

A Review on Medicinal and Pharmacological Potential of Agarwood (*Aquilaria malaccensis* Lamk.), its Chemical Constituents and Oil Quality

Sumona Chetia*, Gurpreet Kaur Bhamra, Kajal Gupta and Rajib Kumar Borah
ICFRE-Rain Forest Research Institute, Jorhat (Assam), India.

(Corresponding author: Sumona Chetia*)

(Received: 05 January 2024; Revised: 13 January 2024; Accepted: 23 April 2024; Published online: 22 January 2025)
(Published by Research Trend)

DOI: <https://doi.org/10.65041/BiologicalForum.2025.17.1.21>

ABSTRACT: The present paper is an overview of *Aquilaria malaccensis* phytochemistry, its medicinal and pharmacological properties and its utilization in traditional medicine and drug industry. The plant is used in treatment against variety of diseases due to the presence of chromone derivatives, sesquiterpenes, terpenoids, flavonoids and phenolic compounds. This review also describes the chemical standards formulated by API (Ayurvedic Pharmacopoeia of India) such as permissible limit of foreign matter, purity, strength, macroscopic and microscopic characters for drug preparation from agarwood. So far, no scientific and common grading system has been developed to grade agar oil based on its chemical composition which leads to the lack of coordination and regulation at international level. GC-MS analysis of agar oil reveals that oxygenated sesquiterpenes responsible for its unique aroma and quality are present in high grade agar oil. Some of the constituents such as α -guaiene, α -agarofuran, β -eudesmol, agarospirol, 10-epi- γ -eudesmol, etc are only found in high grade agar oil. In conclusion, these chemical compounds present in high grade agar oil can be used as standards for determining the best quality oil which can be followed by all traders and buyers in the international market.

Keywords: Agarwood high grade oil, sesquiterpenes, chromone derivatives, medicinal properties, GC-MS analysis.

INTRODUCTION

Aquilaria malaccensis (Thymelaeaceae) or agarwood also popularly known as “Wood of Gods” is one of the critically endangered species found extensively cultivated in Assam and other North-Eastern states of India, which have been in practice as traditional medicine. There are plenty of medicinal and pharmacological properties contained within the agarwood plant. It was reported that out of 21 species of *Aquilaria* four species are assessed as Critically Endangered (*A. crassna*, *A. khasiana*, *A. malaccensis* and *A. rostrata*), one species as Endangered (*A. microcarpa*) and eight species as Vulnerable (*A. banaensis*, *A. beccariana*, *A. cumingiana*, *A. hirta*, *A. filaria*, *A. rugosa*, *A. sinensis* and *A. yunnanensis*) (CITES, 2022). While, the remaining seven species are assessed as Data Deficient due to a lack of recent data on distribution, population and threat information.

(a) Scientific name: *Aquilaria malaccensis* Lamk.

(b) Pharmacopoeial name of the medicinal plant: Agarwood

(c) Local name (Specify language):

Assamese: Xasi, Sashi

Bengali: Agar Chandan, Agor

English: Eagle Wood

Hindi: Agar

Kannada: Krishna Agarwood

Malayalam: Akil

Punjabi: Ooda

Sanskrit: Aguru

Tamil: Aghil

Telegu: Agarwood

It is a medium to large sized tree of height ranging from 20-40 meters. Agar tree grows well in high humid, tropical to sub-tropical climate with annual rainfall of about 1500 to 6500 mm and a mean annual maximum temperature of 22-28°C and minimum temperature of 14-21°C. The tree requires a lot of sunshine (70% sunlight) and is found in natural forest, at an altitude of a few meters to about 1000 meters above msl, while it grows best around 500 meters above msl. *Aquilaria* species occurs naturally in all ecological zones and in a wide variety of soils ranging from clay loam to sandy loam soil except heavy clay soil. The species prefers soft and sandy clay soil with pH ranging from 6.4-7 (Harvey-Brown, 2018). It naturally grows on good forest soil of slightly acidic reaction, with a light to medium soil texture and well drained with high organic matter content. It can also be grown in marginal soils and in shallow soil over rocky beds in hilly slopes.

The heartwood of the plant is rich in secondary metabolites such as alkaloids (Liriodenine), saponins,

steroids, terpenoids, tannins, flavonoids, phenolic compounds, essential oil and resins which are responsible for its drug value (Satapathy *et al.*, 2009). Numerous medical conditions, including inflammation, cancer, and oxidative stress have been traditionally treated using *Aquilaria malaccensis* (Nahar *et al.*, 2023). The wood of the plant predominantly contains 2-(2-phenylethyl)-4H-chromone derivatives and sesquiterpenes (Wang *et al.*, 2016), which are primarily responsible for its immense value in perfumery and pharmaceutical industry. The plant essential oil also contains compounds such as selinene, dihydroselinene, agarol, β -agarofuran, vetispira-2(11), valerianol, dihydrokaranone and tetradecanoic acid (Naf *et al.*, 1992, 1995).

