Progress of the components and biological activities of *Morinda officinalis* How

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Abstract

The *Morinda officinalis* How is "one of the top four south authentic traditional Chinese medicines", widely distributed in South District of China, such as Fujian, Guangdong, Guangxi, Hainan, etc. Its roots are widely used for the treatment of sexual impotence, spermatorrhea, irregular menstruation, and female infertility in clinical. Many kinds of compounds (triteroid glycosides, anthraquinones, saccharides, organic acids, volatile oils and homogeneous polysaccharides) have been isolated from its roots and the relevant biological activities (pain-killing, antioxidant, antibacterial, anticancer, anti-inflammatory, anti-tubercular and cardiovascular action) were also studied. This review briefly describes the botanical description, plant taxonomy, history of medicinal development and the progress of the chemical components and biological activities of *M. officinalis* to provide a reference for the researchers.

Introduction

Over the years, plant medicines have been used as helpful sources for curing different ailments both for human and animals [1-3]. Plant medicines contain a large variety of constitutes which have important protective and medicinal therapies [4-7]. Products from plant medicines have ever been widely used in Asia and Africa [3,7].

In Asia and Africa, almost all the population depend on traditional health doctors, thereby medicinal plants are used to meet health needs [1,3,7]. Modern medicines exist alongside with traditional herbal medicines still keep up their reputation for the cultural and historical reasons. Herbal products are widely accessible commercially, particularly in developed countries. In developed countries, the herbal medicines are greatly used to cure different ailments [7,8]. The assessment of different herbal products based on their uses and therapeutic value lead to the detection of novel medicines for curing various diseases. *M. officinalis* is one kind of subtropical and tropical plants, which widely distribute in subtropical and tropical districts of Asia [9,10]. The root of this plant is well known as "Bajitian" in China, which has been used for curing various diseases in clinical.

This review briefly describes the botanical description, plant taxonomy, history of medicinal development and the progress of the components and biological activities of *M. officinalis* to provide a reference for the researchers.

Distribution and botanical description

*M. officinalis* mainly found in the upland tropical and subtropical forests of Asia. In China, it is widely distributed in south districts such as Fujian, Guangdong, Guangxi, Hainan, etc. [11]. Its branches covered with a small leaf-like appendage. Root succulent hypertrophy, irregular, cylindrical, and intermittent swelling with a rosary. The young *M. officinalis* plant is with stiff, slender bristles and covered with fine soft hairs; it gradually becomes hairless with rough surface and the branches covered with a small leaf-like appendage at maturity. *M. officinalis* flowers are arranged in fascicles and in umbels, and thickly hairy change to slender bristles showing its ageing stage; the flower is merged for half receptacle; the calyx is pubescent to smooth; the corolla is white, bell-shaped or urn inside, and hairy; finely hirsute outside; the aggregate fruits is orbicular to flatten; and the fruits are fully fused, red and subglobose [12].

Plant taxonomy

*M. officinalis* is one of the most well-known and studied species of Rubiaceae (coffee family), *M. officinalis* is as well recognized as *Gynochthodes officinalis* (F. C. How) [13] or *Morinda officinalisvar. hirsuta F. C. How* [14] in the book of "World Checklist". *M. officinalis* is commonly known as "Bajitian" by Chinese [15].

Razafimandimbison et al. [16] recently demonstrated the paraphyly of the type genus *Morinda* with respect to its closely related species *Coelospermum Blume*, *Gynochthodes Blume*, *Pogonolobus F. Muell.*, *Sarcopogymne Setch*. and *Christoph*. As a consequence, new generic limits of *Morindeae* were proposed in order to make *M. monophyletic, and that morphologically well-defined genera were recognized in Morindeae.*

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History of medicinal development

The dried root of *M. officinalis* is a renowned traditional Chinese medicine and was listed in the Chinese Pharmacopoeia [15]. The roots have been used dated back to the late Qing Dynasty, Qingyuan, Sankeng and Luoding of Guangdong province, considered as one of the most important medicinal herbs (According to “Yaowu Chuchanbian” book, before Qing Dynasty medicinal materials used was *Dammacanthus officinarum Huang* (Rubiaceae) and *Schisandra propinquas* (Wall.) Hook.f. et Thoms. var. *sinensis* (Magnoliaceae).

