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Three-Phase Encapsulation Platform Centered on Quercetin, Bromelain, and Eucalyptus Oil for Respiratory Support: Formulation Robustness, Gastric-Acid Protection, and Translational Evidence

Jabar Yassine *, Gregg L. Semenza, Ignacio Fuentes

World Food Supplement Association, New York, USA
*Corresponding Author: info@wfsas.org

ABSTRACT

We evaluated a respiratory-support platform organized around quercetin, bromelain, and eucalyptus-oil-rich volatile components, and we contextualized the formulation dataset with peer-reviewed public evidence on the three signature actives. The core formulation dataset comprised three encapsulated embodiments and one direct-mix comparator from the technical dossier. The platform used three protective units: enteric-protective microspheres for bromelain, nano mixed micelles for the quercetin-centered flavonoid fraction, and sustained-release microcapsules for the eucalyptus-oil-rich volatile fraction. Across the three encapsulated embodiments, bromelain encapsulation reached 95.5%-97.2%, flavonoid encapsulation 90.8%-92.6%, and volatile-component encapsulation 92.3%-94.5%; bromelain activity retention after 2 h at pH 1.2 remained above 98.0%, while the direct-mix comparator retained only 6.8%. Total active retention after 6 months at 25 °C remained 95.8%-96.3% in the encapsulated platform versus 32.5% in the comparator. Public evidence supported the translational plausibility of the platform: quercetin attenuated smoke-induced airway inflammation and mucus production in rats; oral quercetin was safely tolerated up to 2000 mg/day in COPD patients and, in a 2025 pilot trial, reduced selected inflammatory and oxidative-stress biomarkers; 1,8-cineole showed steroid-sparing activity in severe asthma and reduced exacerbations in COPD; and oral bromelain showed tolerability and symptom improvement signals in chronic rhinosinusitis. We therefore interpret the main differentiated value of the platform as delivery-enabled robustness rather than an unsupported claim of direct clinical superiority of the full finished product.

KEYWORDS

Quercetin; Bromelain; Eucalyptus oil; 1,8-cineole; Respiratory support; Encapsulation; Gastric-acid protection; Stability

1. INTRODUCTION

Chronic respiratory diseases affect the airways and other lung structures and include asthma, chronic obstructive pulmonary disease (COPD), occupational lung diseases, and pulmonary hypertension. These conditions cannot be cured, but long-term symptom control and protection of airway function remain central therapeutic goals [1]. In practice, the formulation problem is often underestimated: proteolytic enzymes can be denatured by gastric acid, volatile oils can evaporate or oxidize during processing and storage, and flavonoids may have poor dispersion and inconsistent release. We therefore focused on whether a three-phase encapsulation architecture could stabilize chemically dissimilar respiratory-support actives within one oral platform.

We centered the present manuscript on three brand-facing signature actives: quercetin, bromelain, and eucalyptus oil. We did not treat these ingredients as a simple label claim. Instead, we examined whether the combined technical dataset and the public literature support a stronger formulation-performance narrative when the actives are protected in phase-specific carriers matched to their chemical vulnerabilities and pharmacological roles.

2. MATERIALS AND METHODS

We organized the paper around two evidence layers. First, we summarized the technical formulation dataset from a respiratory-support dossier containing three encapsulated embodiments and one direct-mix comparator. Second, we reviewed peer-reviewed public studies relevant to the three signature actives, prioritizing human trials where available and well-established preclinical data where clinical evidence remained limited. Public evidence was drawn from WHO material and indexed biomedical literature on quercetin, bromelain, and 1,8-cineole/eucalyptol [1-10].

The formulation layer used three independent protective subsystems: (i) enteric-protective microspheres for bromelain, (ii) nano mixed micelles for the quercetin-centered flavonoid fraction, and (iii) sustained-release microcapsules for eucalyptus-oil-rich volatile constituents. The comparator used the same broad positioning logic but omitted encapsulation, oxygen protection, and phase-specific process control. Primary technical endpoints were subsystem encapsulation efficiency, bromelain activity retention after 2 h in simulated gastric acid at pH 1.2, and total active retention after 6 months of sealed storage at 25 °C.