PHARMACOLOGICAL POTENTIAL OF *AQUILARIA MALACCENSIS*

(a) Anti-cancer activity. The leaves of *Aquilaria malaccensis* is known to contain antioxidant and cytotoxic activity against several cancer cells. In a study conducted by Millaty *et al.* (2020), the metabolites of chloroform and ethanol extracts of *A. malaccensis* leaves was screened using Gas Chromatography–Mass Spectrometry (GC–MS). Results revealed that metabolites such as 9–Hexadecanoic acid and Tetracosanoic acid, derived from chloroform extracts have potential as anticancer activity. Nahar *et al.* (2023) in their study revealed that *A. malaccensis* showed significant cytotoxicity against A549 lung cancer cells at 1000 $\mu\text{g/mL}$. Their study revealed that the plant extracts from *A. malaccensis* could exert a cytotoxic effect on lung adenocarcinoma cells through the activation of an intrinsic signaling pathway. Zaid *et al.* (2022) in a study proved that ethanolic extract of *A. malaccensis* leaves has the potential as anti-cancer agent for curing chronic myeloid leukemia K-562 cell line. The ethanolic leaf extract obtained from *Aquilaria malaccensis* leaves is cytotoxic on MCF-7 cells, resulting to apoptotic cell death, thus helping in reducing the abnormal growth of cancer cells (Aziz *et al.*, 2023).

(b) Anti-inflammatory activity. A recent study conducted by Eissa *et al.* (2022) investigates the anti-inflammatory activity of both ethanolic extract and isolated compounds from *A. malaccensis* leaves. The anti-inflammatory activity of the extract and eight compounds was evaluated, and they demonstrated the ability to suppress NO levels in RAW 264.7 cells induced by LPS/IFN- γ . The essential oil from agarwood also has a potential to cure many chronic inflammatory diseases by blocking some of the major pathways causing inflammation (Alamil *et al.*, 2022).

(c) Anti-diabetic activity. The leaf extract of *A. malaccensis* proved to be effective against Type 2 diabetes mellitus which affects the glucose metabolism resulting in hyperglycemia. The experiment findings by Bahtiarsyah *et al.* (2023) suggested that the presence of compound palustrol in leaf extract of *A. malaccensis* reduce the glucose level. Sukito *et al.* (2020) also found the highest anti-diabetic activity in

the methanol extract of leaves from infected species. Moreover, the methanolic extract of *A. malaccensis* possesses the ability to control the lipid peroxidation and biochemical disruption associated with insulin resistance (Derouiche *et al.*, 2019). The methanolic and aqueous leaf extract of *A. malaccensis* showed dose dependant inhibitory effects against alpha-glucosidase activity with (Inhibitory Concentration) IC₅₀ values of 428.92 and 425.09 $\mu\text{g/mL}$ respectively, which potentially lower the blood glucose level in diabetic patients without inflicting harmful side effects (Zulkifle, 2018).

(d) Anti-oxidant activity. The experimental findings by Halim *et al.* (2022) proves that the ethanol, ethyl acetate and n-hexane extracts of *A. malaccensis* leaves showed an anti-oxidant activity when evaluated by three different type assays. Out of all, the ethanol extract had the highest anti-oxidant activity for all assays. The result of another anti-oxidant activity test showed that agarwood leaf extract has IC₅₀ (Inhibitory Concentration) value of 56,985 dan 44,382 $\mu\text{g/mL}$, which meant very strong anti-oxidant activity category (Surjanto *et al.*, 2019). Batubara *et al.* (2020) also proved that the ethanol extract of *A. malaccensis* leaves had a very strong antioxidant activity which can reduce free radicals in our body.

(e) Anti-microbial activity. In many experiments, leaf extracts of *A. malaccensis* showed significant antimicrobial activity against the gram-positive and negative bacteria. In a study by Afendi *et al.* (2019) the antibacterial activities of *Aquilaria malaccensis*, *Aquilaria sinensis* and *Aquilaria subintegra* leaf extracts against *Staphylococcus aureus* and *Escherichia coli* were evaluated. Results showed that among the three species of *Aquilaria*, *A. malaccensis* possess the best antibacterial activity at zone of inhibition even tested at the smallest concentration of 75 mg/mL. In an experiment conducted by Batubara *et al.* (2020), the antibacterial and antifungal activities of agarwood leaf extract was tested against three species of bacteria (*Staphylococcus epidermis*, *Staphylococcus aureus* and *Propionibacterium acnes*) and two fungi species (*Candida albicans* and *Trichophyton* sp.) known for commonly causing skin infection in human. The results revealed that, 5% concentration of ethanol leaf extract inhibited the bacterial and fungal growth zone diameter. The antimicrobial activity was attributed to the bioactive compounds such as flavonoids and tannins present in the extract. Crude leaf extract of *A. malaccensis* was tested for antibacterial activity against Gram-negative bacteria *i.e.*, *Acinetobacter baumannii*, *Klebsiella pneumonia* and *Escherichia coli* (Jihadi *et al.*, 2020). The outcome of the experiment showed significant antibacterial activity against these bacteria spp. and to develop potential treatment against bacteria. Mei *et al.* (2014) revealed that volatile oil had antibacterial activity against methicillin-resistant *Staphylococcus aureus*.

