chemistry proceedings

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Proceeding Paper

Patent Landscape and Applications of Organic Menthol Crystals: An In-Depth Analysis of Emerging Trends and Industrial Applications †

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† Presented at the 4th International Online Conference on Crystals, 18–20 September 2024; Available online: https://sciforum.net/event/iocc2024.

Abstract: Menthol, a cyclic monoterpene alcohol commonly derived from mint essential oils, is widely utilized across the pharmaceutical, cosmetic, and personal care industries due to its cooling, analgesic, and aromatic properties. This study presents a comprehensive patent landscape analysis of organic menthol crystals and their derivatives, with a focus on identifying current trends and emerging applications. Patent data were retrieved from The Lens and Google Patents, and 23,515 relevant patents were analyzed using international patent classification codes. The results revealed significant applications in pharmaceuticals, personal care, and drug delivery systems, with notable innovations in controlled-release formulations, cancer treatments, and pain relief products. Emerging trends include the combination of menthol with other natural compounds, advances in microencapsulation for controlled drug delivery, and its use as flavor enhancement in the tobacco industry. The United States leads in menthol-related patents, followed by China and the European Union. This analysis provides valuable insights into the future of menthol applications, suggesting that its role in therapeutic and cosmetic industries will continue to grow, driven by technological advancements and regulatory factors.

Keywords: menthol crystals; patent analysis; pharmaceutical applications; personal care products; natural compounds; plant-derived ingredients

Citation: El Boukhari, R.; Fatimi, A. Patent Landscape and Applications of Organic Menthol Crystals: An In-Depth Analysis of Emerging Trends and Industrial Applications. *Chem. Proc.* **2024**, *15*, 2. https://doi.org/10.3390/chemproc2024015002

Academic Editor: Rodolfo Reda

Published: 28 November 2024

1. Introduction

Menthol, a natural compound widely recognized for its cooling properties, and its derivatives find extensive use in industries ranging from pharmaceuticals and cosmetics to food and flavoring, owing to its cooling effect and characteristic minty aroma [1]. It is a naturally occurring cyclic monoterpene alcohol, commonly derived from mint essential oils (Figure 1). Menthol crystals, either synthesized from natural or synthetic precursors, are of great commercial interest due to their versatility and global demand (Figure 2). Menthol derivatives are synthesized through targeted chemical reactions, such as esterification, to modify their molecular structure and enhance characteristics like melting point and volatility, optimizing their properties for specific applications [2–4]. Degradation mechanisms also play a critical role in determining the practical applications and environmental impact of menthol and its derivatives. Atmospheric degradation, primarily initiated by hydroxyl radicals, leads to various breakdown products and provides insights into the environmental behavior of these compounds [5]. Additionally, menthol derivatives exhibit reactivity with other chemicals, such as phosphorus oxychloride, resulting in the formation of complex structures that may have further potential applications [6].

Beyond its conventional applications, menthol exhibits a promising safety profile and potential therapeutic properties, such as anti-inflammatory and anticancer activities [1]. In this regard, research has extensively examined menthol's safety profile and its potential anticancer properties [7]. Studies have revealed that menthol inhibits the growth of various cancer cells through mechanisms such as apoptosis induction, cell cycle arrest, disruption of tubulin polymerization, and inhibition of tumor angiogenesis. Its efficacy has been particularly noted in cancers like prostate and colon cancer, suggesting its promise as a candidate for novel anticancer therapies [7]. Moreover, investigations into menthol's effects on cancer treatment, respiratory health, and digestive issues underline its dual potential for benefits and risks to human health [7–10].

Menthol is commonly used in treatments for nasal congestion and upper respiratory tract infections. It acts as a cooling agent that stimulates sensory receptors, providing symptomatic relief from dyspnea and enhancing the perception of airflow in the nasal passages. This effect is particularly beneficial in managing symptoms of allergic rhinitis [11,12]. While menthol is generally considered safe for use, it can provoke allergic reactions and exacerbate conditions such as asthma and allergic rhinitis in sensitive individuals. Studies indicate that menthol can stimulate histamine release, which may lead to adverse respiratory effects [11,13].

