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Patent Landscape of *Aquilaria* Species: Trends in Sustainable Agarwood Agribusiness Innovation

Yumi Zuhanis Has-Yun Hashim[1]*, Nur Erina Syafiqa binti Mohd Rozali[1], Nurhusna Samsudin[1], Phirdaous Abbas[1], Anis Najiha Ahmad[1], Saripah Salbiah Syed Abdul Azziz[2], Manar A. Eissa[3], and Mohd Hafidz Mahamad Maifiah[1]

[1]International Institute for Halal Research and Training,
International Islamic University Malaysia, 57028 Kuala Lumpur, Malaysia
[2]Faculty of Science and Mathematics,
Sultan Idris Education University, Tanjung Malim 35900 Perak, Malaysia
[3]Department of Pharmacology and Toxicology,
University of Mississippi Medical Center, Jackson, MS 39216 USA

***Aquilaria* spp. is renowned for its fragrant, resin-impregnated wood, commonly known as agarwood, which is highly valued in the perfumery industry. Beyond this prized resin, the tree yields a wide range of materials – including leaves, fruits, seeds, flowers, oil, roots, branches, and hydrosol – many of which are being developed into consumer products. Despite its rich ethnobotanical history, strong market demand, and growing scientific interest, a gap remains between research and practical innovation. This study bridges that gap by analyzing 296 unique patents related to *Aquilaria* filed between 2010–2022 and drawn from Espacenet, WIPO PatentScope, Google Patents, and ASEAN Patentscope. Patent trends revealed that China leads global innovation, with most patents originating from companies and research institutes. Induction technologies (including high-pressure, fungal, and liquid methods) and therapeutic uses (notably anti-inflammatory and digestive-related applications) dominate the landscape. Beyond medicinal innovations, patents also highlight *Aquilaria's* role in consumer products and sustainable cultivation. Notably, half of the patents specify the inoculation status of the agarwood material used, a critical but inconsistently reported factor that affects downstream applications. Beyond tracking innovation, these findings spotlight *Aquilaria's* untapped potential in pharmacology and consumer markets. They also underscore the urgent need to align commercialization with conservation, guiding stakeholders toward sustainable cultivation and agribusiness practices that secure both industry growth and the future of this endangered species.**

Keywords: agarwood, *Aquilaria*, innovations, medicinal, non-medicinal, patents

INTRODUCTION

The *Aquilaria* tree – a valuable non-timber forest product (NTFP) – provides resin, leaves, seeds, and oil used across industries. Its fragrant resin, known as agarwood, forms in response to natural injury or artificial induction (Herath and Jinendra 2023) and is the world's most valuable NTFP, with chips selling for up to USD 250/g and essential oil reaching USD 20,000/L (Blaser *et al*. 2021). As of 2022, the global agarwood oil market was valued at USD 0.25 billion and projected to reach USD 0.43 billion by 2032 (More 2021). Among the 22 known *Aquilaria* species, *A. malaccensis*, *A. crassna*, and *A. sinensis* dominate both research and trade (WFO 2022).

*Corresponding author: yumi@iium.edu.my

Because of overharvesting, *Aquilaria* is listed under CITES Appendix II, prompting widespread plantation-based cultivation to ensure a sustainable supply (UNEP-WCMC 2014; Hashim *et al*. 2016). In Malaysia, the Malaysian Timber Industry Board regulates *Aquilaria* under INTESA to align with CITES (Azren *et al*. 2021). Indonesia has more than three million trees cultivated across 21 provinces, highlighting regional domestication success (Samsudin *et al*. 2021). These programs both protect wild populations and stimulate agribusiness by ensuring raw-material stability.

Despite rapid growth in *Aquilaria* research, its translation into large-scale commercialization remains limited. A bibliometric analysis (1959–2021) showed a shift from chemical to biological and applied innovation (Hashim *et al*. 2022), but how this knowledge converts to marketable technology is unclear, necessitating tools such as patent landscape analysis to bridge research and application.

