



Mini Review

Economic Value of Agarwood and Its Prospects of Cultivation

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Abstract

Aquilaria are genera of tropical trees that produces a valuable resinous wood called agarwood. Agarwood plant have been widely used as traditional medicines and Ayurvedic medicine. They are used for the treatment of arthritis, asthma, diarrhoea etc effects. It contains bioactive phytochemical sesquiterpenoids, 2 (-2-phenylethyl)-4H-chromen-4-one derivatives, genkwanins, mangiferins, cucurbitacins, other terpenoids and phenolic acids. Many pharmacological studies have been performed on anti-allergic, anti-cancer, anti-inflammatory, anti-microbial, anti-diabetic, anti-oxidant, etc. The aromatic properties of agarwood when burned or distilled are extraordinary and there is high demand for the resinous wood to make incense, perfume and as traditional medicine. *Aquilaria* are native to northern India but over harvesting of this tree as well as other forest trees in the past has ravaged the hill country. With new technology that has been developed to induce agarwood in trees, it is now possible to produce a sustainable high valued agarwood in young plantation trees. The growing of *Aquilaria* in the hill agro-ecosystems of Nepal and cultivation of agarwood as a crop using new technology could provide a new economy for the region.

Keywords: Agarwood; *Aquilaria*; ethnomedicine; economy; traditional medicine

Introduction

Agarwood normally refers to dense, heavy and fragrant resinous wood formed in the trees of *Aquilaria* which belongs to the Thymelaeaceae family of angiosperms. There are 21 *Aquilaria* species which have been documented and 13 of them are recognized as the agarwood-producing species (Lee and Mohamed, 2016). Agarwood is the most expensive and valuable tree in the world, which has a large national and international markets. The resin develops through wounding, pathological, and non-pathological mechanisms (Ng et al., 1997). The

formation of agar in agarwood tree is generally associated with the wounding and fungal infection of the *Aquilaria* trees (Liu et al., 2013; Mohamed et al., 2014). The resin is secreted by the plant cell as defense reaction of plant and deposited around the wounds over the years following the injury, where the accumulation of the volatile compounds eventually forms agarwood (Subasinghe and Hettiarachchi, 2013). The fragrant wood has many cultural and religious value around the world, such as the Chinese, Arabian, and Japanese cultures; Buddhism, Hinduism, Christianity,

Islam etc (Barden *et al.*, 2000). The agarwood plant has also used in the traditional medicine practices of the Southeast Asian communities, such as Chinese, Unani, Tibetan and Ayurvedic medicines (Barden *et al.*, 2000; Blanchette and van Beek, 2005). Agarwood has high demand throughout the world as a raw material for incense, perfume and medicine purposes. The aromatic properties of this resin were discovered long time ago and its fragrance is very desirable. The occurrence of the resin within trees is exceedingly rare, and demand has always been far greater than the quantity available resulting in agarwood having extremely high value. It is often referred to as “black gold” and high-quality agarwood has equaled or exceeded the price of gold in the past (Barden *et al.*, 2000).

The destructive exploitation of agarwood, however, has badly affected the wild population of all *Aquilaria* species. As a consequence, the genus is now listed as endangered species and protected under Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Lee and Mohamed, 2016). As the high demand of quality agarwood, mass cultivation and large plantation of *Aquilaria* trees which serve as a sustainable source to obtain agarwood have greatly resolved the shortage of agarwood supply in the global market. The commercially cultivated agarwood trees have been inoculated to induce resin by physical penetration into the trunk (wounding), insertion of a microbial fungal and response of the tree towards the administered stress (non-pathological). A method of producing agarwood resin by creating an artificial wound in the xylem of agarwood trees have been patented (Blanchette and van Beek, 2005). In response to this situation, sustainable agarwood planting and management with artificial induction of agarwood resin formation have been implemented. This has led to a ready supply of different parts of the agarwood plant, which provides opportunities for the development of a range of value-added products. Therefore, this paper aims to present an overview of the introduction, phytochemistry, ethnomedicinal use, pharmacological activities, commercial cultivation and value of *Aquilaria* spp. This paper will give a platform to review the potential use of agarwood as sources of health beneficial compounds, commercial significance as value added products and pharmaceuticals value.