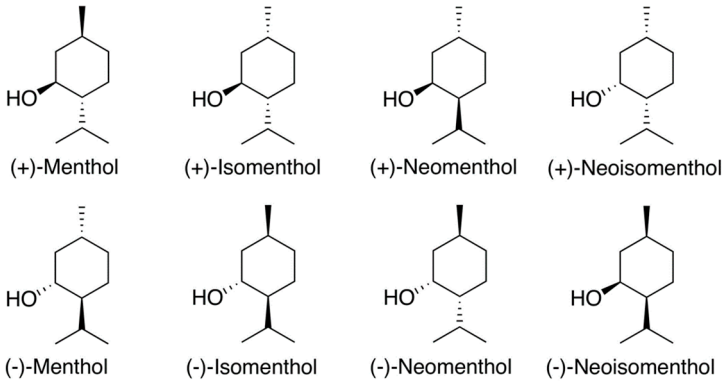

Figure 1. Chemical structures of different isomers of menthol. Menthol has three stereogenic centers, resulting in four pairs of optical isomers. (Reprinted with permission from Dylong et al., 2022 [14]. Copyright© 2022 John Wiley & Sons Ltd.).

Figure 2. Example of (−)-menthol crystals at room temperature. (Reprinted without permission from Lembens et al., 2022 [15]. Licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license).

Despite its versatile functionality and growing industrial demand, a systematic understanding of the innovation surrounding menthol crystals and its derivatives remains limited. Given the increasing emphasis on sustainable and plant-based solutions, plant-derived menthol has garnered particular attention for its potential to replace synthetic alternatives. However, the lack of comprehensive analysis on technological advancements, patenting activity, and industrial applications poses a barrier to recognizing its full potential.

This study addresses this gap by conducting an in-depth patent analysis, aiming to map the current landscape, uncover emerging trends, and identify key innovations in the field of organic menthol crystals and their derivatives. By exploring patent documents, this work seeks to provide valuable insights for researchers, industry stakeholders, and policymakers, highlighting the state of the art and guiding future developments in the field.

2. Methods

The search focused on patents related to the applications of menthol crystals in various sectors, including pharmaceuticals, cosmetics, personal care, and other industries, from 2010 to 2023. Patent documents were retrieved using specialized databases (The Lens and Google Patents databases [16,17]), with keywords such as "menthol", "menthol crystals", and "applications" combined with Boolean operators to refine the search [18]. Relevant patents were classified based on their industrial application and technical focus using International Patent Classification (IPC) codes [19]. As examples, commonly identified IPC codes could include the following:

- A61K: preparations for medical, dental, or toilet purposes (e.g., pharmaceutical formulations involving menthol).
- A61Q: specific cosmetic or personal care applications (e.g., skin-conditioning products).
- C11B: essential oils and perfumes, highlighting menthol's role in flavor and fragrance applications.
- A01N: pest control and agricultural uses.

Additionally, the analysis considered the geographical distribution of patents (i.e., patent jurisdiction), filing trends over time—from 2010 to 2023—and the types of organizations (e.g., institutions, companies, or independent inventors) responsible for patenting activity. This systematic classification enabled the identification of key technological advancements, emerging trends, and gaps in innovation.

3. Results

3.1. Patent Classification: Technical Areas of Menthol Application

The patent analysis identified 23,515 patents related to organic menthol crystals, with key applications identified across various industries. The patents were categorized into specific technical areas based on the International Patent Classification (IPC) codes, revealing the diverse utility of menthol (Figure 3).

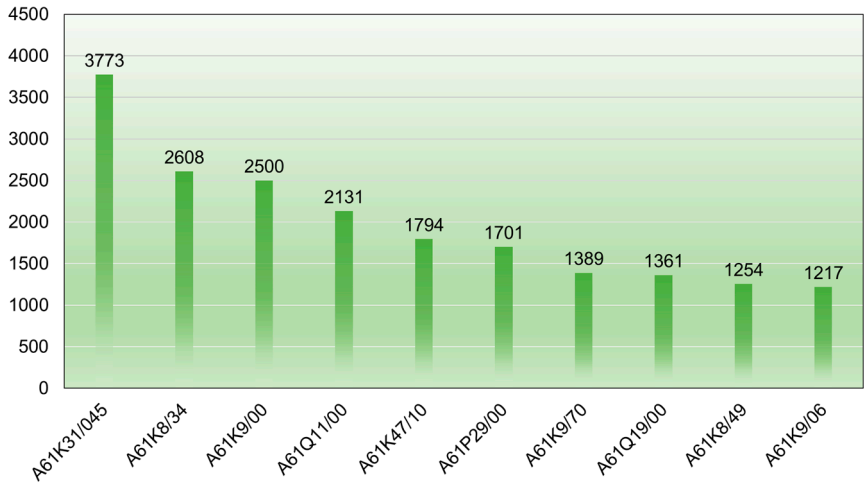

Figure 3. Patent document count as a function of top 10 IPC codes related to organic menthol crystals.