Patent landscape analysis examines patent data to uncover innovation trends and technological trajectories. The World Intellectual Property Organization (WIPO 1967) defines a patent as legal protection for an invention offering a novel and useful solution. Patents serve as measurable indicators of innovation and forecasting tools (Abbas *et al*. 2014; Burhan *et al*. 2017; Ponta *et al*. 2022). This approach has been applied in many fields, from bioremediation (Saraswat 2014) and agricultural fungi (Srivastava *et al*. 2021) to human gene therapy (Zhou and Wang 2021) and plant resources such as *Hypericum* and wild orchids (de Carvalho Meirelles *et al*. 2019; Masters *et al*. 2020). However, no comprehensive patent landscape for *Aquilaria* currently exists despite its increasing economic significance.

This study, therefore, performs a neutral patent analysis of *Aquilaria* from 2010–2022, classifying patents by country, ownership type, and innovation category (medicinal *vs*. non-medicinal). The findings map technological development, identify emerging applications, and inform future research and sustainable agribusiness innovation within the agarwood sector.

MATERIALS AND METHODS

Data Survey

This study analyzed patents related to products and methods involving *Aquilaria* species, sourced from four patent databases: Espacenet®, WIPO PatentScope®, Google Patents®, and ASEAN Patentscope®. Espacenet®, managed by the European Patent Office, provides access to over 120 million global patent records since 1782. WIPO PatentScope® covers patents under the World Intellectual Property Organization, whereas Google Patents® aggregates records from over 100 major patent offices. The ASEAN Patentscope®, introduced in 2012 by the ASPEC Task Force, supports regional research and development cooperation and technology sharing across ASEAN nations.

The search methodology adapted elements from de Carvalho Meirelles *et al*. (2019) and Masters *et al*. (2020). The keyword "*Aquilaria*" was used in the title or abstract fields, with a timeframe from 2010–2022. This period aligns with findings by Hashim *et al*. (2022), who observed a significant increase in agarwood-related publications starting in 2010. The search was conducted on 01 Mar 2022.

Data Analysis

After retrieval, patent entries were cleaned by removing redundant and divisional data. Redundant data referred to entries with the same title, inventors, and publication numbers, whereas divisional patents shared similar titles but had different publication numbers and dates. A total of 296 unique patent entries remained for analysis. Table 1 summarizes the number of patents retrieved by the database and search parameters.

Patents were categorized by year, registration country, and ownership type (individual, company, or academic). Innovations were then grouped into medicinal (*e.g.* pharmacological, therapeutic, or biological applications) and non-medicinal (*e.g.* induction techniques, agarwood production, culture methods). Subcategories were added as patterns emerged to deepen analysis, discussed in the Results section.

Table 1. Number of patents found in the databases analyzed with the keyword "*Aquilaria*" in the "title" or "title + abstract" search terms.

Keywords	Number of patents			
	Espacenet	WIPO PatentScope	Google Patents	ASEAN Patentscope
Aquilaria (title)	217	193	225	9
Aquilaria (title + abstract)	672	564	631	—

RESULTS AND DISCUSSION

The findings of this patent landscape are presented in a neutral, evidence-based manner to map the innovation environment surrounding *Aquilaria*-related technologies. Observations regarding sustainability and competitiveness are offered as contextual insights from the data, not prescriptive strategies.

Aquilaria Patent Data Survey

Overall, the number of both scientific articles and patents related to *Aquilaria* has steadily increased between 2010–2022, as depicted in Figure 1. In earlier years, publications far outpaced patent filings, but more recently, the gap has narrowed. In some years, the number of patents approaches or even matches the number of articles indexed in Web of Science or Scopus. This trend may reflect a growing focus on commercialization and recognition of intellectual property as essential in the agarwood sector (Chen *et al*. 2024; Stim 2024).

Geographic and Ownership Distribution

Patent ownership in the *Aquilaria* space is highly skewed by country. China holds 82% (245 patents), followed by Korea (7%), Taiwan (5%), Malaysia (2%), and India (1%). China's dominance likely stems from traditional medicine demand, strong government support, and a large population driving herbal research (Liu and Ma 2020). Korea's patents focus on herbal mixtures and personal care; Taiwan shows interest in anti-inflammatory uses of *A. malaccensis* seeds. Malaysia emphasizes sustainability and conservation, whereas India's approach prioritizes scalable, modern techniques for compound yield.

