	β -Lactose
8	8.98	3.95	D-Alanine, N-propargyloxycarbonyl-, isohexyl ester
9	10.00	2.94	3,5-Dihydroxy-6-methyl-2,3-dihydro-4H-pyran-4-one
10	10.22	1.04	d-Mannose
11	11.47	11.44	5-Hydroxymethylfurfural
12	11.68	1.33	6-Acetyl-.beta.-d-mannose
13	11.98	0.29	Melezitose
14	12.27	1.23	Melezitose
15	12.47	0.64	Melezitose
16	12.94	0.51	Melezitose
17	13.43	0.35	Melezitose
18	13.52	0.44	b-Hydroxylauric acid
19	14.07	0.60	Melezitose
20	14.20	0.59	l-Gala-l-ido-octonic lactone
21	15.33	0.29	Melezitose
22	15.86	0.53	Melezitose
23	16.17	0.26	Melezitose
24	17.65	0.34	β -Lactose
25	18.13	0.43	β -Lactose
26	18.74	0.26	β -Lactose
27	19.34	1.15	4-(3-Hydroxy-1-propen-1-yl)-2-methoxyphenol
28	20.39	0.42	Methyl 11-(3-pentyl-2-oxiranyl)undecanoate
29	21.97	0.44	β -D-Galactopyranose, 6-O-(trimethylsilyl)-,cyclic 1,2:3,4-bis(methylboronate)
30	22.15	3.36	Butyl isobutyl phthalate
31	22.35	0.28	β -D-Galactopyranose, 6-O-(trimethylsilyl)-,cyclic 1,2:3,4-bis(methylboronate)
32	22.62	0.56	N-{6-Methoxy-2-methyl-8-[(trimethylsilyl)oxy]hexahydropyrano[3,2-d][1,3,2]dioxaborinin-7-yl}acetamide
33	22.81	0.22	N-{6-Methoxy-2-methyl-8-[(trimethylsilyl)oxy]hexahydropyrano[3,2-d][1,3,2]dioxaborinin-7-yl}acetamide
34	23.61	17.91	γ -Sitosterol

Contd.....

35	23.87	1.44	2,2,19,19-Tetramethyl-3,6,10,14,18-pentaoxa-2,19-disilaicosane
36	24.24	6.46	1-O-Heptylhexitol
37	24.49	1.19	1-O-Heptylhexitol
38	25.63	0.66	Ethyl iso-allocholate
39	26.45	1.73	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate
40	27.74	0.24	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate
41	28.87	0.32	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate
42	29.03	0.27	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate
43	29.39	3.31	Dioctyl phthalate
44	29.64	4.73	Vitamin E
45	29.75	0.26	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate
46	31.23	0.21	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate
47	31.92	3.40	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate
48	32.59	0.65	3a,6b,8a-Trihydroxy-2a-(hydroxymethyl)-1,1,5,7-tetramethyl-4-oxo-1a,1b,1c,2a,3,3a,4,6a,6b,7,8,8a-dodecahydro-1H-cyclopropa[5',6']benzo[1',2':7,8]azuleno[5,6-b]oxiren-8-yl acetate
49	32.92	0.54	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate
50	33.23	1.21	3a,6b,8a-Trihydroxy-2a-(hydroxymethyl)-1,1,5,7-tetramethyl-4-oxo-1a,1b,1c,2a,3,3a,4,6a,6b,7,8,8a-dodecahydro-1H-cyclopropa[5',6']benzo[1',2':7,8]azuleno[5,6-b]oxiren-8-yl acetate
51	33.49	0.55	7b-Hydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-9aH-cyclopropa[3,4]benzo[1,2-e]azulene-5,9,9a-triyl triacetate
52	33.76	0.24	3a,6b,8a-Trihydroxy-2a-(hydroxymethyl)-1,1,5,7-tetramethyl-4-oxo-1a,1b,1c,2a,3,3a,4,6a,6b,7,8,8a-dodecahydro-1H-cyclopropa[5',6']benzo[1',2':7,8]azuleno[5,6-b]oxiren-8-yl acetate

hydroxytoluene (1.51%), methyl glyoxal (1.45%), succindialdehyde (1.44%), methyl pyruvate (1.36%), creosol (1.36%), trans-isoeugenol (1.35%), guaiacol (1.34%), maple lactone (1.33%), 2-furanmethanol (1.21%), 2(5H)-furanone (1.17%), 5-tert-butylpyrogallol (1.15%), glycolaldehyde (1.14%), syringaldehyde (1.10%), vanillyl methyl ketone (1.08%), formic acid (1.06%), 3-methoxycatechol (1.03%), 1-oxiranyl ethanone (1.02%), and 2,6-dimethoxy-4-allylphenol (1.00%), respectively.