(f) Immunological activity. A study by Yana *et al.* (2022) indicated that *A. malaccensis* leaf extract showed a promising immunomodulatory activity against pathogenic bacteria *Staphylococcus aureus*, infected macrophages in vitro. Chloroform and ethanol

extracts at a 50 µg/mL concentration showed the best results with the phagocytic activity. Hegde *et al.* (2019) in their study showed that ethanolic extract of leaves of *Aquilaria malaccensis* was able to exhibit significant immunomodulatory effect against cyclophosphamide and sheep RBC induced immune response. Thus, the phytoconstituents present in extract might be beneficial in the treatment of immune suppression related disorders. A study conducted by Pang *et al.* (2023) revealed that agarwood leaf extract showed enhance immune-stimulatory effects using RAW264.7 murine macrophages.

PLANT PARTS USED FOR MEDICINAL PURPOSES

The plant parts known to possess medicinal properties are leaf, stem, essential oil and fungus infected heart wood. From the leaves of *A. malaccensis*: antidiabetic (Said and Kamaluddin 2016), antioxidant (Simatupang *et al.*, 2015), antibacterial (Khalil *et al.*, 2013) and hepatoprotective properties (Alam *et al.*, 2017) have been reported. Also the leaves of *Aquilaria* are found to be useful in throat itching (Kumar *et al.*, 1980). The young shoots, the first and second leaflets are selected for making agar tea. Pharmacological properties of agar tea include anti analgesic, anti-arthritic, anti-inflammatory, anti-cancer, anti-tumor, anti-oxidant, anti-bacterial, anti-fungal, anti-diabetic etc. Moreover, anticancer (Knecht *et al.*, 2010), antibacterial and antifungal (Chen *et al.*, 2014) activities have been reported from callus and shoot of *A. malaccensis*. Aqueous extract of stem shows activity against immediate hypersensitivity by inhibiting the histamine secretion from mast cell. In ayurvedic medicinal practices, topical application of *Aquilaria malaccensis* stem paste is useful in skin disorders while leaf paste is useful in leprosy and pruritus.

The wood of the plant has also been used as antidepressant (Kakino *et al.*, 2010) thus aiding to improve the neural activity. Benzene extract of the wood showed CNS depressant activity. Woodfumes of infected agarwood possesses antiseptic, antioxidant and insecticidal activities. Heartwood of *A. malaccensis* is found to show anti-arthritic (Rahman *et al.*, 2016) along with improving neural activity. The agarwood with a resin content exceeding 25% can be used for medicinal purposes (Peng *et al.*, 2020). The agarwood powder is mainly used in the manufacture of fumigators, pastilles and agarbatties. The essential oil is known for stimulant, cardiogenic and carminative properties. The chemical constituents present in the essential oil prevent denaturation of protein accounting to antiarthritics property and can also be used for anxiety and depression treatment accounting to anxiolytic property. The essential oil of infected agarwood is one of the highly priced essential oils used in perfumery industry across the world. The volatile oil of agarwood also contains a variety of anti-tumor components, which have inhibitory effects on many kinds of cancer cells (Dahham *et al.*, 2016).

MAJOR CHEMICAL COMPOUNDS RESPONSIBLE FOR DRUG VALUE

The whole plant contains various chemical constituents: sesquiterpenes, chromones, phenolics, steroids, benzophenones, flavonoids, terpenoids, lignans and other compounds naturally found in all trees. Among all these bioactive compounds, chromones and terpenoids (sesquiterpenoids) are the major compounds that are potentially known for their pharmaceutical value, bioactivity and medicinal properties.

(a) Sesquiterpenes: Most of the sesquiterpenes obtained from genus *Aquilaria* are oxygenated. Dahham *et al.* (2016) found that the sesquiterpene component (β -caryophyllene) was found to possess antibacterial activity against six kinds of human pathogenic bacteria and two kinds of fungi. Wang *et al.* (2016) revealed that the compound 5-deoxylongiferol isolated from agarwood showed antibacterial effect on *Staphylococcus aureus* and *Ralstonia solanacearum*. Prezizaanes are the tricyclic sesquiterpenes found in *A. malaccensis* with a special fragrance (Nakanishi *et al.*, 1984), which possess antidiabetic activity. Similarly, agarol obtained from *A. malaccensis*, an eudesmane sesquiterpene, and 8bH-Dihydrogmelofuran and gmelofuran, a cadinene sesquiterpenes isolated from *A. malaccensis* were reported to have anticancer, antioxidant and antimicrobial properties (Dahham *et al.*, 2016). A study conducted by Nakanishi *et al.* (1984), revealed three sesquiterpenes as α -agarofuran, -10-epi- γ -eudesmol and oxo-agarospirol as major contributors to the fragrant nature of agarwood.