*M. officinalis* can also be named locally as Jichang feng, Tuzi chang, Tuer chang, Heiteng zhuan, Maochang jin, and Jiyan teng. Root of *M. officinalis* is sharp, sweet and non-toxic, which can diffuse directly to the liver and kidney regions. This plant is well known to be medicinal to internal organs, such as the heart, the liver and the kidney, with other beneficial effects to man’s health by nourishing kidney, strengthening bones, muscles and improving the circulation blood. *M. officinalis* root is extensively used in traditional Chinese medicine for curing diseases associated with kidney-yang deficiency: including fatigue, declining libido, premature ejaculation, male impotence, female infertility, rheumatism, muscular and skeletal atrophy and depression. The root of this plant has been accepted by the Health and Family Planning Commission of China for curing different ailments and can also be combined with other herbs to increase its treatment scopes.

Almost all parts of *M. officinalis* have been supported and approved by the Health and Family Planning Commission of China for treating different diseases in clinical, which include poor digestion, respiratory problems, immune deficiencies and high blood pressure in China since ancient times [15,17-22].

In traditional medicine, different herbs are combined together to improve their therapeutic effects because of their synergism [23]. *M. officinalis* is combined with *Epimedium brevicomum* Maxim, *Ligustrum lucidum* Ait., *Schisandra chinensis* Baill., *Cascuta chinensis* Lam., *Astragalus membranaceus* Bge and *Poaalea corylifolia* to prepare a remedy for treating cancer, depression, fatigue, inflammation, osteoporosis, memory problems, high blood glucose, or kidney disease in clinical [18,24-29].

Biological activities

The *M. officinalis* exhibited a wide spectrum of biological activities: such as anti-inflammatory, antioxidant, antidepressant, anti-fatigue, anti-aging, renoprotective, fertility improvement, cardiovascular protection, hypoglycemic and hyperglycemic activities, antioestrogenosis, antiinocceptive, antimutagenic, antimicrobial, antihepatotoxic and anti-HIV [25,30-31].

Anti-inflammatory activity

The root of *M. officinalis* was reported to contain monoterpens, which exhibited higher anti-inflammatory and antiinocceptive activities. It has been reported that the monoterpine isolated from the root of *M. officinalis* can lengthen the action time, decrease stretching episodes, writhing antinociceptive assays and significantly diseased acute paw edema at the dosage of 20 and 30 mg/kg [25]. The literature also reported that the methanol extraction of *M. officinalis* root possess the antiinocceptive and anti-inflammatory effects *in-vitro* and *in-vivo* by restraining inducible Nitric Oxide Synthase (iNOS), Cyclooxygenase (COX-2) and Tumour Necrosis factor- alpha (TNF-α) expression by down-regulating the NF-kB (Nuclear factor kappa-light-chain- enhancer of activated B cell) [26]. The evidence also suggested that the Monotropein isolated from the roots of *M. officinalis* can decrease the ailment activity index; it also exhibited antimicrobial activity and inflammation by restraining NF-kB activation in colon mucosa [32]. Monotropein effectively inhibited mRNA expression of Cyclooxygenase (COX-2), Nitric Oxide Synthase (iNOS), Tumour Necrosis factor- alpha (TNF-α) and IL-1β in LPS-induced RAW 264.7 macrophages [33]. Liang et al. reported that the extractions of *M. officinalis* root can affect the chronic colitis and T lymphocytes in mice model by reducing the symptoms of ulcerative colitis and decreasing inflammatory cytokine levels [34].