On comparing the results of GC/MS and Py-GC/MS, different chemical components were detected in each technique, although Py-GC/MS detected, a higher number of chemical components as compared to GC-MS. Different materials are more likely to be the cause of this phenomenon than different detection method. Further experimentation is required to determine if the solvents used in this study cannot effectively extract the components from *E. tirucalli*.

Thermogravimetric was used to observe the change in the sample weight with increasing test temperature, and obtained the percentage of weight lessness, initial decomposition temperature, final temperature and reaction rate for the sample. These data were used so that we can understand more fully the properties of components contained in *E. tirucalli*.

Three phases of TGA curve were clearly visible, and were marked as P_1 (temperature $<80^\circ\text{C}$), P_2 (80°C < temperature $<200^\circ\text{C}$) and P_3 (200°C < temperature). In P_1 , the TGA curve decreased due to evaporation of water and solvent, and the derivative thermogravimetry curve fluctuated because temperature at which water began to evaporate did not reach the vaporization temperature for solvent. In P_2 , the gentle curve indicated continuous endothermic process was occurring. In this phase, the quality and property of samples were not activated significantly. When temperature continually increased to P_3 , the DTG curve increased because hemicelluloses began to degrade, and when temperature was above 250°C , cellulose also began to degrade (Li *et al.*, 2015; Razaliet *et al.*, 2017; Rahman *et al.*, 2017; Xiao *et al.*, 2001; Hosoya *et al.*, 2007).

Functional analysis : According to GC/MS and Py-GC/MS analysis, many components from *E. tirucalli* were detected. The purpose of this study was to detect the chemical components contained in this tree species in order to explore their usefulness or potential value.

In medicine field, γ -sitosterol is a molecule that possess antihyperglycemic activity and can dock well with various targets related to diabetes mellitus. It can be considered as a potent

Table 4 : Py-GC/MS analysis of *E. tirucalli* wood powder

PK	RT (min)	PeakArea (%)	Composition
1	3.70	0.02	2-Propenamide
2	4.09	5.65	dl-Alanine
3	4.26	1.64	Acetaldehyde
4	4.32	1.85	Glycidol
5	4.67	1.17	Methyl glyoxal
6	4.80	0.28	Methyl glyoxal
7	4.93	0.66	Formic acid
8	4.99	0.40	Formic acid
9	5.17	0.04	Methylazoxymethanol acetate
10	5.24	0.15	Dihydroxyacetone
11	5.41	1.14	Glycolaldehyde
12	5.48	1.02	1-Oxiranyl ethanone
13	5.62	0.28	Azetidine
14	5.70	0.14	Methyl formate
15	5.86	0.06	Acetic acid
16	6.63	0.14	1-Propanol, 2-methyl-
17	6.79	2.44	Hydroxyacetone
18	6.86	0.24	Hydroxyacetone
19	7.01	0.11	Methyl formate
20	7.12	0.07	Acetic acid, hydroxy-
21	7.23	0.15	2,3-Pentanedione
22	7.44	0.11	Acetic acid, hydroxy-, methyl ester
23	7.52	0.51	1,4-Dioxin, 2,3-dihydro-
24	7.64	0.19	Diethyl carbonate
25	7.79	0.19	Ethyl formate
26	7.85	0.12	Ethyl ether
27	7.93	0.15	3-Methylethcathinone
28	8.02	0.10	1,2-Ethanediol, monoformate
29	8.39	0.17	1H-Pyrrole, 1-methyl-
30	8.62	0.20	3-Nitro-2-methyl propene
31	8.69	0.45	Cyclopropane, (bromomethyl)-
32	9.15	2.46	Hydroxyacetone
33	9.55	1.44	Succindialdehyde
34	9.61	0.28	Formic acid, chloro-, (3,4,4-trimethyl-1,2-dioxetan-3-yl)methyl ester
35	9.73	1.36	Methyl pyruvate
36	9.91	0.34	Pentanal
37	10.01	0.40	N'-(Diaminomethylidene)formohydrazide
38	10.29	0.09	Oxirane, (ethoxymethyl)-
39	10.41	0.17	Furfural
40	10.60	0.06	2-Butenal, 2-ethyl-
41	10.65	0.08	Butyric acid hydrazide
42	10.74	0.08	Pyrazine, methyl-
43	10.79	0.06	Butanoic acid, 3-hydroxy-, methyl ester
44	10.97	0.11	Cyclopropane, 1-propenyl-
45	11.06	1.72	Furfural
46	11.34	0.12	7-Azanorbornene
47	11.44	0.18	CH ₂ =C(CH ₃)CH ₂ COOH
48	11.62	0.06	L-Talose, 6-deoxy-3-C-methyl-2-O-methyl-
49	11.70	0.05	1,6:2,3-Dianhydro-4-O-acetyl-.beta.-d-allopyranose
50	11.80	1.21	2-Furanmethanol
51	12.01	0.07	2-Buten-1-ol, (Z)-
52	12.14	0.47	2-Propanone, 1-(acetyloxy)-
53	12.22	0.15	2(3H)-Furanone, 5-methyl-
54	12.34	0.03	Propanal, dimethylhydrazone
55	12.50	0.03	4-Cyclopentene-1,3-dione
56	12.62	0.03	1-Penten-3-yne

Contd.....

