

Menthol-Eucalyptol Sensory Modulation in a Sugar-Free Herbal Hard Candy: Volatile Retention, Cough-Reflex Evidence, and Respiratory Comfort

Yassine Igoundaz¹, Kaito Yoshida², Freddie Dawson³

^{1,2,3}National Laboratory of Medicine LLC, USA



DOI : <https://doi.org/10.61796/jhsm.v1i4.35>



Sections Info

Article history:

Submitted: July 15, 2026

Final Revised: August 10, 2026

Accepted: August 30, 2026

Published: September 25, 2026

Keywords:

Menthol

1,8-Cineole

TRPM8

Cough reflex

Eucalyptus oil microcapsule

Respiratory comfort

ABSTRACT

Objective: Menthol and eucalyptus-derived 1,8-cineole are widely used in cooling-aromatic respiratory products, but their physiological relevance depends on both sensory delivery and preservation of volatile constituents during manufacture. We evaluated a sugar-free herbal hard candy containing eucalyptus oil microcapsule powder and menthol, with emphasis on 1,8-cineole retention, flavor uniformity and the human evidence linking menthol/cineole exposure to cough sensitivity and respiratory comfort. **Method:** In the optimized process, eucalyptus oil was microencapsulated with maltodextrin and gum arabic, spray-dried, and added together with menthol only after the candy mass had cooled to 92°C. **Results:** Relative 1,8-cineole retention reached 82.1%, compared with 64.5% when an equivalent amount of liquid eucalyptus oil was directly incorporated and 68.2% when the microcapsule fraction was added at 128°C. The optimized candy also produced highly uniform eucalyptus flavor and high overall sensory acceptance. Human challenge studies show that menthol can increase capsaicin or citric-acid cough thresholds in healthy subjects and in patients with chronic cough, with cough-count responses varying across studies. Separately, oral cineole at pharmacological doses has demonstrated symptom-related effects in randomized studies of acute bronchitis, asthma and chronic obstructive pulmonary disease. **Novelty:** The NVTIA formulation therefore combines a manufacturing strategy that preserves a volatile eucalyptus marker with a menthol-cineole sensory architecture that has independently measurable human physiological correlates. The current findings provide a formulation-level basis for future studies using cough-urge, cough-challenge, perceived airway cooling and respiratory-comfort endpoints under product-specific exposure conditions.

INTRODUCTION

Cough is both a protective airway reflex and a sensory experience. The urge to cough can be modulated by chemical and thermal signals arriving through trigeminal and vagal sensory pathways, and menthol is one of the best-characterized cooling agents in this context. The identification of TRPM8 as a cold- and menthol-responsive ion channel provided a molecular basis for menthol-evoked cooling [1], [2]. Human cough-challenge experiments subsequently demonstrated that menthol can alter cough sensitivity under controlled conditions [3]–[5].

Eucalyptus oil contributes a complementary aromatic dimension. Its principal monoterpene, 1,8-cineole (eucalyptol), has been examined at pharmacological oral doses in randomized studies of acute bronchitis, asthma and chronic obstructive pulmonary disease [7]–[10]. These trials concern exposure levels and routes that differ from those of a hard candy, but they establish clinically relevant respiratory physiology around the

same molecular constituent. In a confectionery delivery system, the immediate scientific question is whether the formulation can preserve and distribute volatile constituents consistently enough to support reproducible sensory and cough-related investigation, with pharmacological cineole studies providing a complementary respiratory-physiology context.

The studied hard candy addresses this challenge by microencapsulating eucalyptus oil with maltodextrin and gum arabic and by adding the microcapsule powder and menthol after staged cooling. The process is intended to reduce thermal exposure of the volatile fraction and to prevent local oil aggregation within the polyol matrix. An experienced sensory panel and gas-chromatographic marker-retention analysis provide direct measures of the success of that strategy.

This study had two linked objectives. First, we quantified the effect of microencapsulation and addition temperature on 1,8-cineole retention and eucalyptus-flavor uniformity. Second, we mapped these formulation-specific observations to primary human studies of menthol-mediated cough sensitivity and cineole-related respiratory outcomes.

RESEARCH METHOD

Volatile-cooling formulation and process

The volatile-cooling fraction of the optimized candy consisted of 0.220 part eucalyptus oil microcapsule powder and 0.035 part menthol per 100 parts formulation. For a 2.50-g candy, this corresponds to 5.50 mg microcapsule powder and 0.875 mg menthol. The microcapsule powder was produced from eucalyptus oil, maltodextrin and gum arabic at a 1:8:2 weight ratio in the optimized process. The wall materials were dissolved at 50°C, followed by shear emulsification at 8000 r/min for 10 min, two homogenization passes at 25 MPa, and spray drying at 165°C inlet and 82°C outlet temperatures.