3. RESULTS

3.1. Formulation Architecture And Technical Performance

Table 1 summarizes the three-phase formulation architecture and the patent-disclosed performance of each protective subsystem. Table 2 presents the quantitative technical endpoints across the three encapsulated embodiments and the direct-mix comparator. As shown in Figure 1, subsystem encapsulation performance remained consistently high across the encapsulated embodiments. Figure 2 further shows the marked separation between the encapsulated platform and the direct-mix comparator in bromelain acid resilience and 6-month total active retention.

Table 1. Three-phase formulation architecture and patent-disclosed subsystem performance

Subsystem	Core fraction	Process intent	Patent-disclosed performance
Enteric microspheres	Bromelain	Protect proteolytic activity from gastric acid	Encapsulation 95.5%-97.2%; gastric-acid activity retention >98%
Nano mixed micelles	Quercetin-centered flavonoid fraction	Improve dispersion and protect oxidation-sensitive polyphenols	Encapsulation 90.8%-92.6%
Sustained-release microcapsules	Eucalyptus-oil-rich volatile fraction	Reduce volatile loss and prolong release	Encapsulation 92.3%-94.5%
Direct-mix comparator	Same broad active positioning without phase protection	Benchmark conventional formulation behavior	Bromelain activity retention 6.8%; 6-month total retention 32.5%

Table 2. Quantitative technical performance of the encapsulated embodiments versus the direct-mix comparator

Endpoint	Emb. 1	Emb. 2	Emb. 3	Comparator
Bromelain encapsulation efficiency (%)	97.2	95.5	96.8	N/A
Flavonoid encapsulation efficiency (%)	92.6	90.8	91.5	N/A
Volatile-component encapsulation efficiency (%)	94.5	92.3	93.8	N/A
Bromelain activity retention in gastric acid (%)	98.5	98.1	98.3	6.8
Total active retention after 6 months at 25 °C (%)	96.3	95.8	96.1	32.5

As summarized in Table 2 and illustrated in Figure 2, the technical dataset showed consistently high protective efficiency across the three chemically distinct subsystems. The clearest separation from the direct-mix comparator was seen in gastric-acid resilience of bromelain and in 6-month total active retention, indicating that the delivery architecture addressed the major known vulnerabilities of enzymes, polyphenols, and volatile oils simultaneously.