57	12.73	0.27	Cyclopent-4-ene-1,3-dione
58	12.87	0.02	1-Cyclopropanecarbonitrile, 1-amino
59	12.96	0.14	Styrene
60	13.21	0.03	Rhamnose
61	13.35	0.33	Methyl methacrylate
62	13.46	0.22	2-Cyclopenten-1-one, 2-methyl-
63	13.60	0.23	Ethanone, 1-(2-furanyl)-
64	13.82	1.17	2(5H)-Furanone
65	13.96	0.11	L-Talose, 6-deoxy-3-C-methyl-2-O-methyl-
66	14.25	2.27	1,2-Cyclopentanedione
67	14.36	0.06	2H-Pyran-2-one, 5,6-dihydro-
68	14.52	0.03	2-Methyl-2,3-divinyloxirane
69	14.58	0.11	2(5H)-Furanone, 5-methyl-
70	14.63	0.07	2,5-Furandione, 3-methyl-
71	14.76	0.02	N-Methyl-7-azabicyclo(2,2,1)hept-2-ene
72	14.82	0.05	Cyclohexane, 1,4-dimethyl-, trans-
73	14.87	0.04	2(1H)-Pyridinone, 5-methyl-
74	15.03	0.13	Oxirane, (butoxymethyl)-
75	15.20	0.21	1-Methyl pyrrolidin-3-amine
76	15.33	0.46	2-Furancarboxaldehyde, 5-methyl-
77	15.45	0.25	2-Cyclopenten-1-one, 3-methyl-
78	15.54	0.04	Oxirane, 2-methyl-2-propyl-
79	15.71	0.06	4-Pyridinol
80	15.83	0.12	1-(Dimethylamino)pyrrole
81	15.89	0.39	Phenol
82	16.18	0.03	Ethanol, 2-(2-ethoxyethoxy)-, acetate
83	16.36	0.04	2,4-Hexadiene, 2,5-dimethyl-
84	16.49	0.21	2H-Pyran-2,6(3H)-dione
85	16.58	0.76	2-Methyliminoperhydro-1,3-oxazine
86	16.75	0.07	1,3,6-Trioxocane
87	17.03	0.08	1H-Pyrrole-2-carboxaldehyde
88	17.15	0.13	5-Azacytosine
89	17.23	0.08	N-Methyl-7-azabicyclo(2,2,1) hept-2-ene
90	17.30	0.06	2-Propenal, 3-(dimethylamino)-
91	17.43	0.05	d-Glycero-d-galacto-heptose
92	17.63	1.33	Maple lactone
93	17.73	0.09	1H-1,2,4-Triazole, 1-(2-propenyl)-
94	17.82	0.03	Bicyclo[1.1.0]butane
95	17.88	0.11	2-Cyclopenten-1-one, 2,3-dimethyl-
96	17.94	0.04	7-Tridecanone
97	18.09	0.19	4-Methyl-5H-furan-2-one
98	18.21	0.07	Decane, 2,4,6-trimethyl-
99	18.27	0.16	Phenol, 2-methyl-
100	18.45	0.24	2-Cyclopenten-1-one, 2-hydroxy-3,4-dimethyl-
101	18.62	0.26	(S)-(+)-2',3'-Dideoxyribonolactone
102	18.71	0.62	2-Heptene, 2-methoxy-
103	18.88	0.39	p-Cresol
104	19.03	0.17	2-Cyclopenten-1-one, 3-ethyl-
105	19.15	0.09	Ethanone, 1-cyclopentyl-
106	19.26	0.12	Furyl hydroxymethyl ketone
107	19.32	0.06	2,5-Piperazinedione, 3-methyl-6-(1-methylethyl)-
108	19.42	1.34	Guaiacol
109	19.54	0.10	2-Mercaptophenol
110	19.76	1.76	2(3H)-Furanone, dihydro-4-hydroxy-
111	19.97	0.04	N,O-Diacetyl-4-hydroxytranylcypromine
112	20.03	0.03	3-Ethyl-3-hexene
113	20.16	0.22	Maltol
114	20.28	0.34	2-Cyclopenten-1-one, 3-ethyl-2-hydroxy-
115	20.45	0.75	2H-Pyran-3(4H)-one, dihydro-6-methyl-

Contd.....