Botanical Description

Agarwood plants are classified under the family Thymelaeaceae (The Plant List, 2013). Agar tree (*Aquilaria malaccensis*) are found in places with a diverse geographical environment. It is distributed in India eastwards to the island of New Guinea, including all Southeast Asian countries such as India, Japan, Malaysia, Myanmar, Indonesia, Cambodia, Thailand etc., and north to Hainan Island in southern China (Persoon, 2008). However, it is now rarely seen in such habitats because of

over-harvesting. It grows a tropical climate with optimal sunlight, shade, moisture and rainfall range of 1800-3500 mm. Agarwood, has many different names depending on the region of the world i.e., *gaharu* in the South East Asia, *oud* in the Middle East, *chen xiang* in China, *jinkoh* in Japan and *agar* in India; is a highly valuable aromatic dark resinous heartwood of *Aquilaria* species (Liu *et al.*, 2017). *Aquilaria* trees is an evergreen tree, 6 to 20 m tall (Blanchette and van Beek, 2005). The smooth bark is grayish to dark grey, and the wood is white to yellowish. Its leaves are alternate, leathery, obovate to elliptic, generally 5 to 11 cm long and 2 to 4 cm wide. The apex of each leaf is short acuminate, with entire and smooth margins. Its flowers are yellowish green, fragrant, in a terminal or axillary umbel. The fruit is a woody obovoid capsule with an outer covering of short grey hairs, 2.5 to 3 cm long, opening in two flat valves when ripen. When the fruit is open.

Uses of Agarwood and Its Value

Agarwood is a valuable, non-timber forest product which has been used throughout different societies for medicinal, cultural and religious purposes (Swee, 2008). The agarwood is traded in various forms of product derivatives, such as oil, wood, wood chips, flakes and powder. High quality wood is used as incense in Arabian households (Compton and Ishihara, 2004). It has been reported as a component of many traditional Ayurvedic remedies in the Indian subcontinent as well as being used in Tibetan, Chinese, Malayan and Vietnamese medicine (Antonopoulou *et al.*, 2010; Barden *et al.*, 2000; Kiet, 2003; Lim and Anack, 2010). Agarwood is used throughout the world; there are two major regions of consumption i.e. the Northeast Asia and Taiwan, Korea, Japan, etc. (Antonopoulou *et al.*, 2010; CITES, 2005; Compton and Ishihara, 2004). Small Wood chips are ground into a powder for the distillation of oil, making of incense, production of traditional medicines (Persoon, 2008; Sitepu *et al.*, 2011). An essential oil distilled from agarwood has a very long history of use as perfume. The oil is always in high demand from Middle Eastern countries, where it is used as a customary perfume (Barden *et al.*, 2000). Agarwood perfumes are commonly prepared in both alcoholic and non-alcoholic carriers, with the oil functioning as a fixative (Sitepu *et al.*, 2011). The agarwood oil is also used as a fragrance in the production of cosmetics and personal care products, such as soaps and shampoos (Chakrabarty *et al.*, 1994). The market value of agarwood derivative products is dependent on the classification or grading of agarwood, which is determined by a cumulative factor of the fragrance strength and longevity and purity (Barden *et al.*, 2000).

Agarwood is most well-known for its fragrance and use as incense and for perfume. The resin filled agarwood is harvested from trees by extracting it from the surrounding

white, unaffected wood. The fragrance of agarwood has a pleasant aroma but it also has important aromatherapy and medicinal qualities. It is well known for its use in ceremonies of many different religions. Agarwood carvings made into various sculptures and religious objects such as prayer beads are also in high demand. Agarwood is considered to have such important esteem many people display larger pieces of the wood as a symbol of prestige and object of great beauty.