The sugar-alcohol candy matrix was vacuum-cooked at 148°C and -0.085 MPa to 97% solids. Botanical extracts and acid-base regulators were introduced after cooling to 108°C. The mass was subsequently cooled to 92°C before the eucalyptus oil microcapsule powder and menthol were mixed in at 30 r/min for 2 min. The candy was cast, cooled at 18°C for 12 min and hermetically packaged.

Relative 1,8-cineole retention was determined by gas chromatography using an external-standard approach. Three formulation conditions were compared: the optimized microcapsule-plus-low-temperature process; direct addition of an equivalent amount of liquid eucalyptus oil at 92°C; and addition of the microcapsule powder plus menthol at 128°C. The latter two comparators isolated the contribution of microencapsulation and post-cooking temperature, respectively. Sensory evaluation used a blinded three-grade scheme in 10 individuals with food-sensory-evaluation experience.

Primary human evidence was identified through a structured PubMed/MEDLINE

search updated to 18 August 2026. Search concepts included menthol, TRPM8, cough reflex, cough threshold, capsaicin, citric acid, eucalyptus, eucalyptol, 1,8-cineole, bronchitis, asthma, COPD and randomized trial. Because the finished candy also contains licorice and Platycodon, a supplementary search covered licorice gargle, licorice lozenge, Kikyo-to and sore throat. Mechanistic TRPM8 studies were retained to explain menthol-evoked cooling. Human studies were grouped by endpoint and exposure route, so topical throat studies were not pooled with menthol challenge or pharmacological cineole trials.

RESULTS AND DISCUSSION

Results

Volatile retention and flavor distribution

The optimized microencapsulation-plus-low-temperature process produced a relative 1,8-cineole retention of 82.1%. Direct incorporation of liquid eucalyptus oil reduced retention to 64.5%, while high-temperature addition of the microcapsule powder and menthol yielded 68.2%. Because the formulation composition was otherwise preserved in the high-temperature comparator, this result identifies post-cooking thermal exposure as a major determinant of volatile-marker loss. The liquid-oil comparator additionally showed visible local oil aggregation in the candy body, whereas the optimized microcapsule powder remained uniformly dispersed.

Sensory findings tracked the analytical results. Eight of 10 panelists rated eucalyptus-flavor uniformity in the optimized candy as excellent and the remaining two as good. By contrast, direct liquid-oil incorporation generated only one excellent rating, five good ratings and four poor ratings for uniformity. The data therefore show that marker retention and spatial flavor consistency improved in parallel under the optimized process.

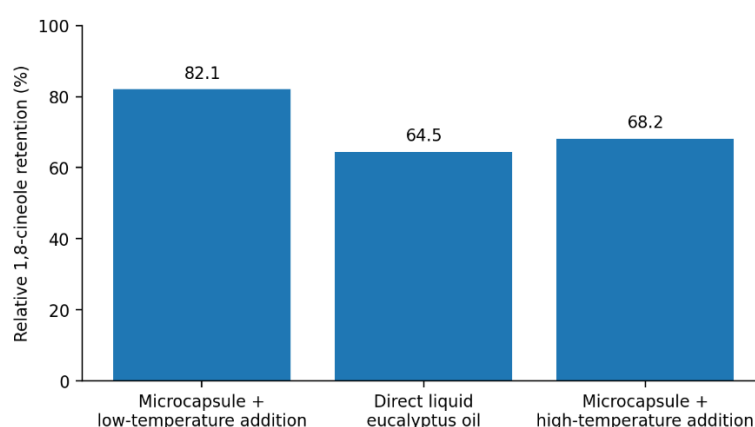


Figure 1. Relative 1,8-cineole retention under the optimized process and two process comparators. Values are direct experimental observations.

Human evidence for menthol-mediated cough modulation

Menthol-related human studies demonstrate measurable modulation of cough physiology. In 20 healthy adults, Morice and colleagues found that inhaled menthol in

eucalyptus oil reduced citric-acid-evoked cough relative to pine oil and air [3]. Wise et al. independently showed that menthol vapor increased the capsaicin concentration required to elicit cough in controlled challenge experiments [4]. In patients with chronic cough and environmental airway sensitivity, a randomized double-blind crossover study found that 1% nebulized menthol increased capsaicin cough threshold compared with placebo and 0.5% menthol [5].