116	20.62	0.08	Pyridine, 1-oxide
117	20.74	0.03	1-Nonyne
118	20.78	0.07	1,3-Pentadiene
119	20.87	0.15	Phenol, 2,3-dimethyl-
120	20.96	0.04	2H-Pyran-2-one, 4-hydroxy-3,6-dimethyl-
121	21.06	0.38	2(3H)-Furanone, dihydro-4-methyl-
122	21.30	0.42	Oxalic acid, 4-chlorophenyl tetradecyl ester
123	21.44	0.29	2,3-Dihydroxybenzaldehyde
124	21.64	0.13	Cyclopenta[c]thiopyran, octahydro-, cis-
125	21.69	0.09	Creosol
126	21.82	0.06	5-Hydroxymethyl uracil
127	21.85	0.07	Creosol
128	22.01	1.20	Creosol
129	22.22	1.60	Catechol
130	22.38	0.12	Catechol
131	22.48	0.06	Benzofuran, 2,3-dihydro-
132	22.58	0.32	1,4:3,6-Dianhydro-.alpha.-d-glucopyranose
133	22.69	0.08	9-Oxabicyclo[4.2.1]nonan-2-ol, acetate
134	22.77	0.13	3,4-Anhydro-d-galactosan
135	22.90	0.72	5-Hydroxymethylfurfural
136	23.05	0.03	Bicyclo[8.2.0]dodecane, 11,11-dimethyl-
137	23.12	0.03	Citronellal
138	23.21	0.06	1,6-Octadiene, 3-ethoxy-3,7-dimethyl-
139	23.36	0.08	Undecanal
140	23.45	0.31	1,2-Benzenediol, 3-methyl-
141	23.58	1.03	3-Methoxycatechol
142	23.78	0.57	Phenol, 4-ethyl-2-methoxy-
143	23.83	0.30	Ethanone, 1-(2,5-dihydroxyphenyl)-
144	23.94	0.10	1H-Inden-1-one, 2,3-dihydro-
145	24.07	0.31	1,2-Benzenediol, 4-methyl-
146	24.12	0.36	Isosorbide
147	24.22	0.07	Ethanol, 2-propoxy-
148	24.27	0.06	2-Fluorophenylhydrazine
149	24.35	0.10	Benzaldehyde, 4-hydroxy-
150	24.46	1.69	2-Methoxy-4-vinylphenol
151	24.59	0.01	2-Methyl-9-.beta.-d-ribofuranosylhypoxanthine
152	24.72	0.02	Methyl pentadecyl ether
153	24.80	0.12	5-Methoxymethoxy-6-methyl-hept-6-enoic acid, methyl ester
154	24.85	0.06	Bicyclo[2.2.2]octane-2-carboxylic acid, 6-oxo-, (r1,trans-2,cis-4)-
155	24.90	0.08	Diallylmethylsilane
156	25.11	3.53	Syringol
157	25.19	0.46	Eugenol
158	25.31	0.58	Phenol, 3,4-dimethoxy-
159	25.44	0.05	5-t-Butyl-hexa-3,5-dien-2-one
160	25.54	0.04	Undecylenic acid
161	25.61	0.10	Benzene, 2-fluoro-1,3,5-trimethyl-
162	25.68	0.13	Pentane, 3-(2,2-dichloro-3-methylcyclopropyl)-
163	25.74	0.04	1H-Indole, 5-methyl-
164	25.82	0.24	Benzene, 1,2,3-trimethoxy-5-methyl-
165	25.95	0.61	Vanillin
166	26.00	0.29	Phenol, 2-methoxy-4-(1-propenyl)-
167	26.06	0.20	(E)-3,7-Dimethylocta-2,6-dien-1-yl 3-methylbutanoate
168	26.23	0.31	CH ₃ C(O)CH ₂ CH ₂ OH
169	26.47	0.11	2-Butanone, 4-[(trimethylsilyl)oxy]-
170	26.59	1.51	3,5-Dimethoxy-4-hydroxytoluene
171	26.66	1.35	trans-Isoeugenol
172	26.70	0.24	Ethanone, 1-(2,3,4-trihydroxyphenyl)-
173	26.84	0.14	(4-Fluorophenyl)carbamic acid, 5-phenyl-[1,2,4]oxadiazol-3-yl ester
174	26.99	0.28	Nonanoic acid

Contd.....