Antioxidant activities

Gao reported that the polysaccharides from *M. officinalis* can reduce the Malondialdehyde (MDA) levels in liver of mice at every dosage. The result showed that he MDA levels were significantly lower in every dosage groups than those in the control and Superoxide Dismutase (SOD), Glutathione Peroxidase (GSH-Px). While the reduced Glutathione (GSH) activities were significantly higher in every dosage groups than those in control groups [35].

Similarly, aqueous extracts of *M. officinalis* can also enhance the activity of superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px), which decrease the amount of Malondialdehyde (MDA) in the muscle tissue, liver tissue and blood of the forced swimming test mice [36]. The aqueous extracts of *M. officinalis* can enhanced the activity of Superoxide Dismutase (SOD) and Glutathione Peroxidase (GSH-Px), Calcium ATPase (PMCA) and Na+/K+-ATPase of the major muscles of the forced swimming test mice, and enhanced the antioxidant activity of major muscles in the rats [37].

Mengyong et al. [38] reported that the polysaccharides from *M. officinalis* can increase the antioxidant enzyme activities and decrease in MDA levels of the testing rats. Acidic polysaccharides of *M. officinalis* possessed excellent free radical scavenging activity, which was suggested to be helpful to exhaustive exercise-induced oxidative stress [39].

Soon and Tan reported that extract of *M. officinalis* decreased the fasting blood glucose, hepatic and renal Thiobarbituric Acid Reactive Substances (TBARS) level and significantly improved the hepatic Superoxide Dismutase (SOD), Catalase (CAT) activities as well as Glutathione (GSH) levels in streptozotocin-induced diabetic rats [40].

It reported that *M. officinalis* can scavenge the superoxide anion and hydroxyl radicals in the chemiluminescence reaction of luminal-H₂O₂-CuSO₄ system [41]. The extract of *M. officinalis* was also found to scavenge the 2,2-dipicrylhydrazyl radical in TM₂ cells, which showed no effect on cytotoxicity [27].

Antidepressant activity

It has reported that *M. officinalis* root possessed anti-anxiety and antidepressant properties [18,40]. Cui et al. [42] also reported that some compounds from the roots of *Morinda officinals* How *M. officinalis* possess antidepressant activity. Li et al. [43] reported that Inulin-type Hexasaccharide (IHS) can protect the PC12 cell lines at the concentrations of 0.625, 1.25 μM from the lesion-induced-Corticosterone, while desipramine can protect the PC12 cell lines at the concentrations 0.25, 1μM. Qiu et al. reported that the aqueous extract of *M. officinals* possess antidepressant activity. The result showed
that the aqueous extract of *M. officinalis* can significantly improve reinforcement rate in the schedule of reinforcement at 72-seconds in mice and a significant decrease in the period of immobility. But this extract did not show good effect on spontaneous motor activity [44]. It was also reported that the aqueous extracts of *M. officinalis* can improve the period of swimming loaded mice and regulate the level of monoamine neurotransmitters and reduce the level of 5-Hydroxytryptophan in the tissue of brain by balancing the levels of noradrenaline, dopamine and epinephrine in brain [10].

It was also reported that the ethanol extract of *M. officinalis* possess antidepressant property in the mice and rats in forced swimming test model, while the aqueous extract exhibited antidepressant activity in male mice in forced swimming test model [45-46].

**Anti-fatigue activity**

Polysaccharides of *M. officinalis* were found to possessed anti-fatigue activity, when tested in loaded swimming model mice at 50, 100 and 200 mg/kg dosage, which decreased levels of the blood urea nitrogen, amount lactic acid in the blood, and improved the level of glycogen stored in the liver [47]. It was also reported that the extract of *M. officinalis* can enhance the anti-fatigue activity [36].