Based on the literature and the IPC Portal administered by the World Intellectual Property Organization (WIPO) [20], the key findings for each classification code in this study could be synthesized as follows:

1. A61K31/045: This class covers patents involving organic active ingredients, with menthol prominently featured, particularly in pharmaceutical preparations [21]. Menthol is extensively studied for its anticancer properties, particularly its ability to induce apoptosis, arrest the cell cycle, and disrupt tubulin polymerization in cancer cells. This suggests a growing interest in menthol's potential therapeutic applications in oncology [7].
2. A61K8/34: Menthol is widely used in cosmetic preparations, such as lotions and balms, due to its cooling and soothing effects [1]. This classification focuses on personal care products where menthol is a critical ingredient for sensory enhancement. The patent activity in this area reflects menthol's importance in skin care formulations that offer both functional and sensory benefits [22].
3. A61K9/00: Menthol is also utilized in medicinal preparations, particularly in controlled-release formulations and topical products. This classification focuses on medicinal preparations characterized by a special physical form [23]. The ability of menthol to enhance the permeation of active ingredients makes it valuable in formulations where targeted and sustained release is essential, such as pain relief patches and gels [9].
4. A61Q11/00: This classification focuses on oral hygiene compositions where menthol is used as a flavoring agent and for its refreshing properties [24]. Toothpaste, mouthwash, and similar products benefit from menthol's ability to provide a long-lasting fresh sensation. Its inclusion in oral care products highlights its widespread acceptance in formulations meant for daily use [1].
5. A61K47/10: This classification focuses on organic compounds such as alcohols, phenols, and their salts [25]. As an organic compound, menthol plays a role in chemical preparations that involve specific additives. Its ability to enhance the formulation's performance, particularly in topical applications, has made it a popular choice for pharmaceutical and cosmetic products alike. Menthol is particularly noted for its role in pain and inflammation relief in this category [1].
6. A61P29/00: This class pertains to therapeutic applications of menthol, particularly in the treatment of pain and inflammation through topical application [26]. Menthol's cooling and analgesic properties are widely recognized, making it a common component in formulations designed for pain management, muscle relief, and anti-inflammatory effects [27].
7. A61K9/70: This classification focuses on medicinal preparations characterized by a special physical form [28]. Menthol is employed in controlled drug delivery systems for its permeation-enhancing properties. This classification underscores the growing focus on menthol as a facilitator in drug delivery technologies, particularly in transdermal patches and other advanced delivery systems that require the active ingredient to penetrate the skin barrier efficiently [29].
8. A61Q19/00: Menthol's use in skin care preparations is further emphasized in this category, which includes products like creams and lotions [22]. Its cooling effect makes it a key component in formulations designed to soothe irritation, reduce redness, or provide relief from heat-related discomfort [8].
9. A61K8/49: This class involves solid forms of medicinal preparations, such as tablets and powders, where menthol is used for its flavoring properties or as an active ingredient [30]. In these solid formulations, menthol serves both functional and sensory roles, enhancing the palatability and user experience [14].
10. A61K9/06: This classification focuses on medicinal preparations characterized by special physical forms, such as ointments [31]. This category highlights menthol's role in topical applications for pain relief. The patents in this area demonstrate the extensive use of menthol in products like pain-relief creams, gels, and balms that are applied directly to the skin for localized relief [9].

3.2. Global Patent Distribution

3.2.1. Patent Applicants: Leading Innovators in Menthol Applications

The global demand for menthol and its derivatives spans various industries, from pharmaceuticals and personal care to flavors and fragrances. Major companies are driving innovation by leveraging menthol's cooling, soothing, and sensory-enhancing properties in a range of products. Table 1 highlights key patent applicants who lead the way in menthol-related technologies, showcasing how different industries, including personal care, chemicals, and tobacco, are utilizing this versatile compound. US-based companies, in particular, dominate the landscape, but international firms also play a crucial role in advancing menthol's applications across diverse sectors.

Table 1. Top 10 patent applicants as leading innovators in menthol applications.

Patent Applicant [1]	Patent Count
Procter & Gamble (Cincinnati, OH, United States)	583
Colgate Palmolive Co. (New York, NY, United States)	237
Takasago Perfumery Co. LTD (Tokyo, Japan)	216
BASF SE (Ludwigshafen, Germany)	214
Symrise AG (Holzminden, Germany)	205
Kao Corp (Tokyo, Japan)	192
Lion Corp (Tokyo, Japan)	188
Japan Tobacco INC (Tokyo, Japan)	174
Philip Morris USA INC (Richmond, VA, United States)	145
Warner Lambert Co. (Morris Plains, NJ, United States)	144

[1] Individual, company, or organization that files a patent application to seek legal protection for an invention [28].