(b) Chromones: 2-(2-phenylethyl) chromone compounds isolated from agarwood have inhibitory action on five kinds of human tumor cells (Suzuki *et al.*, 2017). Sugiyama *et al.* (2018) found that several 2-(2-phenylethyl) chromones isolated from agar incense could inhibit PED 3A in phosphodiesterase (PDEs). Chromone derivatives like epifriedelanol, 5-hydroxy-7,4'-dimethoxyflavone, luteolin-7,3',4'-trimethyl ether, luteolin 7,4'-dimethyl ether, acacetin, aquilarinenside E and 3-C- β -glucoside isolated from the leaves of *A. malaccensis* are used in the treatment of inflammatory disorder.

(c) Alkaloids: The alkaloid Liriodenine from wood was reported to have significant *in vitro* inhibitory activity against the 9 KB tumour test system (Sarma *et al.*, 2015) and was also reported to act *in vitro* upon the cells of human nasopharyngeal carcinoma (Shamma and Castenson 1973).

NATIONAL QUALITY EVALUATION OF THE MEDICINAL PLANT MATERIAL

The Ayurvedic Pharmacopoeia of India (API) is a legal document of standards compiled by Government of India. It is the SOP for the quality of Ayurvedic drugs and substances included therein (under Drugs and Cosmetics Act, 1940). API describes macroscopic and microscopic characters of different parts of Ayurvedic drugs along with their chemical standards of identity, permissible limit of foreign matter, purity and strength. Their protocol has been approved by the Ayurvedic Pharmacopoeia Committee, Ministry of Ayush (Govt. of India).

According to API, Agarum consists of dried heart wood of *Aquilaria malaccensis* Lamk. (Fam. Thymelacaceae), whose heartwood and essential oil are used in pharmacological industries for ayurvedic drug preparation. In ayurveda, for therapeutic purposes essential oil (dose 1-3 g) is generally used.

Quality parameters of Agarum determined by Ayurvedic Pharmacopoeia of India (API):

(i) Macroscopic characters: Drug available in cut pieces, dark brown to nearly black; fracture, hard; no characteristic smell and taste.

(ii) Microscopic characters: Shows mostly uniseriate sometimes biseriate xylem rays; vessels isolated having simple pitted thickening and filled with dark brown contents; xylem fibres short having narrow lumen occupying a major portion of wood; xylem parenchyma less in number and simple pitted; included phloem tissues in pockets partially dis-organised, leaving large circular or oval holes, containing collapsed and broken tissues.

(iii) Powder: Dark brown; showing numerous aseptate fibres, simple pitted vessels with dark brown contents.

(iv) Identity, Purity and Strength of Drug: Quantitative parameters such as Foreign matter (Not more than 1 %), Total Ash (Not more than 13 %), Acid-insoluble ash (Not more than 0.5 %), Alcohol-soluble extractive (Not more than 1 %) and Water-soluble extractive (Not more than 2 %) (Appendix 2, The Ayurvedic Pharmacopoeia of India, 2004).

(v) Thin Layer Chromatography (T.L.C): TLC technique is used to isolate non-volatile mixtures for extracting active ingredient for drug preparation from agarwood. All the agarwood chips and wood are powdered and filtered (26 meshes). Then, the powder (1 g) was extracted in methanol (25 ml) for 30 min. T.L.C.

of the alcoholic extract of agarum on Silica gel 'G' plate is performed using Toluene: Ethylacetate (9:1) shows in visible light two spots at Rf. 0.17 and 0.27 (both light brown). Under U.V. (366 nm) five fluorescent zones appear at Rf. 0.17, 0.27, 0.36, 0.57 and 0.80 (all blue). On exposure to Iodine vapour eight spots appear at Rf. 0.05, 0.11, 0.15, 0.24, 0.33, 0.57, 0.73 and 0.80 (all yellow). On spraying with Vanillin-Sulphuric acid reagent and after heating the plate for ten minutes at 105°C five spots appear at Rf. 0.13, 0.18, 0.25, 0.37 and 0.59 (all violet) (The Ayurvedic Pharmacopoeia of India, 2004).

vi) Heavy metal content: The permissible limits of heavy metal contents in drug are given as: Lead (10 ppm), Arsenic (3 ppm), Cadmium (0.3 ppm) and Mercury (1 ppm) (The Ayurvedic Pharmacopoeia of India, 2016).

MAJOR CHEMICAL CONSTITUENTS PRESENT IN AGARUM

The major chemical compounds extracted from *Aquilaria malaccensis* are sesquiterpenoids and chromones. From the analysis of essential oil, 182 sesquiterpenes and 240 2-(2-phenylethyl) chromones, 17 phenylpropanoids and 36 flavonoids have been isolated and identified from agarwood produced by *Aquilaria* plants including *A. sinensis*, *A. malaccensis*, *A. crassna*, *A. filaria* and *Gyrinops salicifolia*.

The chemical compounds are divided into two categories:

(A) Volatile compounds of agarwood

(B) Non-volatile compounds of agarwood (Fatty acids, chromones, terpenoids, steroids, flavonoids, alkaloids)

Table 1: Chemical constituents in agarwood and essential oil.