175	27.07	0.16	Methyl 6-O-[1-methylpropyl]-.beta.-d-galactopyranoside
176	27.20	0.11	Bicyclo[2.2.2]octa-2,5-diene, 1,2,3,6-tetramethyl-
177	27.31	0.30	Apocynin
178	27.44	0.23	Phenol, 5-methoxy-2,3,4-trimethyl-
179	27.74	0.65	.beta.-D-Glucopyranose, 1,6-anhydro-
180	27.82	1.15	5-tert-Butylpyrogallol
181	27.96	0.92	D-Allose
182	28.02	1.08	Vanillyl methyl ketone
183	28.13	0.84	D-Allose
184	28.19	1.55	D-Allose
185	28.54	3.53	1,2,4-Cyclopentanetrione, 3-(2-pentenyl)-
186	28.65	0.16	Octan-2-one, 3,6-dimethyl-
187	28.73	0.27	5-Methoxy-2-allylphenol
188	28.89	0.31	1-(3,4-Methylenedioxyphenyl)propane-1-ol
189	29.04	0.14	Styracitol
190	29.14	1.00	4-Allyl-2,6-dimethoxyphenol
191	29.25	0.34	2,6-Dimethyl-1-nonen-3-yn-5-ol, TMS derivative
192	29.32	0.27	d-Talonic acid lactone
193	29.75	0.73	3(2H)-Benzofuranone, 4,6-dimethoxy-
194	29.83	0.76	Phenylamine, N,4,5-trimethyl-2-nitro-
195	29.98	0.51	d-Talonic acid lactone
196	30.08	0.82	(E)-2,6-Dimethoxy-4-(prop-1-en-1-yl) phenol
197	30.13	0.47	Benzenepropanol, 4-hydroxy-3-methoxy-
198	30.23	0.55	6-O-Acetyl-1,3:2,4:5,7-O-trimethylene-beta-sedoheptitol
199	30.38	1.10	Syringaldehyde
200	30.62	0.59	4-((1E)-3-Hydroxy-1-propenyl)-2-methoxyphenol
201	30.77	0.21	5-Acetyl-1,3:2,4-di-O-methylene-d-arabitol
202	30.87	0.44	4-Methoxymethyl-6-methyl-1H-pyrazolo[3,4-b]pyridin-3-ylamine
203	31.02	0.37	[1,4]Oxathiino[2,3-b]-1,4-oxathiin, hexahydro-8a-methyl-
204	31.19	2.82	(E)-2,6-Dimethoxy-4-(prop-1-en-1-yl) phenol
205	31.26	0.16	d-Glycero-d-galacto-heptose
206	31.46	0.41	9-Acetoxynonanal
207	31.71	0.21	Butanoic acid, 3-oxo-, propyl ester
208	31.85	0.07	Undeca-3,4-diene-2,10-dione, 5,6,6-trimethyl-
209	32.02	0.78	Ethanone, 1-(4-hydroxy-3,5-dimethoxyphenyl)-
210	32.21	1.80	Coniferol
211	32.71	0.23	2-Piperidinone, N-[4-bromo-n-butyl]-
212	32.94	0.76	Desaspidinol
213	33.23	0.15	Bicyclo[3.3.1]nonan-9-ol, 9-methyl-
214	33.50	0.03	4H-1-Benzopyran-2-carbonyl chloride, 4-oxo-
215	34.47	0.33	Benzo[b]thiophene-5-carboxylic acid, 1,1-dioxide
216	34.72	0.04	Propanoic acid, 2-(tricyclo[3.3.1.1 ^{3,7}]dec-2-ylidene)-
217	34.93	0.04	2-Chlorophenethyl alcohol, n-propyl ether
218	35.02	0.04	Z-11-Pentadecenal
219	35.40	0.22	12-Methyl-E, E-2,13-octadecadien-1-ol
220	35.43	0.15	Octadecanoic acid
221	35.73	0.20	1,4-Dimethyl-8-isopropylidenetricyclo[5.3.0.0(4,10)]decane
222	36.22	0.03	Isopropyl 5-hydroxy-3,7,11-trimethyl-2,10-dodecadienoate
223	36.83	0.43	5-(3-Hydroxypropyl)-2,3-dimethoxyphenol
224	37.07	0.06	1-(7-Nitro-3,4-dihydro-1H-isoquinolin-2-yl)-ethanone
225	37.37	0.04	15-Hydroxypentadecanoic acid
226	37.79	0.58	trans-Sinapyl alcohol
227	37.95	0.07	9-Octadecenamide
228	38.29	0.16	4-(7-Hydroxy-2,2,7-trimethyltetrahydro [1,3] dioxolo [4,5-c] pyran-4-yl)-3-methylbut-2-enoic acid, methyl ester
229	39.18	0.79	n-Hexadecanoic acid
230	39.40	0.10	8-Hexadecenal, 14-methyl-, (Z)-
231	39.62	0.07	Dibutyl phthalate
232	40.12	0.04	Pyrene, hexadecahydro-
233	40.26	0.04	Acetamide,2,2,2-trifluoro-N-[2-hydroxy-2-(3,4-dimethoxyphenyl)ethyl]-
234	40.90	0.16	3,5-Dimethoxy-4-hydroxycinnamaldehyde

Fig. 2 : TG analysis curve of the *E. tirucalli* leaching liquor with different extraction solvents.

antidiabetic drug (Balamurugan *et al.*, 2012). γ -sitosterol also acts as growth inhibitor for apoptosis of cancer cells and initiate cell cycle arrest to exert potential anticancer activity (Sundarraj *et al.*, 2010). Melezitose monoesters with long-chain fatty acids are a promising surfactant that has pharmaceutical applications (Carvalho *et al.*, 2015).