In terms of ownership types, 40% of patents are held by companies, 29% by independent inventors, and 27% by universities or institutes. Some are co-owned across sectors. This distribution reflects the industry's active role in IP protection, including strategies like "fencing" or "blocking" to maintain competitive advantage (Brantnell and Baraldi 2022; de Carvalho Meirelles *et al*. 2019). For instance, Dongguan Guanxiang Gardening Technology Co., Ltd. patented a green extraction method for *A. sinensis* flower leaf tea, underscoring practical and eco-conscious innovation. Patents were categorized into medicinal and non-medicinal inventions, then sub-classified by subject matter, as listed in Table 2.

Patents on *Aquilaria* Related to Medicinal Applications

Aquilaria has long been a significant component in traditional remedies practiced by Chinese, Indian, Malay, and Unani communities, as well as in perfumery (Mohamed 2016). More recently, ethnopharmacological research using modern scientific techniques has begun to substantiate these traditional claims with evidence-based

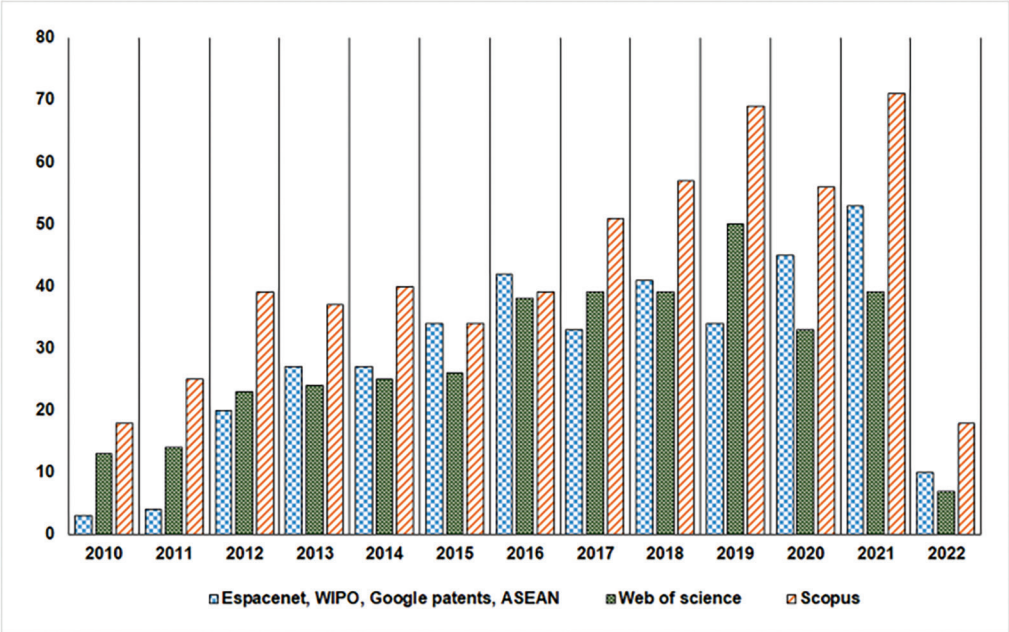

Figure 1. Comparison between total numbers of patents and total number of scientific articles published in Web of Science and Scopus databases per year from 2010–2022 using the keyword "*Aquilaria*" (note: data for 2022 includes only entries until March and does not exclude duplicates).

Table 2. Medicinal and non-medicinal patent subcategories for *Aquilaria*-related technologies.

Medicinal application subcategories	Non-medicinal application subcategories
Anti-inflammatory effect	Induction technology
Carminative effects on the digestive system	Agarwood production or devices
Anti-tumor and anti-cancer effects	Cultivation
Anti-aging effect	Non-edible product
Anti-oxidant effect	Extraction or separation process
Anti-diabetic effect	Plant disease protection, pest, or disease
Other therapeutic effects	Cosmetic and personal care
	Chemical compounds or composition
	Culturing process
	Edible product
	Method for species identification