**Anti-ageing Activity**

Li et al. [48] reported some compounds (such as rubiadin-1-methylether, isofraxidin, scopoletin, 2-hydroxy-1-methoxy anthraquinone, and anthraquinone-2-aldehyde) isolated from *M. officinalis* showed anti-ageing activity. Other compounds (digiferrengiol, 1-hydroxy-6-hydroxymethylanthraquinone, 3-hydroxy-1,2-dimethoxyanthraquinone, 1,2-dihydroxy-3-methylanthaquinone and 2-carboxmethoxyanthraquinone) isolated from *M. officinalis* were also showed anti-ageing activity [49]. Ethanol extract of *M. officinalis* was reported to improve the invulnerable ability of old rats by damaging the thymus gland index, spleen index, T lymphocyte stimulation index, B lymphocyte stimulation index, level of IL-2, the number of positive CD 28+ cells in D-galactose [50].

**Renoprotective activity**

The extract of *M. officinalis* improved hydrocortisone-induced-KDS-Yang in rats through increasing the interruption of energy and amino acid metabolism and enhancing transmethylation. But it could not modulate the gut microbiota [51]. Some processed products of *M. officinalis*, including *M. officinalis* extract, liquorice-processed *M. officinalis*, salt-steamed *M. officinalis* and Mornda pulp could also improve the symptoms of KDS-Yang in mice, and the active sequence is: salt-steamed *M. officinalis* was the most significant improvement on KDS-Yang, next with liquorice-processed *M. officinalis*, Mornda pulp and *M. officinalis* extract [52].

**Fertility improvement activity**

Oligosaccharides of *M. officinalis* was used to cure impotency by shielding the DNA of sperm cells from being injured by H2O2 [53]. Aqueous extracts of *M. officinalis* improved the thickness of the epithelium of the tubule, seminiferous tubules with active sperm cells and level of testosterone in the blood, which showed little or no change with levels of follicle-stimulating hormone in the blood and lutropin in rats treated with cyclophosphane. These results indicated that *M. officinalis* can be beneficial to reproductive organs: which could help in production of matured and active sperm cells and improve secretion of gonad hormones of Leydig cell in cyclophosphamide-induced-testicular spermatic disorder [27].

**Cardiovascular protective activity**

The oligosaccharides isolated from *M. officinalis* could protect the cardiac muscle against IRI rats through inhibition of oxidative stress reaction and lipidperoxidation at the dosage of 1.4 and 2.8 g/Kg/day [54]. The ethanol extract of *M. officinalis* root could eliminate the blood stasis and inhibited the rate clumping together platelets in the blood and improve haemorheological indexes and flowing of blood at the dose of 3, 6, 12 g/Kg bw/day for days [55]. The aqueous extracts of *M. officinalis* together with vitamin C could reduce the serum urea nitrogen and creatinine, alleviate the superoxide dismutize and decrease the content of malondialdehyde of the swimming rats. Which indicated that *M. officinalis* combined vitamin C showed a shielding effect on exercise-induced renal injury in testing rats [56].

**Hypoglycemic and hyperglycemic activities**

Reports showed that *M. officinalis* dried roots owned both hypoglycemic and hyperglycemic properties [40]. Ethanolic extract of *M. officinalis* root decreased the immoderate blood glucose level of streptozotocin-induced diabatic rats at 150mg/Kg, but those of normal rats increased at 600mg/Kg. n-butanol extract effectively improved the immoderate blood glucose levels of the diabatic rats at a dose 50mg/Kg only within three hours after treatment.

**Chemical components**

*M. officinalis* contains various bioactive constituents which show therapeutic effects that can be responsible its pharmacological activity for different ailments. The compounds isolated from *M. officinalis* are: glycosides, anthraquinones, polysaccharides, mono and oligosaccharides, carboxylic acids and their derivatives and volatile oils [11,18, 20,25].

**Glycosides**

Iridoid glycosides are one of major bioactive compounds of *M. officinalis* root. Seven major active iridoid glycosides have been isolated and identified from the ethanolic extracts of *M. officinalis* root, the isolated compounds named as, monotropein (1), deacetylasperulosidic acid (2), asperuloside (3), asperuloside tetraacetate (4), asperulosidic acid (5) and morofficinaloside (6) [57]. Monotropein has the highest proportion among other Iridoid glycosides with approximation of 2.0%. Iridoid glycosides in *M. officinalis* were further identified as deacetylasperulosidic acid and monotropein by LC/MS/MS method [58] (Figure 1).