Vitamin E is a fat-soluble small-molecule organic compound that can be used for the treatment of nonalcoholic steatohepatitis (Sanyal *et al.*, 2010). Vitamin E supplementation can reduce the risk of cardiovascular disease, cancer, premature senility, and other diseases, and can also promote human immune function; it also exerts certain preventive effects on diseases. Vitamin E (alpha-tocopherol) enable plants to resist high salt, drought and low temperature (Lee *et al.*, 2005; Zhang and Wang, 2016; Ahamed *et al.*, 2017; Fu and Liu, 2017).

Butyl isobutyl phthalate exerts hypoglycemic effects as an α -glucosidase inhibitor and can be developed as a new medicine to treat diabetes (Bu *et al.*, 2010; Jeon *et al.*, 2018; Kim *et al.*, 2018). In industry field, 2-ethylhexanol and epoxidized soybean oil can be used to prepare synthetic lubricant base stocks alone or with polyalphaolef in (Hwang *et al.*, 2003). 5-hydroxymethylfurfural is an important chemical obtained by dehydration of fructose and sucrose, and a variety of derivatives can be produced from it through reactions such as oxidation, hydrogenation and condensation (Zhao *et al.*, 2007). 2-furanmethanol (furfuryl alcohol) can be used to make tartaric acids, plasticizers, solvents and rocket fuel. In addition, it is also widely used in industrial sectors as dye, synthetic fiber, rubber, pesticide, and in foundries. Furfural is a potential biofuel, and its derivatives are potential biofuel components with rich sources (Lange *et al.*, 2012). Hydroxyacetone can be used to synthesize renewable diesel or jet fuel branched alkanes with 2-methylfuran

(Li *et al.*, 2013). 4-allyl-2,6-dimethoxyphenol can be used as an antioxidant in biodiesel blends with rapeseed and soybean and can significantly improve oxidation stability of both types of biodiesel (Lucia *et al.*, 2004).

In food industry, Maltol is a synthetic flavor enhancer that can be added to beverages, baked food, ice creams and candies to enhance or change the inherent flavors of foods and beverages. However, eating excessive maltol can harm the kidneys and neuronal system (Zhang *et al.*, 2018; Kniat, 2018; Shen *et al.*, 2017).

Guaiacol is a flavoring agent and also an expectorant; it is used in drugs, dyes and synthesis of spices (Mageroy *et al.*, 2012). It is an exogenous compound and can be absorbed by plants, which changes the volatile composition of fruits and produces a negative or positive effect in their aroma (Pardo-Garcia *et al.*, 2013). The above investigation shows that the chemical components contained in the *E. tirucalli* stem can be used for the development of anti-diabetic drugs, and can be cardiovascular diseases, immune-enhancing drugs and anti-cancer drugs. And also can be widely used in industrial production and manufacture of food additives.

References

- Ahamed, A.J., K. Loganathan, S. Ananthakrishnan, J. Ahmed and M.A. Ashraf: Evaluation of graphical and multivariate statistical methods for classification and evaluation of groundwater in Alathur Block, Perambalur district, India. *Appl. Ecol. Env. Res.*, **15**, 105-116 (2017).
- Aslam, S., S.U. Rahman, Z. Sabir and B. Maqbool: Evaluation of cosmetics for their potential contaminants and drug resistant microorganisms. *Acta Sci. Malays.*, **1**, 16-19 (2017).
- Balamurugan, R., A. Stalin and S. Ignacimuthu: Molecular docking of γ -sitosterol with some targets related to diabetes. *Eur. J. Med. Chem.*, **47**, 38-43 (2012).
- Botella, L., F. Bimbela, L. Martin, J. Arauzo and J.L. Sanchez: Oxidation stability of biodiesel fuels and blends using the Rancimat and PetroOXY methods. Effect of 4-allyl-2,6-dimethoxyphenol and catechol as biodiesel additives on oxidation stability. *Front. Chem.*, **2**, 43 (2014).
- Bu, T., M. Liu and L. Zheng: α -Glucosidase inhibition and the *in vivo*, hypoglycemic effect of butyl-isobutyl-phthalate derived from the *Laminaria japonica*, rhizoid. *Phytother. Res.*, **24**, 1588-1591 (2010).
- Carvalho, L., J.C. Morales and J.M. PáRez-Victoria: Hemolytic activity and solubilizing capacity of raffinose and melezitose fatty acid monoesters prepared by enzymatic synthesis. *Eur. J. Pharm. Biopharm.*, **92**, 139-145 (2015).
- Chang, S.K., D.H. Baek and K.D. Gang: Characterization of gelatin nanofiber prepared from gelatin-formic acid solution. *Polymer*, **46**, 5094-5102 (2005).
- Chen, J.T., C.Y. Ni, J.W. Lou and W.X. Peng: Molecules and functions of rosewood: *Diospyros celebica*. *Arab. J. Chem.*, **11**, 756-762 (2017).
- Elsayed, J.: Bio-chemical biomarkers in algae *Scenedesmus obliquus*