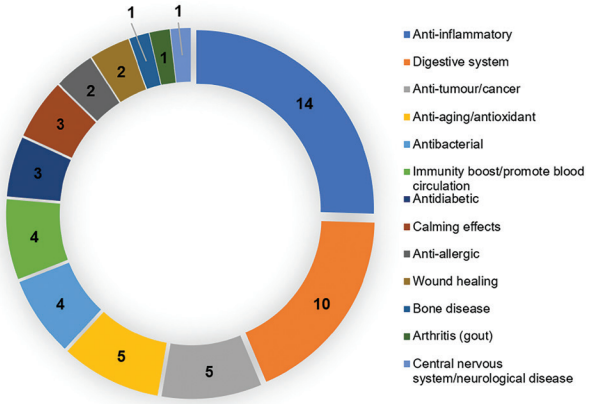

Figure 2. Medicinal or therapeutic patents on agarwood categorized by therapeutic use and the number of registered patents. Search conducted using the keyword "*Aquilaria*" from 2010–2022.

findings. Of the total *Aquilaria*-related patents surveyed, 25% were medicinal in nature, whereas the remaining 75% were categorized as non-medicinal. This classification was based on whether the process or product offered health-related functions. From the medicinal subset, China accounted for the majority, with 74 patents. These were further classified into pharmaceutical combinations (35%), preparative methods yielding therapeutic effects (33%), and edible products with health benefits (32%). In terms of species, *A. sinensis* appeared in 57 % of the medicinal patents, followed by *A. agallocha* (20%), *A. malaccensis* (12%), *A. crassna* (3%), and patents involving *Aquilaria* fruit hulls (1%). About 7% of the patents did not specify the species used.

Reported therapeutic effects included anti-inflammatory, carminative, anti-tumor or anti-cancer, anti-aging, antioxidant, and anti-diabetic properties, among others, as shown in Figure 2. The following section provides examples of patents that target specific medical disorders and symptom relief.

***Aquilaria* anti-inflammatory effect.** Anti-inflammatory properties were the most commonly patented therapeutic effect (25%), particularly in patents involving *A. sinensis*. Examples include KR-101751398-B1 (Kim *et al*. 2017), CN-113350423-A and TW202133871-A (Xie *et al*. 2020a, b), and KR-102187229-B1 (Jung 2019). These covered applications from herbal mixtures and topical formulations to agarwood tea preparations. The tea, noted for its woody, earthy aroma, offers reported anti-inflammatory and antiviral benefits. Studies also highlighted the commercial potential of agarwood tea, such as in Indonesia, where a business showed an internal rate of return (IRR) of 40.73% and a B/C ratio of 3.6 (Karsiningsih 2016). While the market penetration remains slow, strategic promotion leveraging patent-backed therapeutic claims could accelerate growth.

Carminative effects on the digestive system. Ten (10) patents addressed digestive tract conditions, primarily from China. For instance, CN103005111(A/B) and CN103271183(A/B) describe *A. sinensis* leaf tea that enhances gastrointestinal motility (Chen 2013d; Lu 2013).

Anti-tumor and anti-cancer effects. Several patents target anti-cancer applications using *A. sinensis* such as CN-109045154-A, CN-106106938-A, and CN-101411789-A (Mei *et al*. 2008; Huang and Liang 2016; Yang and Cao 2018). One U.S. patent (US2011160152-A1) describes cucurbitacin-rich extracts from *Aquilaria* fruit hulls (Wang *et al*. 2009).

Anti-aging, antioxidant, and anti-diabetic effects. Two anti-aging patents from the Guangdong Institute of Microbiology involve *A. sinensis* peel extract in whitening and skincare products (Li, Zhang, and Chen 2013). Antioxidant effects were reported in patents CN106106938A and CN106190726A, utilizing agarwood peel and *A. sinensis* wine, respectively (Huang and Liang 2016; Liu 2016). Anti-diabetic patents include WO2017084001A1, which reports squalene as an active ingredient in a preparation aimed at treating diabetes and kidney disease (Chen 2017), whereas KR20150088677A describes improved leptin sensitivity and glucose regulation through aromatized fermented tea (Yoon 2015).