Procter & Gamble, holding 583 patents, leads the innovation in menthol-based products, particularly in personal care and consumer goods, where it leverages menthol's cooling and refreshing properties. In the same area, companies like Colgate Palmolive Co., with 237 patents, focus primarily on dental and hygiene products, utilizing menthol for its soothing and refreshing effects in oral care items like toothpaste and mouthwash. On the other hand, Takasago Perfumery Co. LTD, which holds 216 patents, operates in the flavors and fragrances sector, where menthol is likely used to create distinctive aromatic profiles, enhancing scent formulations with its cooling characteristics. In a similar space, Symrise AG, with 205 patents, explores menthol's sensory applications, particularly in perfumes and personal care products, further cementing its importance in the fragrance industry. BASF SE, with 214 patents, focuses more on chemical compositions and industrial applications. The company likely uses menthol's functional properties to improve chemical formulations, setting it apart from the more consumer-focused applications seen in personal care products. Similarly, Kao Corp, which holds 192 patents, targets personal care items such as cosmetics and shampoos, where menthol's cooling effects enhance product performance and consumer comfort. In the tobacco sector, companies like Japan Tobacco INC (174 patents) and Philip Morris USA INC (145 patents) lead the way, capitalizing on menthol's flavor-enhancing qualities. Menthol plays a crucial role in improving the sensory experience of tobacco products, making it a key additive in this industry. US companies, such as Procter & Gamble and Colgate Palmolive Co., lead the way with the highest number of menthol-related patents, dominating the personal care and hygiene sectors. Meanwhile, Warner Lambert Co., with 144 patents, focuses on the pharmaceutical side, utilizing menthol's cooling and soothing effects in over-the-counter medications like throat lozenges and topical analgesics. This diversity in applications highlights menthol's broad utility across industries.

3.2.2. Jurisdiction: Regional Focus on Menthol Innovation

Menthol-related innovations are distributed across various global regions, with significant patent activity reflecting the diverse industries utilizing this compound (Table 2).

Table 2. Top 10 jurisdictions focusing on menthol innovation.

Jurisdiction [2]	Patent Count
China	7451
United States	6736
World [3]	3404
Europe [4]	2113
Japan	1382
United Kingdom	513
Republic of Korea	453
Canada	299
Russia	162
Australia	147

[2] Specific geographic area or legal authority where laws and regulations, such as those governing patents, are enforced [30]. [3] Patents filed through the international PCT system administered by WIPO [32]. [4] Patent protection is primarily obtained through the European Patent Office (EPO) [33].

China leads the way with 7451 patents, largely driven by the country's extensive manufacturing capabilities and advancements in consumer products. In the United States, 6736 patents emphasize menthol's critical role in personal care, pharmaceuticals, and tobacco, demonstrating the compound's importance across key sectors. Globally, 3404 patents highlight the international relevance of menthol innovations, with a significant number of patents filed through the international patent system PCT (i.e., the Patent Cooperation Treaty system administered by the WIPO, streamlining protection across multiple jurisdictions) [34]. European patents, totaling 2113, reflect the compound's widespread application in industries like pharmaceuticals and personal care across the continent. Japan, with 1382 patents, shows a strong focus on menthol in the flavor, fragrance, and personal care sectors, highlighting its role in enhancing sensory experiences. In the United Kingdom, 513 patents point to moderate innovation, particularly in pharmaceuticals and consumer goods. Emerging trends are also visible in the Republic of Korea, which has 453 patents, particularly in the cosmetics and pharmaceutical industries. Smaller jurisdictions, such as Canada (299 patents), Russia (162 patents), and Australia (147 patents), show growing interest in menthol-related applications, with patents focused on pharmaceutical and personal care products. This global distribution of patents underscores the widespread utility and growing demand for menthol innovations.

4. Discussion

4.1. Emerging Trends in Menthol Innovation Based on Synthesis of Key IPC Codes

Emerging trends in menthol innovation were identified, showcasing advancements in its synthesis methods, applications in medicinal formulations, and incorporation into consumer products [1]. The analysis of the classifications reveals several emerging trends that could be discussed as follows [35]:

- Therapeutic applications;
- Cosmetic and personal care;
- Drug delivery systems;
- Combination with natural compounds.