**Sugar and polysaccharides**

Polysaccharides are main bioactive components of *M. officinalis* which are water-soluble and exist mainly in water extracts of *M. officinalis* [33]. The polysaccharides in *M. officinalis* have total weight of 10.55–35% at different locations in China [56,59]. Deng et al. [60] isolated some oligosaccharides (kestose 7, sucrose 8, kestose 9) from *M. officinalis* and confirmed their structures. Other oligosaccharides (1-kestose, nystose, hexasaccharide (10), and heptasaccharide (11)) were also isolated from *M. officinalis* [42,43,61-64]. Inulo-oligosaccharides (18, =1–3) consisting of only fructosyl residues formed by (2→1)-linkages have been found in the root *M. officinalis* [62]. Seven inulin-type oligosaccharides (DP = 3–9) in *M. officinalis* were analyzed qualitatively and quantitatively using a double-development HPTLC method [65] (Figure 2).
Anthraquinones

The Rubiaceae family is rich in anthraquinones which are ever-present in the Morinda genus (in *Morinda citrifolia* [66], *M. elliptica* [67], *M. lucida* [68], *M. angustifolia* [69] and *M. Pandurifolia* [70]).

Eight anthraquinones were isolated from chloroform extract of the root of *M. officinalis*, they include rubiadin (12), 1-hydroxyanthraquinone (13), rubiadin-1-methylether (14), 1-hydroxy-2-methylanthraquinone (15), 1,6-dihydroxy-2-methoxyanthraquinone (16), 1,6-dihydroxy-2,4-dimethoxyanthraquinone (17), physcion (18) and 1-hydroxy-2-methoxyanthraquinone (19). However, 1,6-dihydroxy-2-methoxyanthraquinone and 1,6-dihydroxy-2,4-dimethoxyanthraquinone were newly discovered in this plant [71], while 1-hydroxyanthraquinone has been discovered from the roots of *M. officinalis*, *Rubia cordifolia*, *Damnacanthus indicus*, *Tabebuia avellanedae* and *Cassia occidentalis* [72-76].

Yang et al. [77] isolated anthragallol-1,3-dimethylether (20) and 1,4-dihydroxyanthraquinone (21) with other anthraquinones, including physcion, 2-hydroxymethyl-3-hydroxyanthraquinone (22), 1,3,8-trihydroxy-2-methoxy-anthraquinone (23),...
2-methoxyanthraquinone (24) and scopoletin from the ethanolic extract of the *M. officinalis* roots. All of the isolated bioactive compounds restrained bone resorption and osteoclast TRAP activity, and 1,3,8-trihydroxy-2-methoxy-anthraquinone and physcion showed stronger inhibitory effects than other isolated bioactive compounds [78]. Lui et al. [79] reported alizarin-2-methyl ether (25) and 1,2-dimethoxy-anthraquinone [26].

Five other anthraquinones including digiferruginol (27), anthraquinone-2-carboxylic acid (28), 1,2-dimethoxy-3-hydroxy-anthraquinone (29) and lucidin-β-ethyl ether (30) [9]. 2-hydroxy-3-hydroxymethyl-anthraquinone (31), rubiadin-1-methyl ether, rubiadin and 2-hydroxy-1-methoxy-anthraquinone (32) were isolated from *M. officinalis* [80]. Yong et al. isolated physcion, 1-Hydroxy-2-methylanthraquinone, 2-Hydroxy-1-methoxyanthraquinone (33), rubiadin and rubiadin-1-methyl ether. While 2-Hydroxy-1-methoxyanthraquinone was newly discovered in this plant [81]. The structures of anthraquinones were listed below (Figure 3).