Other therapeutic effects. Additional patents covered antibacterial (4), immune-boosting or circulatory (4), calming (3), anti-allergic (2), and wound-healing (2)

effects. CN111423937A, for instance, presents agarwood pure dew as a non-smoke calming alternative (Feng *et al*. 2020). Isolated patents addressed bone disorders (CN107184741A), arthritis (CN112546124A), and CNS disorders (CN215651981U). Despite broad anti-inflammatory claims, only one patent targets gout specifically (CN112546124A), underscoring the need for more targeted applications (Patil *et al*. 2021).

While agarwood is widely cited for sedative effects in traditional Chinese and Japanese medicine (Chinese Pharmacopoeia Commission 2010; Compton and Ishihara 2004), few modern patents reflect this. A recent bibliometric review emphasized the need to translate traditional uses into patentable, evidence-backed innovations (Hashim *et al*. 2022). Overall, this patent analysis reveals a clear disconnect between the scientific validation of *Aquilaria's* biological effects and their translation into real-world innovations, suggesting an opportunity that is ripe for strategic and forward-thinking IP development.

Recent Medicinal Patents of *Aquilaria* (2021–2022)

To reflect current trends, Table 3 compiles *Aquilaria*-related medicinal patents filed between 2021–2022. Once again, anti-inflammatory applications appear most frequently across filings. In total, fifteen patents from China, Korea, Malaysia, and Taiwan were identified, spanning uses from skin repair and immune support to anti-cancer and calming therapies.

Aquilaria's anti-inflammatory potential continues to be supported by extensive *in vitro* and *in vivo* studies, largely attributed to bioactive flavonoids and phenolic compounds, which are increasingly recognized for their therapeutic relevance (Li, Zhang, and Cai 2021). However, none of the patents in this set could be directly linked to *Aquilaria*-based products currently on the market, revealing a persistent gap between research findings and product development. With growing scientific clarity, the next step is bold translational work that moves these discoveries beyond the lab.

Patents on *Aquilaria* Related to Non-medicinal Uses

The patent search identified a total of 222 technologies, approaches, and items related to non-medicinal applications of *Aquilaria* species filed between 2010–2022, as shown in Figure 3. These fall into various categories: induction technology (22%), agarwood production or devices (21%), cultivation (16%), non-edible products (8%), extraction or separation processes (6%), plant disease protection (5%), cosmetics and personal care (5%), chemical compositions (5%), culturing processes (5%), edible products (4%), and species identification methods (3%).

Among these, induction technology dominates with 64 patents (22%), aimed at replicating natural agarwood formation while enhancing yields in cultivated trees (Tan *et al*. 2019). Artificial techniques include chemical inducers, fungal and bacterial agents, and mechanical wounding. Chemicals are often preferred in industry due to

Table 3. *Aquilaria* patents with therapeutic effects between the years 2021–2022.

No.	Title	Patent number	Country	Therapeutic effects	Publication date	Type of ownership
1	Method for Manufacturing *Aquilaria agallocha* Gongjin-Dan (Traditional Herbal Medicine) with Excellent Internal Resorption Rate	KR-102222753-B1	Republic of Korea	Digestive system	25 Feb 2021 04 Mar 2021	Independent
2	Application of *Aquilaria sinensis* Leaf Extract in Preparation of Medicines for Treating Gout	CN-112546124-A	China	Arthritis	26 Mar 2021	University
3	Electrospun Nanofibers Incorporated with *Aquilaria malaccensis* Extract and Method for Producing the Same	MYP-I2019006352	Malaysia	Anti-inflammatory and wound healing	29 Apr 2021	University
4	Chinese Medicine Nutritional Supplement for Improving Immunity and Vitality Using Deer Antlers, *Angelica gigas*, *Cornus officinalis* Fruits, *Aquilaria agallocha,* and Pear Syrup as Main Ingredients, and Manufacturing Method Thereof	KR-1020200139282-B1	Republic of Korea	Digestive system and boost immunity	14 Dec 2020 08 Dec 2021	Independent
5	Artificial Aquilaria wood, Aquilaria Wood Essential Oil Enrichment Liquid, Aquilaria Wood Soap, and Production Method Thereof	CN-111700075-B	China	Antibacterial, Anti-inflammatory, tranquilizing effect	17 Aug 2021	Company

Table 3. Continued . . .