Pharmacology of Agarwood

Agarwood has bioactive products that function as effective anti-microbial compounds, it may have anticancer activity, can be used as an antidepressant and used to promote good health in general (CITES 2005, Dash *et al.* 2008, Mei *et al.* 2008, Miller and Miller 1995). Pharmacological actions of agarwood including the anti-diabetic (Feng *et al.*, 2011; Jiang and Tu, 2011; Pranakhon *et al.*, 2015; Zulkiflie *et al.*, 2013), anti-inflammatory (Chitre *et al.*, 2007; Kumphune *et al.*, 2011), anti-cancer (Dahham *et al.*, 2014, 2015a; Gunasekera *et al.*, 1981), anti-depressant (Okugawa *et al.*, 1993; Takemoto *et al.*, 2008), and anti-oxidant (Dahham *et al.*, 2014; Han and Li, 2012; Nik Wil *et al.*, 2014; Owen and Jones, 2002; Ray *et al.*, 2014; Sattayasai *et al.*, 2012; Tay *et al.*, 2014) activities.

Ethnopharmacology of Agarwood

The traditional use of agarwood in different locality had been recorded in different aspect (Table 1). The Chinese medicine uses it as a natural sedative, pain reliever, digestive aid and carminative (Ye *et al.*, 2016; Liu *et al.*, 2017). Agarwood has been widely used as remedial perfumes, traditional medicine, religious purposes and aromatic food ingredient (Liu Y. *et al.*, 2013). Some of the earliest known uses of agarwood were recorded in ancient

literatures, religious and medical texts. The word “aloes” which means agarwood was found occurring in the Sanskrit poet, Kalidasa that can be dated back to c. 4th–5th century CE (Lee and Mohamed, 2016). Agarwood is used in a different community, with the majority of its medicinal uses involved in anti-inflammatory and related activities. For instance, it is used to treat rheumatism, arthritis, body pain, asthma and gout (Borris *et al.*, 1988).

The Main Phytochemical Constituents of Agarwood

The phytochemical constituents of agarwood mainly consist mixtures of sesquiterpenes and 2-(2-phenylethyl) chromones (PECs) (Naef, 2011; Chen *et al.*, 2012; Subasinghe and Hettiarachchi, 2015). Sesquiterpenes are divided into several categories *i.e.* agarofurans, agarospiroanes, guaianes, eudesmanes, eremophilanes and prezizaanes (Chen *et al.* (2012c)). The number and types bioactive metabolite consist of depending on the agarwood source, extraction methods and analysis approaches used (Fazila and Halim, 2012; Jong *et al.*, 2014). Several flavonoids, benzenoids, steroids and lignans are major bioactive chemical compound found in agarwood (Chen *et al.*, 2013a, 2013b). Data shown in the Table 2 shows that different bioactive chemical compounds are isolated from agarwood plant *i.e.* aquilarin B, phorbol 13-acetate and dihydrocucurbitacin F. Phytochemical screening of agarwood presence of flavonoids, tannins, alkaloids, terpenoids and saponins (Kamonwannasit *et al.*, 2013; Khalil *et al.*, 2013; Nik Wil *et al.*, 2014; Vakati *et al.*, 2013). Over 150 compounds as reviewed by Naef (2011) have been identified in agarwood from different sources. Among them, there are 70 sesquiterpenes and about 40 types of PECs which have been recognized (Naef, 2011).

Table 1: Ethnopharmacology of *Aquilaria* spp.