Sensory endpoints may follow distinct response patterns. In a crossover study of 42 healthy children, menthol significantly improved perceived nasal patency without changing objective spirometric flow, and the reduction in citric-acid cough count was not different from the eucalyptus-oil placebo [6]. This pattern is informative for product development because it indicates that perceived cooling/patency and cough suppression are separable outcomes and should be measured independently in future candy studies.

Clinical respiratory context for 1,8-cineole

Clinical cineole trials provide a separate respiratory-disease context. In 242 adults with acute bronchitis, cineole 200 mg three times daily produced greater improvement in the Bronchitis Sum Score by day 4 than placebo, with a particularly strong difference in cough-fit frequency [7]. A 247-patient asthma trial using the same three-times-daily 200-mg dose for 6 months reported significant improvement across combined lung-function, symptom and quality-of-life criteria [8]. In stable COPD, 242 patients receiving 200 mg cineole three times daily for 6 months experienced lower exacerbation frequency, severity and duration, alongside improvements in dyspnea and health status [9]. A smaller 32-patient trial in steroid-dependent asthma found a greater tolerated reduction in oral prednisolone dose during 1,8-cineole treatment [10].

These studies use pharmacological oral cineole doses and disease-specific treatment periods that provide a complementary exposure context to confectionery delivery. Their relevance to the present formulation lies in demonstrating that 1,8-cineole has respiratory biological relevance in humans in addition to its role as an aroma marker. The current formulation results, in turn, address the upstream delivery problem of preserving eucalyptus-derived volatiles through candy manufacture.

Table 1. Primary human studies informing menthol/cineole respiratory physiology. Disease-treatment cineole doses provide clinical context for dose interpretation alongside product-specific exposure.

Study	Design	Exposure	Endpoint	Key finding
Morice et al. [3]	Randomized inhalation challenge; n=20 healthy adults	Menthol in eucalyptus oil vs pine oil/air	Citric-acid-evoked cough	Menthol reduced evoked cough relative to both placebo conditions.

Study	Design	Exposure	Endpoint	Key finding
Wise et al. [4]	Controlled cough-challenge experiments	Menthol vapor vs solvent headspace	Capsaicin cough threshold	Menthol vapor significantly increased cough threshold.
Millqvist et al. [5]	Randomized, double-blind crossover; 14 chronic-cough patients + 15 controls	0.5% or 1% nebulized menthol vs placebo	Capsaicin cough threshold	In chronic cough, 1% menthol increased cough threshold vs placebo and 0.5% menthol.
Kenia et al. [6]	Pseudo-randomized crossover; n=42 children	Menthol vs eucalyptus-oil placebo	Perceived nasal patency and citric-acid cough	Perceived patency improved; cough-count change did not differ from placebo.
Fischer & Dethlefsen [7]	Double-blind multicenter RCT; n=242 acute bronchitis	Cineole 200 mg three times/day vs placebo for 10 d	Bronchitis Sum Score and cough fits	Greater BSS improvement by day 4; cough-fit frequency difference p=0.0001.
Worth & Dethlefsen [8]	Double-blind multicenter RCT; n=247 asthma	Cineole 200 mg three times/day vs placebo for 6 mo	Lung function, symptoms, quality of life	Multiple clinical criteria favored cineole.
Worth et al. [9]	Double-blind multicenter RCT; n=242 COPD	Cineole 200 mg three times/day vs placebo for 6 mo	Exacerbations, dyspnea, health status	Lower exacerbation burden and improvements in dyspnea/health status.

Study	Design	Exposure	Endpoint	Key finding
Juergens et al. [10]	Double-blind RCT; n=32 steroid-dependent asthma	1,8-cineole 200 mg three times/day vs placebo	Prednisolone-sparing capacity	Greater tolerated reduction in oral steroid dose with cineole.

Discussion

The formulation and human evidence converge on a sensory-neurophysiological model centered on cough-reflex modulation and perceived airway sensation. Menthol activates TRPM8, a cold-sensitive sensory channel originally characterized in 2002 [1], [2]. In human challenge experiments, this sensory pathway is associated with increased cough thresholds under several conditions [3]–[5]. The present candy provides a controlled oral source of menthol within a matrix that also carries eucalyptus volatiles. The manufacturing data are therefore highly relevant: if thermal processing or poor dispersion alters the local concentration and release of these volatile compounds, the magnitude and reproducibility of perceived cooling and cough-related sensory responses will also vary.