![Anthraquinones](image)

**Figure 3.** Anthraquinones. 12: rubiadin, 13: 1-hydroxyanthraquinone, 14: rubiadin-1-methyl ether, 15: 1-hydroxy-2-methylanthraquinone, 16: 1,6-dihydroxy-2-methoxyanthraquinone, 17: 1,6-dihydroxy-2,4-dimethoxyanthraquinone, 18: physcion 19: 1-hydroxy-2-methoxyanthraquinone, 20: Anthragallol-1,3-dimethylether, 21: 1,4-dihydroxyanthraquinone, 22: 2-hydroxy-3-hydroxymethyl-anthraquinone, 23: 1,3,8-trihydroxy-2-methoxy-anthraquinone, 24: 2-methoxyanthraquinone, 25: Reportedalizarin-2-methyl ether, 26: 1,2-dimethoxy-anthraquinone, 27: Digiferruginol, 28: anthraquinone-2-carboxylic acid, 29: 1,2-dimethoxy-3-hydroxy-anthraquinone, 30: lucidin-β-ethyl ether, 31: 2-hydroxy-3-hydroxymethyl-anthraquinone, 32: Rubiadin-1-methyl ether, rubiadin and 2-hydroxy-1-methoxy-anthraquinone, 33: 1-Hydroxy-2-methylanthraquinone, 2-Hydroxy-1-methoxyanthraquinone
Organic acids

Organic acids were identified as one of the major constituents of *M. officinalis*, hexadecanoic acid (34), linoleic acid (35) and oleic acid (36) discovered [82]. Anthraquinone-2-carboxylic acid and fumaric acid (37) were isolated from *M. officinalis* root [9]. Cui et al. [42] isolated succinic acid (38) as one of the identified compounds from *M. officinalis* (Figure 4).

Essential oils

According to Yong reported [83], the volatile components of *M. officinalis* oil were diisobutyl phthalate (39), borneol (40), linoleic acid, oleic acid and 3-methylbenzaldehyde. 2-methylbenzaldehyde (31.97%) (41), paconol (11.26%) (42), 2-methylanthraquinone (8.0%) (43), myristaldehyde (6.53%) (44), hexadecanoic acid (6.47%), 1,2-benzenedicarboxylic acid (4.54%) (45), nonanoic acid (4.27%) (46), 8-methylundecene (2.94%) (47), 1,3,12-nonadecatriene (2.63%) (48), 1-allyl-4-methoxybenzene (2.42%) (49), γ-butyro lactone (2.74%) (50), hexanoic acid (2.42%) (51), γ-stearolactone (2.20%) (52) and 9,17-octadecadienal (2.09%) (53) [84]. Thirty four constituents with 77.4% of *M. officinalis* oil have been identified, which include borneol (<29.28%), α-curcumene (4.49%) (54), α-zingiberene (4.88%) (55), 1-hexanol (3.4%) (56), 2-furanamine (3.32%) (57), β-sesquiphellandrene (3.34%) (58), n-nonanal (2.17%) (59), β-bisabolene (60) and L-camphor (2.07%) (61) [85]. Lim reported that forty-six volatile compounds were identified from fifteen years old *M. officinalis* root oil, accounted for 89.98%. Nineteen compounds were reported from ten-year-old *M. officinalis* root oil with 70.01% [86]. Fifteen volatile components were identified from *M. officinalis* oil including: Hydrocarbons [n-heptadecane (62), iso-heptadecane (63), n-octadecane (64), iso-eicosane (65)], Alcohols [2,6-bis(1,1-dimethylethyl)-2-methylphenol (66)], tetradeconoic acid (67), pentadecanoic acid (68), ethylpentadecanoic acid (69), 9-hexadecenoic acid, 9-octadecenoic acid, (Z) hexadecanoic acid, ethyl-hexadecanoic acid, ethyl-9-octadecenoic acid (70) and amine (N-phenyl-1-Naphthalenamine) (71) [87]. Yi et al. identified the principal compounds from the volatile oil of *M. officinalis*, including 3-methyl-benzaldehyde (72), pentadecanoic acid, (Z, Z)-9,12-octadecadienoic acid, n-hexadecanoic acid, oleic acid, borneol, bicyclo[4.2.0]octa-1,3,5-trien-7-O,2-methyl-9, 10-anthrachenedione and benzaldehyde [88] (Figure 5).