Locality	Ethnomedicinal uses	Reference
India	Treatment of diarrhoea, vomiting, dysentery, anorexia, mouth and teeth diseases, inflammation, arthritis, cardiac disorders, cough, asthma, leprosy and anorexia	Anon (1978); Iyer (1994)
China	Treatment of gastric problems, coughs, rheumatism and high fever; and used as sedative, analgesic and carminative agents	Chinese Pharmacopoeia Commission (2010)
Bangladesh	Treatment of rheumatism	Rana <i>et al.</i> (2010)
Indonesia	Treatment of joint pain	Grosvenor <i>et al.</i> (1995)
Japan	Stomachic and sedative agent	Okugawa <i>et al.</i> (1993)
Korea	Treatment of cough, asthma, stomachic agent, tonic, sedative and expectorant	Takagi <i>et al.</i> (1982); Yuk <i>et al.</i> (1981)
Malaysia	Tonic and stimulant	Burkill (1935)
Philippines	Stop bleeding of the wounds, Treatment of malaria (substitute for quinine)	Lemmens and Bunyapra Phatsara (2003)
Thailand	Treatment for diarrhoea, dysentery and skin diseases.	Kamonwannasit <i>et al.</i> (2013)

Table 2: Phytochemical compounds of *Aquilaria* spp.

Secondary Metabolites	Part	Species	References
Guaiane Sesquiterpenes	Agarwood	<i>Aquilaria agallocha</i>	Ishihara et al., 1991
Eudesmane Sesquiterpenes	Wood	<i>Aquilaria malaccensis</i>	Nakanishi et al., 1984
Agarofuran Sesquiterpenes	Agarwood	<i>Aquilaria agallocha</i>	Maheswari et al. 1963
Agarospirane Sesquiterpenes	Agarwood	<i>Aquilaria malaccensis</i>	Nakanishi et al., 1984
Eremophilane Sesquiterpenes	Agarwood	<i>Aquilaria malaccensis</i>	Wu et al., 2012
Prezizane Sesquiterpenes	Agarwood	<i>Aquilaria malaccensis</i> ,	Yoneda et al., 1984
Miscellaneous Sesquiterpenes	Wood	<i>Aquilaria agallocha</i>	Wu et al., 2012
Chromones	Wood	<i>Aquilaria agallocha</i>	Nakanishi et al., 1984
Di-Epoxy-Tetrahydrochromone	Agarwood	<i>Aquilaria crassna</i> ,	Yagura et al., 2003
Mono-Epoxy-Tetrahydrochromone	Agarwood	<i>Aquilaria sinensis</i>	Li et al., 2014
Aglycon Flavonoids	Leaves	<i>Aquilaria sinensis</i>	Qi et al. 2009; Cheng et al., 2013
Mono-Glycoside Flavonoids	Leaves	<i>Aquilaria sinensis</i>	Qi et al. 2009; Feng et al., 2011
Di-Glycoside Flavonoids	Leaves	<i>Aquilaria sinensis</i>	Qi et al. 2009; Yang et al., 2004
Xanthons	Leaves	<i>Aquilaria sinensis</i>	Qi et al. 2009 Cheng et al., 2013
Isoflavonoid	Stem	<i>Aquilaria sinensis</i>	Wu et al., 2014
Aglycon Benzophenones	Leaves	<i>Aquilaria sinensis</i>	Qi et al. 2009
Mono-Glycoside Benzophenone	Leaves	<i>Aquilaria sinensis</i>	Qi et al. 2009 Cheng et al., 2013
Di-Glycoside Benzophenone	Petioles and leaves	<i>Aquilaria sinensis</i>	Wang et al., 2015
Abietane And Podocarpane	Agarwood	<i>Aquilaria sinensis</i>	Yang et al., 2014
Diterpenoid			
Aglycon And	Petioles and leaves	<i>Aquilaria sinensis</i>	Wang et al., 2015
GlycosideCucurbitane Triterpenoid			
Tirucallane Triterpenoid	Petioles and leaves	<i>Aquilaria sinensis</i>	Cheng et al. 2013; Wang et al. 2015
Oleanane Triterpenoid	Leaves	<i>Aquilaria sinensis</i>	Cheng et al., 2013
Benzofuran-Type Lignan (Aglycon And Glycoside)	Stem	<i>Aquilaria sinensis</i>	Wu et al., 2014
Coumarinolignan	Whole plant	<i>Aquilaria agallocha</i>	Bhandari et al., 1982
Nucloesides	Petioles and leaves	<i>Aquilaria sinensis</i>	Wang et al., 2015
Acetanilide	Leaves	<i>Aquilaria malaccensis</i>	Afiffudden et al., 2015
Glyceride	Stem bark	<i>Aquilaria malaccensis</i>	Mei et al., 2008
Essential Oil	Agarwood	<i>Aquilaria malaccensis</i>	Tajuddin et al., 2013