Chromones	Sesquiterpenes	Phenyl-propanoids	Phenyl-chromones	Flavonoids	Volatile Compounds
Agarotetrol	Eudesmane	Anisic acid	FTPECs	Flavone	Benzylacetone
Oxidoagar-chromones A	Agarospirane	Cinnamaldehyde	DEPECs	Isoflavone	3,5-Di-tert-butylphenol
Isoagarotetrol	Cadinene	Syringin	THPECs	Flavanol	4-Methoxyphenyl acetone
2-(2-phenylethyl) chromone	Guainene	Anisaldehyde	EPECs	Benzophenone	2,4-Di-tert-butylphenol
2-[2-(4-Hydroxyphenyl) ethyl] chromone	Preazines	Benzaldehyde	-	Xanthenes	-

QUALITY EVALUATION OF AGARWOOD OIL

There are various grading methods for determining the quality of agarwood oil. Different countries have various methods to grade/classify the agarwood oil. Till date there is no international common system or scientific protocol for determining the grades on qualitative basis, each sourcing country may have their own grading system or none at all. The market grades are predetermined by sellers and buyers based on experiences and these grades are not necessarily accurate. Conventionally, the agarwood oil was graded according to its colour, aroma and fixative based on human's sense. However, it was difficult to standardize

the quality from the aroma due to human nose cannot smell many samples continuously. In Malaysia, agarwood oil is classified according to the grade of A, B, C and (Sidik, 2008). In India, they use grades too; A, B, C and D but were based on the color of agarwood oil (Naef, 2011). Color black, all resin with no white wood is considered as first grade while heavyweight, multi resin with white wood is the second or inferior grade.

Jayachandran *et al.* (2014) classified 4 grades of agarwood oil (Grade-1,2,3,4) based on the chemical composition present in each grade to determine the quality of oil by using GC-MS (gas chromatography mass spectrometry) analysis. Agar oil obtained from

highly infected tree is specified as Grade 1, moderately infected as Grade 2, less infected as Grade 3 and healthy wood as Grade 4. GC-MS analysis reveals that the highly infected wood oil (G1) contains aromadendrene-2, valencene-2, calarene, 1(5), 6-Guaiadiene, etc. The presence of chemical compounds like aromadendrene and valencene plays an important role in grading of agar oil was also stated by Jayachandran *et al.* (2014). The quantity of these two compounds in the four grades of wood are found in the following order G1>G2>G3 and absent in G4 grade wood oil.

GC-MS analysis identifies the significant existence of common compositions in agar oil and it is considered as the best method for qualitative analysis. The major compounds present in the *Aquilaria malaccensis* oil after GC-MS analysis were 4-phenyl-2-butanone (32.1%), jinkoh-eremol (6.5%) and α -guaiene (5.8%), while the major compounds present in the commercial oil were α -guaiene (10.3%), caryophellene oxide (8.6%), and eudesmol (3.2%). After GC-MS analysis of high grade agarwood oil, it was found that the sesquiterpenes are found to exist in oxygenated form. Other studies revealed that for instance:7-epi- α -Cadinene, beta-guanine, caryophyllene-11, alpha-guaiene, beta-agarofuran, jinkoh-eremol, kusunol, selina-3,11-dien-9-one and oxo-agarospirol are some of the chemical compounds found in high grade oil irrespective of the *Aquilaria* species. These oxygenated sesquiterpenes present in agarwood provides its unique aroma and quality and extracted from highly infected plants. Therefore, these chemical compounds present in high grade agar oil can be used as standards for determining good quality oil.

Globally accepted chemical profile of high grade agar oil (Islam *et al.*, 2022)

Table 2: Compounds in superior grade oil.

Compounds in superior grade oil	
Agarospirol	3-phenyl-2-butanone
β -eudesmol	α -guaiene
Jinkoh-eremol	α -agarofuran
Kusunol	β -agarofuran
Jinkohol II	Nor-ketoagarofuran
10-epi- γ -eudesmol	

Some essential characteristics of superior grade agarwood oil (Islam *et al.*, 2022)

- The superior grade oil does not lose its mobility even when cooled at 4°C for 5 min.
- Pure agarwood oil samples reveal single-stage volatilization at 110-260°C.
- The average grade sample is free moving till 12°C, whereas the poor grade samples lost their mobility even at 22°C.
- The mobility of low quality agarwood oil generally decreases (viscosity increases) with lowering temperature due to the fatty contaminants or due to their richness in fatty constituents.
- 2-(2-phenylethyl) chromone was present in natural agarwood and agarwood formed by physical injury, but not in agarwood formed by chemical stimulation without and with fungal infection

CONCLUSIONS

This paper critically reviews published research studies on medicinal and pharmacological properties of agarwood along with the chemical constituents responsible for its fragrance and drug value. It also covers topics related to its essential oil quality and grading as agarwood trade is highly dependent on its quality. Currently various countries follows different grading methods for determining its quality as till date no international common system or scientific protocol has been established. Conventionally, the agarwood oil is graded according to its physical appearance, colour and aroma. However, recent studies mentioned techniques like GC-MS analysis, which is considered as the best method for qualitative analysis and scientific grading. The review found that certain chemical compounds present in oil can be used to decide the quality, since high grade agar oil consists of a complex mixture of sesquiterpenes, oxygenated sesquiterpenes and chromone derivatives responsible for its unique aroma and quality.