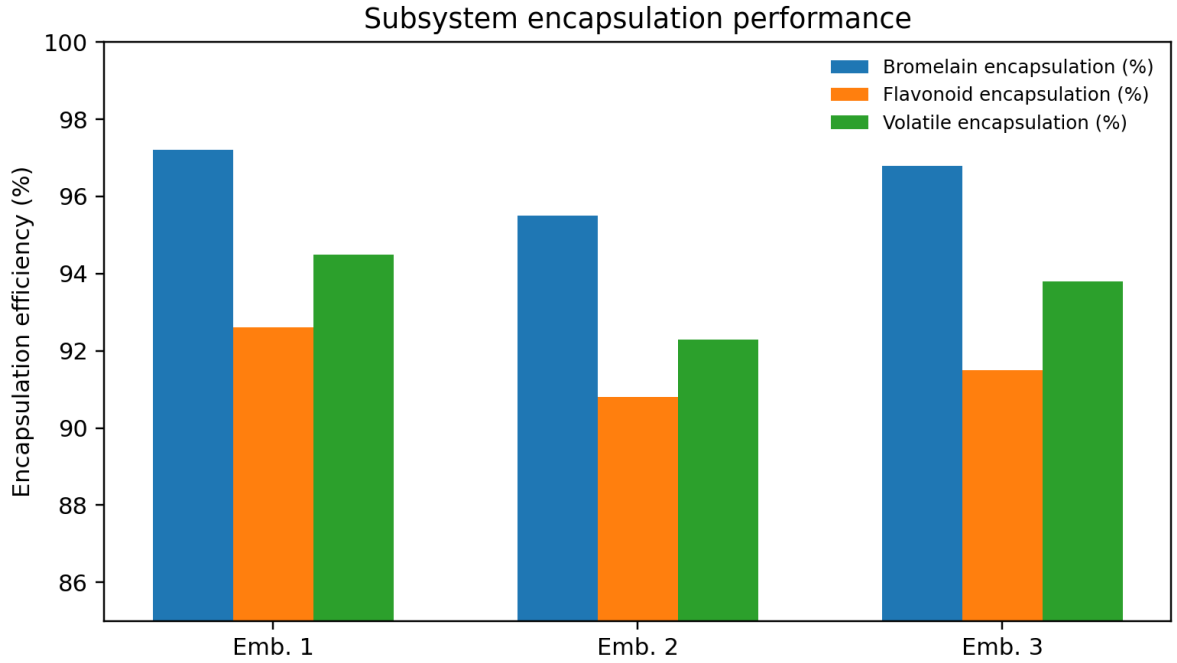

Figure 1. Original source figure preserved: subsystem encapsulation performance across the three encapsulated embodiments

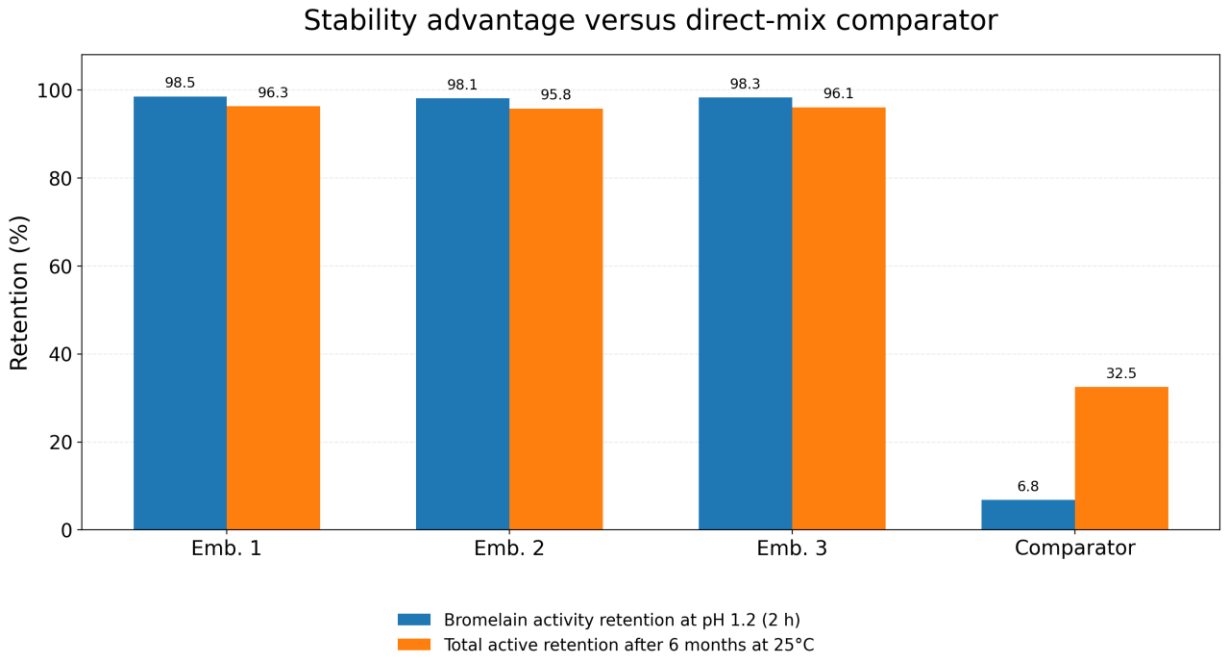

Figure 2. Original source figure preserved: bromelain acid resilience and 6-month active retention versus the direct-mix comparator

3.2. Public Evidence Relevant to the Three Signature Actives

Table 3 summarizes the principal public studies relevant to quercetin, bromelain, and eucalyptus-oil-derived 1,8-cineole, together with their translational relevance to interpretation of the platform.

The public literature does not establish the clinical efficacy of the exact finished three-phase product. It does, however, provide a coherent translational backdrop for the three signature actives. Quercetin is supported by airway-inflammation models and early human respiratory studies, eucalyptus-oil-derived 1,8-cineole has the strongest direct airway trial evidence among the three core actives, and bromelain shows symptom-control signals in sinonasal disease together with a broader safety dataset. These findings make the technical source data more biologically plausible, but they do not replace direct trials of the finished formulation.