Cultivation and Management of Agarwood

The first step to increase supplies of agarwood is to increase the availability of *Aquilaria* trees. Agarwood plant prefers high humid, sub-tropical climate with rainfall 1800-3500 mm per annum. It grows from sea level upto 1000 m altitudes. It is a sun loving plant and requires lot of sunshine. It prefers well-drained deep sandy loam rich in organic matter but can profitably be grown in marginal soils and also in shallow soils over rocky beds with cracks and crevices. It grows well in hill slopes and forest environment. The traditional agar growing areas show that it prefers acidic soil reaction. The mycorrhiza and other beneficial fungi which seems to be responsible for agar formation in the agar tree being soil borne requires acid soil for their population build up. Agarwood is propagated by seeds. This must be done very soon after the fruit has opened and the seed exposed since seed of *Aquilaria* have a short time period for viability. Successful seed storage is difficult and loss of viability occurs very quickly once seeds are exposed to the environment.

Aquilaria plant plantation can be done in sloping lands to reduce mortality. Before plantation prepare the hole 40cm x 40 cm x 40 cm and leave it few days for oxygenated soil helps to root growth. Soil mix with cow dung or other organic manure with 20 grams of Funadan is added to minimize the attack of insects. The hole can be covered to the appropriate level of planting surface. The seedlings are ready to transplant in the ground after attaining a height of 60-90 centimeters. *Aquilaria* can grow on marginal land and under a wide range of conditions. They are fast growing trees and in areas with adequate moisture, can achieve 10 cm DBH in 4 to 6 years. They are especially suited for the hill ecosystem. The natural production of agarwood takes many decades to develop, and as mentioned previously, when it does form it is usually found in a very small percentage of trees. Over the past years, many techniques have been tried to induce agarwood (Ng et al. 1997). A traditional way used by some farmers is to cause repeated wounding of trees. This method may produce a very small amount of low-quality agarwood at times or may be unsuccessful. Fig. 1 shows Agarwood cultivation at various places.



Fig. 1: Agarwood cultivation at various places; A. In Gulmi, B. In Pokhara, C. In nursery

Aquilaria has a unique composition of phloem bundles within xylem. This network of phloem and parenchyma produce and distribute the resin around the injured area to recover the wounds (Blanchette and Van Beek 2005). This accumulated resin is known as agar. Only 7% trees are infected naturally (Ng *et al.* 1997) by ant, snails or fungus and mostly obtained at the junctures of broken branches. Natural fungal infected plants produce best quality agar whereas inferior quality agar is the result of artificial inoculation (Bhuiyan *et al.* 2009). Though there are several artificial inoculation methods in agar farmers practice only iron nailing. Low cost, easy insertion, and local availability are the main reasons behind this practice. Farmers recommend nailing when trees reached 6 to 7 years of age. After 3 to 5 years of nailing, the trees became ready for harvesting and the best time for harvesting is mid-October to mid-March (Chowdhury *et al.* 2017 and Rahman *et al.* 2015).

Nowadays, Fungi-Inoculation method (Oldfield *et al.* 1998) is becoming popular. Resin production could be increased due to fungal infection as the host response very first to minimize the fungal growth damage. *Aspergillus* spp., *Botryodiplodia* spp., *Diplodia* spp., *Fusarium bulbiferum*, *F. laterium*, *F. oxysporum*, *F. solani*, *Penicillium* spp. and *Pythium* spp. could easily infect agar trees (Chowdhury *et al.* 2017). When liquid fungal solutions were inoculated with liquid *Rhizopus* spp. inoculants into the agar tree gives very good agarwood within three month and this condition usually kept for two years. Proper management of the trees is also required as the resinous wood is formed in the tree. Although the procedures may be difficult for individual farmers to apply, cooperatives or agroforestry industry with trained staff can facilitate the application of the technology and carry out the work easily. This technology has a proven record of success and has been used in *Aquilaria* plantations located in Vietnam over many years producing fine quality agarwood that is sold worldwide.