- exposed to heavy metals Cd, Cu and Zn. *Acta. Chem. Malay.*, **1**, 16-20 (2017).
- Fu, H. and X. Liu: A study on the impact of environmental education on individuals' behaviors concerning recycled water reuse. *Eura. J. Mathe. Sci. Technol. Edu.*, **13**, 6715-6724 (2017).
- Gao, W. and J. Yang: Soil environmental quality of vegetable planting base in Sanmenxia city. *J. Environ. Manag. Coll. Chi.*, **1**, 77-79 (2016).
- Hanafiah, M.M., M.Y.M. Ali, N.I.H.A. Aziz and A. John: Biogas production from agro-waste and effluents. *Acta. Chem. Malay.*, **1**, 13-15 (2017).
- Hastilestari, B.R., M. Mudersbach and F. Tomala: *Euphorbia tirucalli* L.-comprehensive characterization of a drought tolerant plant with a potential as biofuel source. *Plos. One*, **8**, e63501 (2013).
- Hosoya, T., H. Kawamoto and S. Saka: Cellulose-hemicellulose and cellulose-lignin interactions in wood pyrolysis at gasification temperature. *J. Anal. Appl. Pyrol.*, **80**, 118-125 (2007).
- Hwang, H.S., A. Adhvaryu and S.Z. Erhan: Preparation and properties of lubricant basestocks from epoxidized soybean oil and 2-ethylhexanol. *J. Am. Oil Chem. Soc.*, **80**, 811-815 (2003).
- Jeon, E., S. Ryu, S. Park, L. Wang, D.C.W. Tsang and K. Baek: Enhanced adsorption of arsenic onto alum sludge modified by calcination. *J. Clean Prod.*, **176**, 54-62 (2018).
- Jiang, S.C., S.B. Ge and M.Z. Wang: Molecules and functions of rosewood: *Dalbergia stevenson*. *Arab. J. Chem.*, **11**, 782-792, (2018).
- Khaleghian, A., Y. Nakaya and H. Nazari: Biodiesel production from *Euphorbia tirucalli* L. *J. Med. Plants Res.*, **5**, 33-45 (2011).
- Khan, I.U., S. Sajid, A. Javed, S.U. Shah, S.N. Khan and K. Ullah: Comparative diagnosis of typhoid fever by polymerease chain reaction and widal test in southern districts of Khyber Pakhtunkhwa. *Acta. Sci. Malay.*, **1**, 12-15 (2017).
- Kim, N.Y., E.J. Jeon, S.H. Jung, S.J. Ahn, M.A. Park and J.S. Seo: Gene expression profiling and expression analysis of freshwater shrimp (*Neocaridina denticulata denticulata*) using expressed sequence tags and short-term exposure to copper. *J. Environ. Biol.*, **39**, 51-57 (2018).
- Kniat, A.: Visualization of a lifeboat motion during lowering along ship's side. *Pol. Marit. Res.*, **24**, 42-46 (2017).
- Lange, J.P., D.J.V. Buijtenen and P.R. Furfural: A promising platform for lignocellulosic biofuels. *Chemsuschem*, **5**, 150-166 (2012).
- Lee, I.M., N.R. Cook, J.M. Gaziano, D. Gordon, P.M. Ridker, J.E. Manson, C.H. Hennekens and J. E. Buring: Vitamin E in the primary prevention of cardiovascular disease and cancer - The Women's health study: A randomized controlled trial. *Digest of the World Core Med. J.*, **14**, 10-11 (2005).
- Li, D. L., L.S. Wang, W.X. Peng, S.B. Ge, N.C. Li and Y. Furuta: Chemical structure of hemicellulosic polymers isolated from bamboo bio composite during mold pressing. *Polym. Composite*, **38**, 2009-2015 (2015).
- Li G. Y., N. Li, S.S. Li, A.Q. Wang, Y. Cong, X. D. Wang and T. Zhang: Synthesis of renewable diesel with hydroxyacetone and 2-methylfuran. *Chem. Commun.*, **49**, 5727-5729 (2013).
- Li, D.L., S.B. Ge, W.X. Peng, Q.D. Wu and J.G. Wu: Chemical structure characteristics of wood/lign in composites during mold pressing. *Polym. Composite*, **38**, 955-965 (2017).
- Mageroy, M.H., D.M. Tieman, A. Floystad, M.G. Taylor and H.J. Klee: A *Solanum lycopersicum* catechol-O-methyltransferase involved in synthesis of the flavor molecule guaiacol. *Plant J.*, **69**, 1043-1051 (2012).
