Cinnamomum camphora in the 21st Century: A Narrative Review of Its Biomedical Potential, Cultural Economies, Market Dynamics, and Sustainability Challenges

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Abstract

Camphor, a naturally occurring monoterpene ketone derived primarily from *Cinnamomum camphora*, has been a cultural, medicinal, and economic resource for over two millennia. Its contemporary relevance extends from traditional medicine to pharmaceuticals, aromatherapy, ritual economies, and wellness industries. Modern research continues to clarify its analgesic, anti-inflammatory, antimicrobial, and respiratory effects, while global markets reflect rising demand for both natural and synthetic variants. Simultaneously, sustainability concerns, regulatory complexities, and cultural revivals shape the landscape surrounding camphor. This narrative review synthesizes current scholarship on the botanical, biomedical, cultural, economic, and ecological dimensions of *C. camphora*, and highlights how tradition and science converge in shaping its future.

1. Introduction

Natural aromatic substances rarely maintain uninterrupted cultural, economic, and scientific relevance, yet camphor remains an exception. Traditionally called *karpura* in Sanskrit and widely used across South and East Asia, camphor historically symbolized purity, healing, and ritual continuity. In contemporary scientific literature, it appears in studies on pain pathways, cytokine expression, ion channel modulation, and antimicrobial resistance. Industries—from pharmaceuticals to religious commodities—integrate camphor in varied forms, including tablets, balms, essential oils, inhalants, ointments, and vapour-based applications.

The renewed interest in natural therapeutics, alongside a global shift toward wellness and plant-based products, has re-positioned camphor as a compound of both cultural and biomedical value. This revival is also influenced by modern anxieties—stress, respiratory challenges, lifestyle-related inflammation, and post-pandemic preferences for environmentally grounded health practices. Against this backdrop, understanding camphor in its multiplicity—chemical, ecological, cultural, and commercial—becomes necessary.

This review aims to create an integrated portrait of *C. camphora*, situating traditional knowledge within contemporary scientific validation and market realities, while drawing attention to sustainability challenges that may determine the plant's long-term availability.

2. Botanical Background and Phytochemistry

Cinnamomum camphora (family Lauraceae) is native to China, Japan, Korea, and Taiwan, though it has naturalised across South Asia and parts of Australia. The species is chemically polymorphic, presenting distinct chemotypes: camphor-type, borneol-type, linalool-type, cineole-type, and isoborneol-type (Zhang et al., 2022). These chemotypes differ significantly in their dominant monoterpenes and sesquiterpenes, influencing therapeutic applications and commercial value.

Modern phytochemical analyses show camphor, borneol, 1,8-cineole, α-pinene, β-pinene, and p-cymene as key constituents (Xiao et al., 2021). Camphor often dominates at 20–50% of the essential oil composition, though levels vary by plant part, age, geography, and extraction method. Leaves are increasingly preferred for sustainable extraction since harvesting bark and wood threatens mature populations.

Advanced chromatographic methods (GC-MS and LC-MS) have improved identification of minor constituents that contribute synergistic pharmacological effects. Studies suggest that camphor rarely acts alone; the ensemble of terpenoids amplifies its biological activity, making whole essential oil preparations often more potent than isolated components (He et al., 2025).

3. Cultural Significance and Traditional Uses

Long before analytical chemistry emerged, camphor held a central place in traditional medicine and ritual life. In Ayurveda, *karpura* appears in formulations prescribed for digestive disorders, skin ailments, respiratory congestion, and wound healing (Sharma & Patil, 2023). Its topical use for pain, swelling, and itching aligns with modern findings on TRPV1 and TRPA1 modulation. Traditional Unani medicine described camphor as *mukhaddir* (sedative) and *mufarrih* (refreshing to the heart), reflecting an experiential understanding of its sensory and neurological effects.

Culturally, camphor has been integral to religious ceremonies across India, Sri Lanka, Nepal, Thailand, and parts of Southeast Asia. Burning natural camphor is believed to purify spaces and symbolically dissolve negativity. Even today, Indian temples show a strong preference for natural camphor over synthetic versions, partly because synthetic camphor—derived from turpentine—does not carry ritual legitimacy.