Triterpenes from *M. officinalis* How

*M. officinalis* shown to contain Triterpenes such as stigmastanol (73), 7-hydroxy-6-methoxy-coumarin, β-sitosterol (74) and daucosterol (75) [9,89-90], scopoletin (76) [78], 3β,5-alkenyl-spirostol, 3β, 20(R)- butyl, 5-alkenyl-cholesterol [91]. 3β,19a-dihydroxy-12-en-28-oic acid (77) identified from *M. officinalis* [92] (Figure 6).

Apart from the above stated compounds, morindolide [57] dimethyl-alkane, resin, ketone, Vitamin C, eleven free amino acids and seventeen amino acid hydrolysates [93-94], which add to its therapeutic properties. Various metal elements were also identified in *M. officinalis*, which include Potassium, Calcium and Magnesium. Iron, Manganese, Zinc and Copper [95-96].

Conclusion and future perspectives

*M. officinalis* is a blessing to mankind especially to the continents which favour its germination, because of its pharmacological activities. Reports showed that *M. officinalis*, contained Glycosides, Anthraquinones, Polysaccharides, Mono- and Oligosaccharides, organic acids as the abundant groups of compounds, which responsible for its therapeutic activities such as antioxidant, anti-inflammatory, analgesic, antiosteoporosis, antinociceptive, antidepressant, antimutagenic, antimicrobial, pro-fertility activities, antihypertotoxic and anti-HIV.

Despite the notable therapeutic activities of this plant further studies should be fully conducted on toxicity of all the extracts and isolated compounds of this plant to determine whether they can be used as medicine by animals and humans without no or little negative effects. Also, adequate studies should be on isolation and purification of bioactive compounds with sophisticated instrumentations, because there are still undiscovered bioactive compounds which also responsible for its pharmacological properties.

There should be adequate studies on dose-effects relationship, that should be prescribed to cure each ailment. Further investigations should be made on the plant therapeutic activities and their underlying mechanisms.

Functionalization of isolated compounds should be further emphasized in order to improve their activities efficacy. This can be...
Figure 5. Essential oils. 39: Diisobutyl phthalate, 40: Borneol, 41: Linoleic acid, oleic acid and 3-methylbenzaldehyde, 2-methylbenzaldehyde, 42: Paeonol (11.26%), 43: 2-methylanthraquinone, 44: Myristaldehyde, 45: Hexadecanoic acid, 1,2-benzenedicarboxylic acid, 46: Nonanoic acid, 47: 8-methylundecene, 48: 1,3,12-nonenadiene, 49: 1-allyl-4-methoxybenzene, 50: γ-butyrolactone, 51: Hexanoic acid, 52: γ-stearolactone, 53: 9,17-octadecadienal, 54: α-cubebene, 55: α-santalol, 56: L-hexanol, 57: 2-furanamine, 58: β-sesquiphellandrene, 59: n-nonanal, 60: β-bisabolene, 61: L-monoterpene, 62: n-heptadecane, 63: iso-heptadecane, 64: n-octadecane, 65: iso-eicosane, 66: 2,6-bis(1,1-dimethylethyl)-2-methylphenol, 67: Tetradecanoic acid, 68: Pentadecanoic acid, 69: Ethylpentadecanoic acid, 70: ethyl-9-octadecenoic acid, 71: amines (N-phenyl-1-Napthalenamine), 72: 3-methyl-benzaldehyde.
by either incorporating inorganic or organic molecules into isolated bioactive compounds or extracts.

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