Create nurseries and establish a new agroforestry crop in the hill country could regenerate this economically important tree which would be of great value to local communities. This would provide a sustainable yield of valuable

agarwood, a new economy for rural people and reduce the exploitation of *Aquilaria* in natural forests since there is no need to cut old growth trees to obtain the agarwood resin.

Commercial value and Future Prosperity

Artificial wounding helps to stimulate resin in *Aquilaria* trees (Beek and Phillips 1999). Several scientific methods such as fungi inoculation (Oldfield *et al.* 1998) and aeration (Blanchette 2006) are remarkable of those which produce many times higher yield as from existing agarwood wounding method. Agar farmers are aware of these new techniques, they would get more profit. In future, induction technology should emphasize to improvement quality agarwood production. The value of agar depends on quality; commercial value of first-grade agarwood is extremely high. It is sold in the form of woodchips, powder, wood pieces, oil, dust, incense ingredients and perfume for several thousand US dollars per kilogram (LaFrankie, 1994; Barden *et al.*, 2000). Agarwood chips start at \$30 per kilo up to \$9,000 per kilo depending on how much resin is inside the chips (Babatunde, 2015). First-grade agarwood is one of the most expensive natural raw materials in the world. When agarwood chips are processed into oil, the agarwood oil was sold at US \$ 30,000 per kg (Nanyang Siang Pau, 15 August 2005). The current global market for Oud oil and other related agarwood products is estimated to be in the range of US\$ 6 to 8 billion (Akter *et al.*, 2013). In other aspect, agar-based enterprises are increasing day by day. This increasing number of agar enterprises had created new employment opportunities for rural people which are playing a vital role in improving livelihoods in those areas. If government specially consider this sector and take policies like Industrial Policy, Import Policy, Export Policy and so on, agar farming will be one of the major foreign currency earning sectors of country. Deforestation and forest degradation are one of the major causes of global warming. These deforested areas will replant valuable species like *Aquilaria*. It will help in carbon sequestration, biodiversity conservation as well as produce better quality agarwood, and to change the economic standards of Country.

Conclusions

The worldwide demand for agarwood for use in incense, carved ornaments, perfumes and traditional medicine has continued to increase in recent years. Agarwood plant have been widely used as traditional medicines as Ayurvedic medicine. They are used for the treatment of arthritis, asthma, diarrhoea etc effects. Phytochemical studies show that they contain sesquiterpenoids, 2 (-2-phenylethyl)-4H-chromen-4-one derivatives, genkwanins, mangiferins, cucurbitacins, other terpenoids and phenolic acids. Many pharmacological studies have been performed on anti-allergic, anti-cancer, anti-inflammatory, anti-microbial, anti-diabetic, anti-oxidant, etc. The natural existing agarwood from old growth forests has been almost completely depleted. The loss of *Aquilaria* from the forest is of great concern and efforts are needed to save the existing genetic diversity that remains. Agar farming provides bi-directional environmental benefits *i.e.*, carbon sequestration and biodiversity conservation. It is a growing economic sector. The hill agro-ecosystems of Nepal & hilly country are ideally suited to grow *Aquilaria* and could be an excellent product of cultivated agarwood. This high valued crop would benefit rural people and contribute greatly to the economy of the region. The Government of Nepal can take suitable policies to uplift this sector and Non-governmental organizations can provide proper training in agar farming and agar processing. It would be one of the major sources for earning foreign currency and boost up the export figure of Nepal.

Author's Contribution

All authors contributed equally at every stages of data collection, preparation and finalized the manuscript. Final form of manuscript was approved by all authors.

Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

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