Microencapsulation produced two advantages in the current system. First, it improved 1,8-cineole retention relative to direct liquid eucalyptus oil. Second, it prevented the visible local aggregation observed with the liquid-oil comparator and improved flavor uniformity. Staged low-temperature addition added a third advantage by limiting post-encapsulation thermal loss. The high-temperature comparator further indicates that the protective benefit of microencapsulation is greatest when it is paired with controlled thermal exposure after encapsulation.

The menthol literature also argues for multidimensional outcome selection. The chronic-cough study [5] and earlier challenge studies [3], [4] support a reduction in experimentally evoked cough sensitivity, whereas the pediatric crossover study showed an effect on perceived patency without a clear between-condition cough-count effect [6]. This response pattern underscores that airway sensation, airflow perception, cough urge and cough motor output represent distinct phenotypes. A product-specific trial can measure each separately—for example, perceived oral/pharyngeal cooling, urge-to-cough ratings, capsaicin or citric-acid cough threshold, spontaneous cough counts, and comfort during exposure to benign irritants.

The cineole disease trials should be interpreted along a complementary axis. The 600-mg/day regimens studied in acute bronchitis, asthma and COPD define a pharmacological clinical literature [7]–[10]. Dose ranges evaluated in those studies provide useful context for understanding the broader physiological repertoire of 1,8-cineole and for refining exposure levels in subsequent formulation-specific

investigations. The hard candy is primarily a local sensory delivery system; accordingly, future research may focus initially on sensory and cough-reflex endpoints, while the pharmacological cineole literature provides dose-context information for subsequent investigations.

The NVTIA formulation also contains licorice, Platycodon, lily and monk fruit extracts. Randomized topical-licorice studies in postoperative throat irritation have reported favorable results in several settings [11]–[13], whereas licorice-Platycodon trials in acute URTI-associated sore throat showed similar short-term improvement in active and placebo groups [14], [15]. These findings add a pharyngeal-comfort dimension to the menthol/cineole literature without implying that the complete candy reproduces any one ingredient study. The causal hierarchy therefore remains straightforward: the formulation data directly establish volatile retention and sensory uniformity; menthol and cineole studies define cough and airway-sensation physiology; and the additional botanicals provide a separate clinical context for future whole-product testing.

Study Considerations and Future Directions

The current study framework was designed to answer an upstream translational question: can a eucalyptus-menthol hard candy preserve and distribute the volatile-cooling fraction sufficiently well to justify reproducible human sensory testing? The retention and sensory-comparison data support that step. Published menthol challenge studies, cineole trials and topical herbal throat studies [3]–[15] then identify candidate endpoints—cooling, cough sensitivity, cough urge and pharyngeal comfort—without substituting ingredient-level evidence for direct evaluation of the finished candy.

Future studies may extend the present observations using a randomized crossover design with the complete candy, a flavor-matched control and standardized pre-exposure conditions. Simultaneous assessment of perceived cooling, nasal/pharyngeal openness, urge to cough, provoked cough threshold and spontaneous cough frequency would help separate sensory perception from cough motor output. Pharmacokinetic or breath-volatile measurements could further characterize the temporal relationship between candy dissolution and exposure to eucalyptus-derived constituents.

CONCLUSION

Fundamental Finding : Retention and spatial uniformity of the eucalyptus volatile fraction in a sugar-free herbal hard candy. Relative 1,8-cineole retention reached 82.1% under the optimized process, compared with 64.5% after direct liquid-oil addition and 68.2% after high-temperature addition. **Implication :** Human experimental studies independently show that menthol can modulate cough sensitivity and perceived airway sensation, while randomized cineole trials demonstrate clinically measurable respiratory effects at pharmacological oral doses. **Limitation :** The findings are based on formulation optimization and independent human experimental studies, without direct product-specific evaluation of the NVTIA candy using cough-reflex, cooling-sensation, or respiratory-comfort endpoints. **Future Research :** Direct product-specific studies of the

NVTIA candy should evaluate cough-reflex, cooling-sensation, and respiratory-comfort endpoints to establish its formulation and physiological effects.