6	Application of *Aquilaria malaccensis* Seed Extract in Preparation of Skin Anti-inflammation Composition	CN-113350423-A	China	Anti-inflammatory	07 Sep 2021	Independent
7	Application of *Aquilaria malaccensis* Seed Extract in Preparation of Skin Repair Composition	CN-113350231-A	China	Skin repair	07 Sep 2021	Independent
8	Application of *Aquilaria malaccensis* Seeds Extract for Preparing Skin Repair Composition Using Crude Ingredients to Repair Damaged Skin and Enhance Skin Care	TW-202133870-A	Taiwan	Skin repair	16 Sep 2021	Independent
9	Application of *Aquilaria malaccensis* Seeds Extract to Prepare Skin Anti-inflammatory Composition Capable of Inhibiting Inflammation Factors in Cells and Releasing Interleukin-1 to Provide Efficient Anti-inflammatory Effect	TW-202133871-A	Taiwan	Anti-inflammatory	16 Sep 2021	Independent
10	*Aquilaria agallocha* Wash-free Sleeping Mask and Preparation Method Thereof	CN-111450040-B	China	Skin problem	21 Sep 2021	Company
11	Aquaculture Solution and Method for *Aquilaria sinensis*	CN-113575394-A	China	Anti-inflammatory	02 Nov 2021	Company University
12	*Aquilaria malaccensis* Wine and Preparation Method Thereof	CN-113599452-A	China	Immunity boost	05 Nov 2021	Company
13	*Aquilaria sinensis* Tea Aroma Improving Device	CN-215224460-U	China	Digestive system	21 Dec 2021	Company
14	Preparation Method and Application of Chemical Components of Anti-cancer Active Site of *Aquilaria sinensis* Flower	CN-113817013-A	China	Anti-cancer	21 Dec 2021	Company University
15	*Aquilaria sinensis* Steam Hot Compress Eye Patch with Functions of Calming Nerves and Helping Sleep	CN-215651981-U	China	Calming effect	28 Jan 2022	Independent

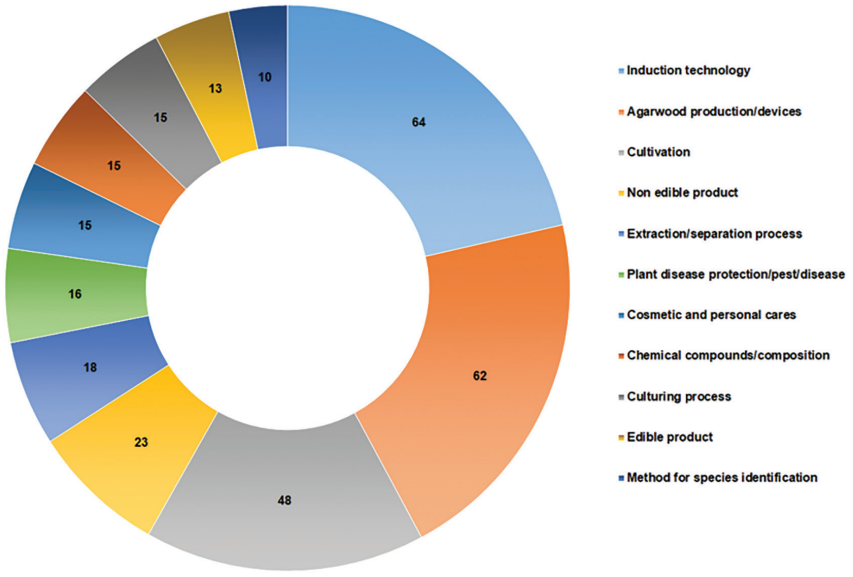

Figure 3. Patent distribution by category for non-medicinal *Aquilaria*-related technologies. Data sourced from keyword search "*Aquilaria*" in selected patent databases (2010–2022).

easier quality control, and patents typically cover aspects like inoculum composition, delivery methods, and resin detection techniques. Given that agarwood formation can take up to a decade, innovation in induction is vital for a consistent, scalable supply.