FUTURE SCOPE

Further research needs to be conducted to prepare more effective drug from agarwood to cure human ailments and also to find the most suitable method for qualitative analysis of agar oil.

Conflict of Interest. None.

REFERENCES

- Afendi, R., Mamat, W. N. A. W., Mahmud, N. H., Ali, A. M., Yunus S. Md. and Wan-Nadilah, W. A. (2019). Evaluation of antibacterial activities of *Aquilaria malaccensis*, *Aquilaria subintegra* and *Aquilaria sinensis* in different solvents extraction. *Bioscience Research*, 16(SI), 81-90.
- Alam, J., Badruddeen, Md. M., Yasmeen, J., Paramdeep, B. and Rahman, Md. A. (2017). Hepatoprotective Potential of Ethanolic Extract of *Aquilaria agallocha* Leaves against Paracetamol Induced Hepatotoxicity in SD Rats. *Journal of Traditional and Complementary Medicine*, 7(1), 9-13.
- Alamil, J. M. R., Paudel, K. R. and Chan, Y. (2022). Rediscovering the therapeutic potential of agarwood in the management of chronic inflammatory diseases. *Molecules*, 27(9), 3038.
- Aziz, A. M. Y., Tuan Johari, S. A., Wan Mamat, W. A., Wan Taib, W. R., Othman, A. S. and Rohin, M. A. (2023). Cytotoxic Activity of Ethanolic Extract *Aquilaria malaccensis* Leaves Against MCF-7 Cells. *Malaysian Journal of Medicine and Health Sciences*, 19(6), 215-221.
- Bahtiarysah, A.A., Hidayati, L., Wijayanti, N. and Nuringtyas, T. R. (2023). Synergistic Activity of *Cinnamomum burmanii* (Nees & T. Nees) Blume and *Aquilaria malaccensis* Lamk. Extracts for Antidiabetic Study. *The Indonesian Biomedical Journal*, 15(2), 132-140.
- Batubara, R., Surjanto, H. T. I., Handika, A. and Afandi, O. (2020). The screening of phytochemical and antioxidant activity of agarwood leaves (*Aquilaria malaccensis*) from two sites in North Sumatra, Indonesia. *Biodiversitas*, 21, 1588-1596.
- Chen, C. H., Kuo, T. C. Y., Yang, M. H., Chien, T. Y., Chu, M. J., Huang, L. C., Chen, C. Y., Hsiao-Feng Lo, Shih-Tong Jeng and Long-Fang O. Chen (2014).