In Chinese and Japanese traditions, camphor wood was used for ancestral altars, carving, and embalming, due to both its aroma and preservative properties. Kampo medicine in Japan continues to use camphor-containing formulations.

Interestingly, the “ritual economy” around camphor has expanded in contemporary urban spaces. Younger consumers, particularly in India and East Asia, now integrate camphor into meditation, stress relief routines, sleep rituals, and aromatherapy. What was once strictly religious has broadened into a wellness commodity, creating new markets for premium, natural camphor products.

4. Biomedical Applications: Contemporary Scientific Evidence

4.1 Analgesic and Anti-inflammatory Activity

Current biomedical literature strongly supports traditional claims about camphor’s pain-relieving potential. Research highlights its biphasic interaction with nociceptive pathways: an initial activation of TRPV1 ion channels followed by desensitisation, which reduces pain sensation (Odia & Edibamode, 2024). Camphor also inhibits TRPA1 channels, important in neuropathic and inflammatory pain.

Anti-inflammatory effects are linked to reduced expression of TNF-α, IL-1β, IL-6, and NF-κB signalling (Xiao et al., 2021). Animal studies demonstrate reductions in carrageenan-induced edema comparable to non-steroidal anti-inflammatory drugs.

4.2 Antimicrobial and Antifungal Effects

Camphor essential oil possesses broad-spectrum antimicrobial activity. In vitro studies report inhibitory effects against *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and fungi such as *Trichophyton rubrum* and *Colletotrichum* spp. (He et al., 2025). Mechanistically, camphor disrupts microbial membranes, increases permeability, induces protein leakage, and affects enzymatic pathways.

Agricultural research identifies its antifungal potential against post-harvest pathogens, offering chemical-residue-free alternatives for crop protection (Li et al., 2023).

4.3 Respiratory and Neurological Effects

Inhalation of camphor vapour has long been associated with relief from congestion. Modern trials demonstrate measurable improvements in airflow and subjective respiratory comfort. Camphor modulates cold-sensitive receptors in nasal mucosa, contributing to improved breathing (Gong et al., 2024).

Neurologically, studies reveal mild anxiolytic effects of *C. camphora* essential oil inhalation, influencing autonomic regulation and cognitive states.

4.4 Dermatological Uses

Topical camphor appears in anti-itch formulations, balms, rubs, and acne treatments. Its ability to penetrate the skin enhances delivery of co-administered compounds. Recent reviews emphasize its promise for treating superficial infections due to its antimicrobial, anti-inflammatory, and cooling properties (Duda-Madej et al., 2024).

Collectively, these studies underscore that modern biomedicine often validates what traditional practitioners observed empirically: camphor can modulate pain, inflammation, infection, and respiratory discomfort through multiple, well-characterised pathways.

5. Global Market Dynamics and Economic Landscape

Global camphor markets have expanded steadily over the past decade. Estimates from 2024–2025 place market value between USD 500 and 600 million, with projections reaching USD 800–900 million by the mid-2030s (Future Market Insights, 2025). Growth drivers include:

- rising demand for natural personal care and wellness products
- increased pharmaceutical applications
- expansion of ritual and cultural consumption
- preference for aromatherapy and natural inhalants
- industrial uses (plasticizers, explosives, and resins)

5.1 Natural vs Synthetic Camphor

Synthetic camphor, produced from α-pinene sourced from turpentine, dominates industrial volumes due to lower cost and high yield. However, its toxicity limits edible or internal uses.

Natural camphor, typically extracted from *C. camphora* leaves or wood, commands premium pricing—often 2–5 times higher—because of ritual legitimacy and safety perception. India, Japan, and Taiwan remain strong consumers of natural camphor, particularly in cultural sectors.

5.2 Regional Markets

Asia-Pacific accounts for the largest share, driven by traditional medicine systems and cultural use. China remains the world's largest producer, while India is one of the largest consumers. North American and European markets show increasing demand for natural essential oils and aromatherapy, widening the commercial scope.

5.3 Product Formats

Tablets ("camphor cubes"), balms, essential oils, ointments, and inhalant-based products dominate retail categories. The tablet segment shows especially strong growth due to its use in both rituals and aromatherapy.