Menthol's therapeutic applications are increasingly recognized for their potential in addressing complex medical needs. Patents categorized under A61K31/045 and A61P29/00 highlight menthol's anticancer and anti-inflammatory properties, particularly its ability to induce apoptosis and enhance drug permeation. These attributes underscore its promise in oncology and pain management, where innovative approaches are critical for improving patient outcomes.

In the realm of cosmetics and personal care, menthol continues to be a cornerstone ingredient. Its cooling and sensory-enhancing effects make it indispensable in personal care formulations, as evidenced by patents classified under A61K8/34 and A61Q19/00. Further-

more, its applications in oral hygiene products, such as those in A61Q11/00, demonstrate menthol's sustained relevance in promoting everyday health and wellness.

The development of advanced drug delivery systems represents a significant area of innovation. Patents under A61K9/00, A61K9/70, and A61K9/06 reveal menthol's utility in controlled-release formulations and topical drug delivery systems. These advancements reflect the pharmaceutical industry's ongoing shift towards more sophisticated and targeted therapies, where menthol plays a crucial role in enhancing the efficacy and patient acceptability of treatments.

Lastly, a notable trend is the combination of menthol with other natural compounds in both pharmaceutical and cosmetic formulations. This synergy, as observed in various patents, has the potential to amplify the therapeutic and sensory benefits of menthol-based products. Such innovations are paving the way for multifunctional solutions that cater to growing consumer demand for natural and effective products.

4.2. Emerging Trends in Menthol Innovation Based on Regional Analysis and Industries

The regional analysis identified the United States as the leading jurisdiction for menthol-related patents, followed by China and the European Union. The geographical distribution reflects the regulatory frameworks and market demands in these regions, which influence the focus of innovation. Companies leading the innovation include major pharmaceutical and cosmetic firms, demonstrating a significant investment in research and development for menthol-based products.

Emerging trends in menthol innovation reveal its broad versatility across various industries. In the pharmaceutical sector, menthol is increasingly recognized for its therapeutic properties, particularly in pain relief and topical treatments. Its effectiveness in providing relief through cooling sensations makes it a valuable ingredient in pain management products. In personal care, menthol is celebrated for its cooling, refreshing, and soothing effects. It is commonly used in cosmetic formulations to enhance the sensory experience of products such as facial cleansers, shampoos, and body lotions, contributing to a more invigorating and pleasant user experience. In the tobacco industry, menthol continues to play a significant role in flavor enhancement. Its use remains prevalent, especially in regions with more relaxed regulatory frameworks. The compound's ability to provide a distinct cooling sensation adds to the overall smoking experience, maintaining its popularity in the market.

5. Conclusions

This patent landscape analysis offers a comprehensive view of global innovation surrounding organic menthol crystals, particularly in the pharmaceutical and personal care industries. Menthol continues to be a critical component across various sectors due to its versatile properties. The identification of emerging trends such as menthol's role in microencapsulation and its therapeutic potential suggests avenues for future research and development. Furthermore, understanding the geographical distribution of patent activity highlights the importance of regulatory landscapes in shaping menthol innovation.

While the current analysis highlights key innovations and technological advancements, the limited scope of this proceedings paper constrains the inclusion of detailed statistical analyses, such as year-by-year distribution and classification of common words used in patents. Future studies should aim to address these aspects to provide a more granular understanding of trends in menthol innovation. A full-length article could explore these dimensions, offering valuable insights into temporal trends and semantic patterns within patent data. Such analyses would further enhance the understanding of the evolving applications of menthol and its derivatives, contributing to the broader discourse on innovation in natural product-based technologies.

Supplementary Materials: The following supporting information can be downloaded at: https://sciforum.net/paper/view/18206, Poster: El Boukhari, R.; Fatimi, A. Organic Menthol Crystals: An Overview of Innovation Based on Relevant Patents. The 4th International Online Conference on Crystals (IOCC 2024), Basel-Switzerland, 18–20 September 2024.

Author Contributions: Conceptualization, R.E.B. and A.F.; methodology, R.E.B. and A.F.; validation, A.F.; formal analysis, R.E.B. and A.F.; investigation, R.E.B. and A.F.; data curation, R.E.B. and A.F.; writing—original draft preparation, R.E.B.; writing—review and editing, A.F.; visualization, A.F.; supervision, A.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available within this manuscript.

Acknowledgments: The authors acknowledge the Cambia Institute and Google for the databases and search service used in this study. In addition, the authors would like to express their gratitude to the academic editor and to the chair of the conference for the opportunity to present this work at the 4th International Online Conference on Crystals, session: Organic Crystalline Materials.

Conflicts of Interest: The authors declare no conflicts of interest.

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