- Identification of Cucurbitacins and Assembly of a Draft Genome for *Aquilaria agallocha*. *BMC Genomics*, 15(1), 578.
- CITES (2022). Convention on International Trade in Endangered Species of Wild Fauna and Flora. Consideration of proposals for amendment of Appendices I and II- *Aquilaria* spp. and *Gyrinops* spp. Nineteenth meeting of the Conference of the Parties, Panama, 14-25 Nov, 2022.
- Dahham, S. S., Hassan, L. E. A., Ahmed, M. B. K., Majid, A. S. A. and Zulkepli, N. N. (2016). In vivo toxicity and antitumor activity of essential oils extract from agarwood (*Aquilaria crassna*). *BMC Complementary and Alternative Medicine*, 16, 1-11.
- Derouiche, S., Degachi, O. and Gharbi, K. (2019). Phytochemistry analysis and modulatory activity of *Portulaca oleraceae* and *Aquilaria malaccensis* extracts against high fructose and high fat diet induced immune cells alteration and heart lipid peroxidation in Rats. *International Research Journal of Biological Sciences*, 8(4), 6-11.
- Eissa, M. A., Hashim, Y. Z. H., Abdul Azziz, S. S. S., Salleh, H. M., Isa, M. L. M., Abd Warif, N. M., Abdullah F., Ramadan, E. and El-Kersh, D. M. (2022). Phytochemical Constituents of *Aquilaria malaccensis* Leaf Extract and Their Anti-Inflammatory Activity against LPS/IFN- γ -Stimulated RAW 264.7 Cell Line. *ACS Omega*, 7(18), 15637-15646.
- Halim, A. P., Wijayanti, N., Hidayati, L. and Nuringtyas, T. R. (2022). Antioxidant Activity Evaluation of Agarwood *Aquilaria malaccensis* Lamk. Leaves Extract Using DPPH, FRAP and ABTS Assays. 7th International Conference on Biological Science (ICBS 2021), *Advances in Biological Sciences Research*, volume 22.
- Harvey-Brown, Y. (2018). Assessment summary of *Aquilaria malaccensis* (agarwood). Available at <https://www.iucnredlist.org/species/32056/281013>. Accessed at 17 July 2023,
- Hegde, K., Shree Durga, P. M. and Sajjan, P. C. (2019). Evaluation of Immunomodulatory Potentials of The Leaves of *Aquilaria malaccensis*. *Research Journal of Pharmacology and Pharmacodynamics*, 11(1), 32-36.
- Islam, M. R., Chakraborty, C. and Banu, S. (2022). Isolation and Characterization of Bacteria and Fungi Associated with Agarwood Fermentation. *Current Microbiology*, 79, 313.
- Jayachandran, K., Sekar, I., Parthiban, K. T. and Damodarasamy, A. (2014). Analysis of different grades of Agarwood (*Aquilaria malaccensis* Lamk.) oil through GC-MS. *Indian Journal of Natural Products and Resources*, 5(1), 44-47.
- Jihadi, N. I. M., Hashim, Y. Z. H. Y., Rahim, N. A., Kamal, K. M., Noor, N. M., Sani, M. S. A and Maifiah, M. H. M. (2020). Antibacterial activity of ethanolic leaf extract of *Aquilaria malaccensis* against multidrug-resistant Gram-negative pathogen. *Food Research*, 4(6), 1962-1968.
- Kakino, M., Tazawa, S., Maruyama, H., Tsuruma, K., Araki, Y., Shimazawa, M. and Hara, H. (2010). Laxative Effects of Agarwood on Low-Fiber Diet-Induced Constipation in Rats. *BMC Complementary and Alternative Medicine*, 10(1), 68.
- Khalil, A. S., Rahi, A. A., Taha, K. K. and Abdallah, K. B. (2013). Characterization of Methanolic Extracts of Agarwood Leaves. *Journal of Applied and Industrial Sciences*, 1(3), 78-88.
- Knecht, D. A., Rebecca, A. L., Alem, W. K., Christian, E. A., Anwar, B. B. and Gabriel, F. (2010). Cucurbitacin I Inhibits Cell Motility by Indirectly Interfering with Actin Dynamics edited by R. C. May. *PLOS ONE*, 5(11), e14039.
- Kumar, Y., Haridasan, K. and Rao, R. R. (1980). Ethnobotanical notes on certain medicinal plants among some Garo people around Balphakram sanctuary in Meghalaya. *Bulletin of the Botanical Survey of India*, 22, 161-165.
- Mei, W. L., Cai, H. C., Domg, W. H., Guo, Z. K., Wang, H., Mei, W. L. and Dai, H. F. (2014). 2-(2-Phenylethyl) chromone derivatives from Chinese agarwood induced by artificial holing. *Fitoterapia*, 98, 117-123.
- Millaty, I., Wijayanti, N., Hidayati, L., and Nuringtyas, T. (2020). Identification of anticancer compounds in leaves extracts of agarwood (*Aquilaria malaccensis* Lamk.). *IOP Conference Series: Earth and Environmental Science*, 457, 012036.
- Naef, R. (2011). The Volatile and Semi-volatile Constituents of Agarwood, the Infected Heartwood of *Aquilaria* Species: A Review. *Flavour and Fragrance Journal*, 26, 73-87.
- Naf, R., Velluz, A., Brauchli, R. and Thommen, W. (1995). Agarwood oil (*Aquilaria agallocha* Roxb.) Its composition and eight new valencane, eremophilane, vetispirane derivatives. *Flavour and Fragrance Journal*, 10(3), 147-152.
- Naf, R., Velluz, A., Busset, N. and Gaudin, J. M. (1992). New nor-sesquiterpenoids with 10 epi eudesmane skeleton from agarwood (*Aquilaria agallocha* Roxb.). *Flavour and Fragrance Journal*, 7(6), 295-298.
- Nahar, J., Boopathi, V., Rupa, E., Awais, M., Kariyathalappil, A., Morshed, Md. N., Murugesan, M., Akter, R., Yang, D., Mathiyalagan, R., Yang, Deok-Chun, Jung, Seok-Kyu (2023). Protective Effects of *Aquilaria agallocha* and *Aquilaria malaccensis* Edible Plant Extracts against Lung Cancer, Inflammation, and Oxidative Stress—In Silico and In Vitro Study. *Applied Sciences*.
- Nakanishi, T., Yamagata, E., Yoneda, K., Nagashima, T., Kawasaki, I., Yoshida, T., Mori, H. and Miura, I. (1984). Three fragrant sesquiterpenes of agarwood. *Phytochemistry*, 23(9), 2066-2067.
- Pang, K. L., Chin, K. Y. and Nirwana, S. I. (2023). Immunomodulatory Effects of Agarwood Leaf Extract on RAW264.7 Murine Macrophages. *Endocrine, Metabolic & Immune Disorders-Drug Targets*, 23(7), 964-976.
- Peng, D. Q., Zhang, X. Y., Wang, C. H., Gong, B., Liu, Y. Y. and Wei, J. H. (2020). Chemical Constituents and Anti-Inflammatory Effect of Incense Smoke from Agarwood Determined by GC-MS. *International Journal of Analytical Chemistry*, 1-19.
- Rahman, H. M., Eswaraiah, M. C. and Dutta, A. M. (2016). Anti-Arthritic Activity of Leaves and Oil of *Aquilaria agallocha*. *Haya: The Saudi Journal of Life Sciences*, 1(1), 34-43.
- Said, F. and Kamaluddin, M. T. (2016). Efficacy of the *Aquilaria malaccensis* Leaves Active Fraction in Glucose Uptake in Skeletal Muscle on Diabetic Wistar Rats. *International Journal of Health Sciences and Research*, 6(7), 162-167.
- Sarma, D. R., Sarmah, J., Gupta, A. and Mishra, R. K. (2015). *Aquilaria malaccensis*, an ayurvedic medicinal herb found in Assam—its therapeutical and pharmacological aspect. *Indian Journal of Tropical Biodiversity*, 23(2), 218-222.
- Satapathy, A. K., Gunasekaran, G., Sahoo, S. C., Kumar, A. and Rodrigues, P. V. (2009). Corrosion inhibition by *Justicia gendarussa* plant extract in hydrochloric acid solution. *Corrosion Science*, 51(12), 2848-2856.