- Pardo-García, A.I., A.M. Martínez-Gil, H. López-Córcoles, A. Zalacain, and R. Salinas: Effect of eugenol and guaiacol application on tomato aroma composition determined by headspace stir bar sorptive extraction. *J. Sci. Food Agr.*, **93**, 1147-1155 (2013).
- Rahman, S.A., A.A. Kahar, A. Mansor, D.L. Murni, A. Hussin, S.A. Sharifudin, T.G. Hun, N.Y. Abdul Rashid, M.A. Othama and K. Long: Identification of potential indigenous microbe from local fermented vegetables with antimicrobial activity. *Sci. Herit. J.*, **1**, 1-3 (2017).
- Razali, A., H.P. Herman and A.H. Zulkifly: Noise exposure during orthopaedics surgery. *Sci. Herit. J.*, **1**, 32-33 (2017).
- Rozainy, M.R., W.W. Khairi, I. Abustan, S.S. Rahim, M.N.N. Khan and N.K.E.M. Yahaya: Comparison method of odour impact evaluation using CALPUFF dispersion modeling and on-site odour monitoring. *Eng. Herit. J.*, **1**, 6-10 (2017).
- Sanyal, A.J., N. Chalasani, K.V. Kowdley, A. McCullough, A.M. Diehl, N. M. Bass, B. A. Neuschwander-Tetri, J.E. Lavine, J. Tonascia, A. Unalp, M.V. Natta, J. Clark, E.M. Brunt, D.E. Kleiner, J.H. Hoofnagle and P.R. Robuck: Ro Pioglitazone, Vitamin E, or placebo for nonalcoholic steatohepatitis. *New Engl. J. Med.*, **362**, 1675-1685 (2010).
- Shen Y., N. Zhao, M. Xia and X. Du: A deep Q-learning network for ship stowage planning problem. *Pol. Marit. Res.*, **24**, 102-109 (2017).
- Silva, A.C.P., D.E.P.D. Faria, N.B.E.S. Borges, I.A.D. Souza, V.M. Peter, and M.O. Guerra: Toxicological screening of *Euphorbia tirucalli*, L.: Developmental toxicity studies in rats. *J. Ethnopharmacol.*, **110**, 154-9 (2007).
- Sundarraj, S., R. Thangam, V. Sreevani, K. Kaveri, P. Gunasekaran, S. Achiraman and S. Kannan: γ -Sitosterol from *Acacia nilotica* L. induces G2/M cell cycle arrest and apoptosis through c-Myc suppression in MCF-7 and A549 cells. *J. Ethnopharmacol.*, **141**, 803-809 (2012).
- Tariq, W., S. Q. Hussain, A. Nasir, N. Tayyab, S. H. Gillani and A. Rafiq: Experimental study on strength and durability of cement and concrete by partial replacement of fine aggregate with fly ash. *Earth Sci. Pak.*, **1**, 10-14 (2017).
- Usman, M., H. Yasin, A. Nasir and W. Mehmood: A case study of groundwater contamination due to open dumping of municipal solid waste in Faisalabad, Pakistan. *Earth Sci. Park.*, **1**, 15-16 (2017).
- Wei, L.L.: Analysis on the causes of serious drought in winter in Sanmenxia City. *J. Anhui Agri. Sci.*, **45**, 172-173 (2017).
- Wu, Y.Q., W.X. Peng and X.G. Li.: Py-GC/MS Analysis on biomedical components of *Phyllostachys pubescens*[C]. In: *International Conference on Bioinformatics and Biomedical Engineering.*, **1** (2009).
- Xiao, B., X.F. Sun and R.C. Sun: Chemical, structural, and thermal characterizations of alkali-soluble lignins and hemicelluloses, and cellulose from maize stems, rye straw, and rice straw. *Polym. Degrad. Stabil.*, **74**, 307-319 (2001).
- Zeng, Y.L., D.Q. Zhang and W.X. Peng: Pyrolysis-GC/MS of bioactive components of acetone extractives of oil-tea cake under 300°C. *Adv. Mater. Res.*, **230**, 847-851 (2011).
- Zhang, G., Y. Ma, L. Wang, Y. P. Zhang and J. Zhou: Multispectroscopic studies on the interaction of maltol, a food additive, with bovine serum albumin. *Food Chem.*, **133**, 264-270 (2012).
- Zhang, L. and L. Wang: Progress on biological function of Vitamin E in plants. *Current Biotechnology*, **6**, 389-395 (2016).
- Zhao, H.B., J.E. Holladay, H. Brown and Z.C. Zhang: Metal chlorides in ionic liquid solvents convert sugars to 5-hydroxymethylfurfural. *Science*, **316**, 1597-1600 (2007).