China leads in this domain with 55 patents. The Hainan Branch of the Institute of Medicinal Plant Development (Chinese Academy of Medical Sciences) and Yunnan Aini Chenxiang Technology Co., Ltd. are among the prominent contributors. The latter patented aroma-enhancing techniques that infuse an agaric precursor containing isoprene and phenylethyl alcohol into white wood, as detailed in patents CN106069499A and CN106069256A (Li and Zhang 2016a, b).

Other non-medicinal patents include 13 related to edible products (*e.g.* tea, wine, coffee, vinegar) such as *A. sinensis* coffee, promoted for its potential to warm the body, relieve pain, and ease asthma (Wu 2021). Twenty-three (23) patents cover non-edible goods like pillows, tobacco, essential oils, acupuncture tools, and paper. Three notable patents (CN103446346A, CN103446345A, and CN103446347A) describe acupuncture devices for managing asthma and gastrointestinal disorders (Chen 2013a, b, c). Separately, Changzhou Adam Biotech Inc. patented a paper-making method using branches and leaves of *A. sinensis*, detailed in CN102943409A (Ye *et al*. 2013).

Cultivation technologies accounted for 48 patents or 16% of non-medicinal filings, focusing on propagation, fragrance enhancement, and sustainable growth strategies. Notably, patent CN104429808A by Yunnan Hongtu Shengyuan Medical Biotechnology Development Co., Ltd. describes high-altitude transplant techniques for seedlings, with better survival rates and reduced costs for foresting elevations of 800–1300 m (Zhang, Wang, and Zhu 2015). As Mueller (2024) emphasizes, patents not only secure innovation but also enable licensing and partnerships, which are key for advancing commercialization and ecological sustainability in *Aquilaria* industries.

Inoculation Status of Agarwood Materials

The formation of agarwood resin in *Aquilaria* species is typically triggered by inoculation, a deliberate process that simulates natural stress or microbial attack. This induction alters the tree's chemical composition, leading to the production of valuable resin highly prized for its distinctive scent and preservative properties (Ismail *et al*. 2014). Because this transformation directly affects the bioactive profile of the plant, knowing whether patented materials are derived from healthy or inoculated trees is essential to interpret their functional or therapeutic claims. Analysis of patent data from 2010–2022 revealed inconsistent disclosure of inoculation status. About 50% of agarwood-related patents specified the use of inoculated materials, 30% relied on healthy trees, 19% did not disclose the status, and 1% were unrelated. Despite the prominence of agarwood resin in the perfumery and essential oil industries, only two patents were filed under perfumes, whereas others fell within extraction and separation technologies. Since inoculation significantly influences the resulting compound profiles and biological activities of *Aquilaria* (Tamuli *et al*. 2005; Jong, Tsan, and Mohamed 2014), future patents should clearly state the inoculation source of the materials used. Doing so would enhance reproducibility, transparency, and downstream innovation in agarwood-based industries.

CONCLUSION AND RECOMMENDATIONS

This study identifies China as the leading applicant for *Aquilaria*-related patents, particularly in induction technology, which remains the most active category. Patented innovations range from high-pressure infusion to fungal and microbial induction methods, reflecting strong industrial interest in optimizing resin yield and quality. Medicinal patents largely focus on anti-inflammatory and digestive health applications, whereas non-medicinal technologies highlight *Aquilaria's* growing potential as a versatile ingredient in consumer products.

Patent analysis, therefore, serves as a vital bridge between empirical research and real-world application. While published scientific data do not always indicate commercial viability, the patent landscape reveals trends that connect laboratory findings to market potential. This study, the first comprehensive analysis of *Aquilaria* patents, provides an overview of global innovation efforts and emphasizes opportunities for refining inoculation methods, isolating bioactive compounds, and expanding pharmacological and industrial applications. Strengthening collaboration between researchers and industry players will be key to transforming these discoveries into accessible, value-added products.

The increasing diversity of *Aquilaria* technologies also signals a rising demand for agarwood-derived materials, reinforcing the importance of sustainable cultivation and ethical sourcing. Historical overharvesting has endangered wild *Aquilaria* populations, making responsible plantation management essential. Future growth in the agarwood sector must therefore balance commercialization with conservation, ensuring that innovation, ecology, and ethics progress together in harmony.

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STATEMENT ON CONFLICT OF INTEREST

The authors declare no conflict of interest.

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