- Shamma, M. and Cantenson, R. L. (1973). The oxoporphinealkaloids. In: *The Alkaloids. Chemistry and Physiology*. Ed Manske R.H.F. vol. 14 Academic Press, London, pp 226-262.
- Sidik, N. A. B. (2008). Comparison of Gaharu (*Aquilaria Malaccensis*) Essential Oil Composition Between Each Country. Bachelor of Chemical Engineering, Faculty of Chemical Engineering and Natural Resources, University Malaysia Pahang.
- Simatupang, J., Batubara, R. and Julianti, E. (2015). Consumers' Acceptance and Antioxidant of the Agarwood (*Aquilaria malaccensis* Lamk.) Leaves Tea Based on the Shape and Size of Leaves. *Peronema Forestry Science Journal*, 4, 1–11.
- Sukito, A., Darmawan, S. and Turjaman, M. (2020). Antioxidant and anti-diabetes activities of agarwood extracts from *Gyrinops versteegii* (Gilg.) Domke and their cytotoxicity, *IOP Conference Series: Earth and Environmental Science*, 415 (1).
- Surjanto, Batubara R., Hanum, T. I. and Pulungan, W. (2019). Phytochemical and antioxidant activity of gaharu leaf tea (*Aquilaria malaccensis* Lamk.) as raw material of tea from middle Tapanuli Regency, North Sumatera Province. *IOP Conf Ser: Earth Environ Sci.*, 260, 012101.
- Suzuki, A., Miyake, K., Saito, Y., Rasyid, F. A., Tokuda, H., Takeuchi, M., Suzuki, N., Ichiishi, E., Fujie, T. and Goto, M. (2017). Phenyl-ethylchromones with in vitro antitumor promoting activity from *Aquilaria filaria*. *Planta Medica*, 83, 300–305.
- The Ayurvedic Pharmacopeia of India. Part I, Vol. 4. New Delhi: Department of AYUSH, Ministry of Health and Family Welfare, Government of India; 2004, 4-5.
- The Ayurvedic Pharmacopeia of India. Part I, Vol. 9. New Delhi: Department of AYUSH, Ministry of Health and Family Welfare, Government of India; 2016: 117-129.
- Wang, H. N., W. H. Dong., S. Z. Huang., W. Li., F. D. Kong., H. Wang., J. Wang., W. L. Mei. and F. Dai (2016). Three new sesquiterpenoids from agarwood of *Aquilaria crassna*. *Fitoterapia*, 114, 7-11.
- Yana, H. Y., Hidayati, L., Wijayanti, N. and Nuringtyas, T. R. (2022). Immunomodulatory Activity of Agarwood *Aquilaria malaccensis* Lamk. Leaf Extracts on *Staphylococcus aureus*-infected Macrophages *in vitro*. *The Indonesian Biomedical Journal*, 14(2), 156-163.
- Zaid, A. A., Wan Mamat, W. A., Tuan Johari, S. A., Othman, A. S. and Abdul Aziz, M. Y. (2022). Cytotoxic Activity of *Aquilaria malaccensis* Ethanolic Leaves Extract on Human Chronic Myeloid Leukaemia K-562 Cell Line. *Asian Journal of Medicine and Biomedicine*, 6(1), 37-42.
- Zulkifle, N. L. (2018). *Antidiabetic activity of Aquilaria malaccensis (agarwood) leaves extracts*. Masters thesis, Universiti Malaysia Pahang.

How to cite this article: Sumona Chetia, Gurpreet Kaur Bhamra, Kajal Gupta and Rajib Kumar Borah (2025). A Review on Medicinal and Pharmacological Potential of Agarar (*Aquilaria malaccensis* Lamk.), it's Chemical Constituents and Oil Quality. *Biological Forum – An International Journal*, 17(1): 124-130.