REFERENCES

- [1] A. M. Peier et al., "A TRP channel that senses cold stimuli and menthol," *Cell*, vol. 108, no. 5, pp. 705–715, 2002, doi: 10.1016/S0092-8674(02)00652-9.
- [2] D. D. McKemy, W. M. Neuhausser, and D. Julius, "Identification of a cold receptor reveals a general role for TRP channels in thermosensation," *Nature*, vol. 416, no. 6876, pp. 52–58, 2002, doi: 10.1038/nature719.
- [3] A. H. Morice, A. E. Marshall, K. S. Higgins, and T. J. Grattan, "Effect of inhaled menthol on citric acid induced cough in normal subjects," *Thorax*, vol. 49, no. 10, pp. 1024–1026, 1994, doi: 10.1136/thx.49.10.1024.
- [4] P. M. Wise, P. A. S. Breslin, and P. Dalton, "Sweet taste and menthol increase cough reflex thresholds," *Pulm. Pharmacol. Ther.*, vol. 25, no. 3, pp. 236–241, 2012, doi: 10.1016/j.pupt.2012.03.005.
- [5] E. Millqvist, E. Ternesten-Hasséus, and M. Bende, "Inhalation of menthol reduces capsaicin cough sensitivity and influences inspiratory flows in chronic cough," *Respir. Med.*, vol. 107, no. 3, pp. 433–438, 2013, doi: 10.1016/j.rmed.2012.11.017.
- [6] P. Kenia, T. Houghton, and C. Beardsmore, "Does inhaling menthol affect nasal patency or cough?," *Pediatr. Pulmonol.*, vol. 43, no. 6, pp. 532–537, 2008, doi: 10.1002/ppul.20797.
- [7] J. Fischer and U. Dethlefsen, "Efficacy of cineole in patients suffering from acute bronchitis: A placebo-controlled double-blind trial," *Cough*, vol. 9, no. 1, Art. no. 25, 2013, doi: 10.1186/1745-9974-9-25.
- [8] H. Worth and U. Dethlefsen, "Patients with asthma benefit from concomitant therapy with cineole: A placebo-controlled, double-blind trial," *J. Asthma*, vol. 49, no. 8, pp. 849–853, 2012, doi: 10.3109/02770903.2012.717657.
- [9] H. Worth, C. Schacher, and U. Dethlefsen, "Concomitant therapy with cineole (eucalyptole) reduces exacerbations in COPD: A placebo-controlled double-blind trial," *Respir. Res.*, vol. 10, Art. no. 69, 2009, doi: 10.1186/1465-9921-10-69.
- [10] U. R. Juergens, U. Dethlefsen, G. Steinkamp, A. Gillissen, R. Repges, and H. Vetter, "Anti-inflammatory activity of 1,8-cineol (eucalyptol) in bronchial asthma: A double-blind placebo-controlled trial," *Respir. Med.*, vol. 97, no. 3, pp. 250–256, 2003, doi: 10.1053/rmed.2003.1432.
- [11] A. Agarwal, D. Gupta, G. Yadav, P. Goyal, P. K. Singh, and U. Singh, "An evaluation of the efficacy of licorice gargle for attenuating postoperative sore throat: A prospective, randomized, single-blind study," *Anesth. Analg.*, vol. 109, no. 1, pp. 77–81, 2009, doi: 10.1213/ane.0b013e3181a6ad47.
- [12] K. Ruetzler, M. Fleck, S. Nabecker, K. Pinter, G. Landskron, A. Lassnigg, J. You, and D. I. Sessler, "A randomized, double-blind comparison of licorice versus sugar-water gargle for prevention of postoperative sore throat and postextubation coughing," *Anesth. Analg.*, vol. 117, no. 3, pp. 614–621, 2013, doi: 10.1213/ANE.0b013e318299a650.
- [13] D. Gupta, S. Agrawal, and J. P. Sharma, "Effect of preoperative licorice lozenges on incidence of postextubation cough and sore throat in smokers undergoing general anesthesia and endotracheal intubation," *Middle East J. Anaesthesiol.*, vol. 22, no. 2, pp. 173–178, 2013.

- [14] N. Ishimaru, S. Kinami, T. Shimokawa, and Y. Kanzawa, "Kikyo-to vs. placebo on sore throat associated with acute upper respiratory tract infection: A randomized controlled trial," *Intern. Med.*, vol. 58, no. 17, pp. 2459–2465, 2019, doi: 10.2169/internalmedicine.2748-19.
- [15] N. Ishimaru, S. Suzuki, T. Shimokawa, K. Iijima, Y. Kanzawa, T. Nakajima, and S. Kinami, "Kikyo-to for acute upper respiratory tract infection-associated sore throat pain: A multicenter randomized controlled trial," *J. Integr. Complement. Med.*, vol. 28, no. 9, pp. 768–774, 2022, doi: 10.1089/jicm.2021.0433.

Yassine Igoundaz

National Laboratory of Medicine LLC, USA

Kaito Yoshida

National Laboratory of Medicine LLC, USA

Freddie Dawson

National Laboratory of Medicine LLC, USA