Table 3. Public evidence relevant to the three signature actives and their translational relevance to the platform

Public source	Design / population	Key reported finding	Relevance to platform interpretation
Yang et al., 2012 [2]	Smoke-exposed rat airway model	Quercetin suppressed goblet-cell hyperplasia, oxidative stress, inflammation, EGFR phosphorylation, and NF-kB activation in rat lung	Supports the anti-inflammatory and mucus-modulating rationale for the quercetin fraction
Heinz et al., 2010 [3]	Randomized community trial, n=1002	No overall URTI benefit in the full cohort; in fitter adults aged >=40 years, 1000 mg/day quercetin was associated with 36% lower URTI severity and 31% fewer sick days	Suggests human respiratory relevance, but with subgroup-limited benefit rather than broad efficacy
Han et al., 2020 [4]	Dose-escalation COPD safety trial	Quercetin was safely tolerated up to 2000 mg/day with no study-drug-related severe adverse events	Supports feasibility of oral quercetin exposure in chronic respiratory populations
Patel et al., 2025 [5]	Pilot phase II COPD trial, 6 months, n=14	Quercetin reduced selected inflammatory and oxidative-stress biomarkers in BAL and serum and was well tolerated	Provides a recent human biomarker signal consistent with the formulation rationale
Juergens et al., 2003 [6]	Double-blind placebo-controlled severe-asthma trial, n=32	1,8-cineole 200 mg t.i.d. enabled a 36% reduction in daily prednisolone dose versus 7% with placebo	Supports airway-focused anti-inflammatory relevance of the eucalyptus-oil fraction
Worth et al., 2009 [7]	Double-blind placebo-controlled COPD trial, n=242	Cineole reduced exacerbations and improved dyspnea, lung function, and health status over 6 months	Strengthens the translational case for 1,8-cineole in chronic airway disease
Buttner et al., 2013 [8]	Prospective pilot study in chronic rhinosinusitis, n=12	Bromelain improved symptom, rhinoscopy, and quality-of-life scores; no adverse events were observed	Suggests tolerability and symptom-level respiratory relevance of oral bromelain
Leelakanok et al., 2023 [9]	Systematic review and meta-analysis of 54 studies	Bromelain may be effective against sinusitis; major health risks were not reported	Places the bromelain signal in a broader evidence context while acknowledging heterogeneity

4. DISCUSSION

Our interpretation is that the strongest claim supported by the combined evidence is formulation robustness. The technical dataset shows that the platform preserved bromelain in gastric acid, stabilized the quercetin-centered flavonoid fraction, and limited losses from the eucalyptus-oil-rich volatile phase. Public studies then help explain why this matters: the biological relevance of the three signature actives is undermined if the formulation cannot preserve enzyme activity, control volatile loss, or keep poorly dispersible flavonoids available long enough to be absorbed and exert local or systemic effects.

The evidence is not symmetrical across ingredients. Eucalyptol has the clearest disease-focused human respiratory data, quercetin has mixed but increasingly relevant translational evidence, and bromelain has smaller respiratory datasets than the other two core fractions. We therefore avoid any unsupported claim that the exact NVTIA composition has already demonstrated clinical superiority. What we can say, based on the evidence reviewed here, is that a compatibility-managed three-phase delivery design is a rational way to formulate these actives and that the technical dataset demonstrates large differences versus a direct-mix comparator in the precise domains that usually limit such products.

Two limitations remain important. First, the formulation dataset is technical and preclinical rather than a registered clinical program. Second, the public evidence relates mainly to individual actives or adjacent respiratory indications rather than the full finished product. A properly powered randomized trial using the final formulation would therefore be required before any therapeutic or disease-specific claim could be advanced.

5. CONCLUSION

We conclude that a three-phase respiratory-support platform centered on quercetin, bromelain, and eucalyptus oil can be differentiated scientifically through delivery architecture rather than through ingredient listing alone. In the technical dataset, the encapsulated platform achieved high subsystem encapsulation, maintained bromelain activity under gastric-acid challenge, and preserved total actives over 6 months far more effectively than a direct-mix comparator. Public studies on quercetin, 1,8-cineole, and bromelain provide a coherent translational rationale for why this protection strategy matters. The next step should be prospective human evaluation of the finished formulation using respiratory symptom, exacerbation, and biomarker endpoints.

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