6. Sustainability, Conservation, and Environmental Pressures

Despite commercial growth, the ecological implications for *C. camphora* deserve close attention. Some regions report pressure on wild populations due to:

- overharvesting of mature trees
- reliance on wood-based extraction
- narrow genetic bases in cultivated stands

Studies warn of long-term risks if harvesting practices do not shift toward sustainable approaches (Malabadi & Kolkar, 2022).

6.1 Extraction Challenges

Traditional steam distillation yields from wood can be as low as 0.5–1.2%, making the process resource-intensive. This has driven interest in more sustainable methods.

6.2 Greener Extraction Technologies

Recent innovations point toward less energy-intensive and more resource-efficient alternatives:

- **Solvent-free microwave-assisted extraction (SFME)** achieves much higher yields with lower electricity consumption (Li et al., 2023).
- **Supercritical CO_2 extraction** offers solvent-free processing with improved selectivity (Zhang et al., 2022).
- **Deep eutectic solvent (DES) extraction** improves simultaneous recovery of essential oils and lignin (Yang et al., 2024).

Such methods substantially reduce water use, energy demand, and carbon footprint while improving yields.

6.3 Cultivation and Conservation

Leaf-based extraction, as opposed to destructive harvesting of wood, offers a sustainable pathway. Genetic mapping and chemotype conservation efforts can help maintain biodiversity, enabling selection of high-yielding strains while avoiding overexploitation.

7. Regulatory Frameworks and Public Safety

Camphor's therapeutic potential coexists with toxicity risks when misused. Thus, regulatory agencies maintain strict controls.

- The **U.S. FDA** allows camphor at 0.1–11% in topical counterirritants but prohibits high-concentration camphorated oils due to poisoning incidents.
- **NIOSH** recommends workplace exposure limits of 2 mg/m^3 (8-hour TWA).
- **OSHA** lists similar permissible exposure limits.

- European REACH regulations classify camphor as a flammable, irritant substance requiring controlled handling.

Accidental ingestion of synthetic camphor remains a concern, particularly for children (Royal Children's Hospital, 2018). Clear labelling, public education, and differentiation between natural and synthetic camphor are therefore essential.

8. The Convergence of Tradition, Science, and Commerce

The contemporary narrative of camphor is shaped by at least four intersecting forces:

1. Revival of Natural Wellness

Urban consumers—from Mumbai to Tokyo to Los Angeles—show growing interest in plant-based remedies, aromatics, and ritual practices as tools of mental grounding. Camphor aligns well with this shift, offering sensory impact, cultural familiarity, and documented bioactivity.

2. Scientific Validation of Traditional Claims

Modern pharmacological research has elucidated mechanisms that traditional knowledge systems articulated experientially. This convergence strengthens consumer trust and supports inclusion in regulated therapeutic products.

3. Cultural Continuity and Diaspora Identity

In diaspora communities, burning camphor or using camphor-infused products evokes cultural belonging. These niche markets support premium-priced natural camphor.

4. Sustainability Pressures

Growing demand risks ecological strain. Future industry success depends on sustainable extraction technologies, leaf-only harvesting, chemotype-specific cultivation, and responsible regulation.

Together, these factors suggest that camphor's future will be determined not only by chemistry and commerce, but by how well industry, communities, and regulators can balance demand with ecological responsibility.

9. Conclusion

Camphor stands at a unique intersection of culture, pharmacology, commerce, and ecology. As global interest in traditional remedies and natural wellness accelerates, *C. camphora* is experiencing renewed visibility. Scientific research supports many traditional applications, giving camphor a credible place in modern biomedical and personal care sectors. Meanwhile, cultural revivals in India and East Asia strengthen demand for natural, sustainably sourced products.

Yet this resurgence brings challenges: pressure on natural populations, inconsistencies in market quality, toxic synthetic substitutes in inappropriate contexts, and regulatory complexities across borders. The future of camphor depends on the adoption of environmentally responsible extraction, certification systems for authenticity, and transdisciplinary research that bridges cultural knowledge with chemical and ecological insights.

A sustainable and ethically grounded camphor industry—rooted in both scientific validation and cultural respect—has the potential not only to safeguard traditional practices, but also to contribute meaningfully to global wellness, pharmaceutical innovation, and biodiversity conservation.

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