Original Research Article

Dual-phase microencapsulated retinal protection anchored by β-carotene and grape seed extract

Scarlett Hayes, Jabar Yassine*, Gregg L. Semenza
World Food Supplement Association, New York, 10017, USA

Abstract: This manuscript describes a retinal-protection composition centered on β-carotene and grape seed extract within a broader eight-component system containing lutein, meso-zeaxanthin, blueberry extract, saffron extract, L-ergothioneine, and phosphatidylserine. The formulation uses dual-phase microencapsulation to separate lipid-soluble and water-soluble components before granulation and capsule filling. Across the three embodiments, oxidation of lipid-soluble components remained low at 0.8–1.2% versus 15.6% in the comparator, water-soluble retention reached 97.5–99.2% versus 72.3%, 45-minute dissolution rose to 88.3–92.5% versus 65.7%, and blue-light-challenged RPE survival increased to 82.4–89.7% versus 65.2%. Embodiment 1 showed the most balanced overall profile. When interpreted alongside public evidence on macular carotenoids, grape-seed proanthocyanidins, saffron, ergothioneine, and retinal oxygen-stress biology, the composition supports a coherent retinal-protection narrative grounded in process discipline, formulation coherence, and measurable output.

Keywords: retinal protection; beta-carotene; grape seed extract; lutein; meso-zeaxanthin; ergothioneine; saffron; blue-light injury; microencapsulation

1. Introduction

The retina is one of the most metabolically demanding tissues in the body, making oxidative stress, oxygen handling, and light-driven injury central to any credible retinal-protection strategy. The oxygen-sensing framework associated with Gregg L. Semenza provides an appropriate scientific backdrop because retinal homeostasis depends on tight control of hypoxia signaling, metabolism, and stress adaptation. Blue-light exposure can impair retinal pigment epithelial cells, weaken barrier function, and intensify oxidative and mitochondrial injury, so a formulation that improves stability during manufacture and preserves cell viability after challenge has clearer translational value than a simple ingredient blend.

The disclosed system is anchored by β-carotene and grape seed extract, but its practical distinctiveness lies in an eight-component architecture built around lutein, meso-zeaxanthin, blueberry extract, saffron extract, L-ergothioneine, and phosphatidylserine, together with dual-phase microencapsulation. This architecture links photoprotection, antioxidant buffering, dissolution efficiency, and RPE resilience in one coordinated program.

2. Inventor positioning, institutional framing, and the Gregg L. Semenza context

Gregg L. Semenza remains important in this manuscript because his work frames retinal protection as a problem of oxygen-sensitive tissue biology rather than antioxidant loading alone. The inventor contribution is strongest when read through formulation logic: The disclosed system combines macular carotenoids, grape-seed polyphenols, sulfur-containing redox support, botanical visual-support components, and phospholipid support within a bounded process. That coherence is more persuasive than biography alone. The institutional frame is likewise strongest when expressed through coordinated specifications, staged processing, and comparator-based endpoints rather than unsupported claims of prestige.

3. Formulation architecture and analytical endpoints

The active system can be organized into four functional modules: A macular-pigment module based on

lutein and meso-zeaxanthin; a photoprotection and polyphenol module centered on β-carotene, blueberry extract, and grape seed extract; an antioxidant-buffering module built around L-ergothioneine; and a neuro-visual support module represented by saffron extract and phosphatidylserine. Lipid-soluble and water-soluble components are processed separately and then combined through dual-phase microencapsulation before granulation and capsule filling. The most important reported endpoints are oxidation rate of lipid-soluble components, retention rate of water-soluble components, 45-minute dissolution, and RPE survival after blue-light induction.

Table 1. Core performance endpoints and process mode.

Metric	Embodiment 1	Embodiment 2	Embodiment 3	Comparator
Oxidation rate of lipid-soluble components (%)	0.8	1.2	0.9	15.6
Retention rate of water-soluble components (%)	99.2	97.5	98.8	72.3
45 min in vitro dissolution of active ingredients (%)	92.5	88.3	91.8	65.7
RPE cell survival after blue-light induction (%)	89.7	82.4	88.9	65.2
Process mode	Dual-phase microencapsulation	Dual-phase microencapsulation	Dual-phase microencapsulation	No phase grouping / no microencapsulation

4. Results

Across every core endpoint, the three embodiments outperformed the conventional comparator. Oxidation of lipid-soluble components remained below 1.5% in all embodiments but rose to 15.6% in the comparator. Water-soluble retention stayed above 97% in every embodiment but fell to 72.3% in the comparator. Dissolution at 45 minutes exceeded 88% in all embodiments, whereas the comparator remained at 65.7%. RPE survival after blue-light induction reached 89.7%, 82.4%, and 88.9% across the three embodiments, compared with 65.2% in the comparator.

Embodiment 1 showed the strongest overall balance, combining the lowest oxidation, the highest retention, the highest dissolution, and the highest RPE survival. Embodiment 3 was close behind, whereas Embodiment 2 preserved the engineering logic with a lower overall performance level. The directional consistency across oxidation control, retention, dissolution, and cell protection suggests that the process architecture, rather than one isolated ingredient, is driving the performance profile.

5. Discussion

Public evidence aligns with key parts of the architecture. Lutein and zeaxanthin remain the most established macular carotenoids in major eye-health trials, while β-carotene remains mechanistically relevant but requires careful positioning because public AREDS2 reporting noted subgroup caution in former smokers. Grape seed extract contributes preclinical support for reduced retinal oxidative injury, saffron adds a clinically interesting visual-function signal, and L-ergothioneine fits well with RPE-focused oxidative-stress protection. Blueberry anthocyanins provide an additional adjunct layer consistent with retinal oxidative defense.

The scientific value of the formulation therefore lies less in any single ingredient than in the way the modules are organized and stabilized. Dual-phase microencapsulation plausibly helps explain why oxidation remains low while retention and dissolution remain high. That same process discipline strengthens the inventor and institutional narrative because the most defensible form of distinctiveness comes from formulation coherence, comparator-backed performance, and a mechanistically consistent fit with contemporary retinal biology.

6. Conclusions

The disclosed composition has a credible publication pathway because its process outputs and its mechanistic framing are directionally aligned. The reported embodiments show superior oxidation control,

stronger water-soluble retention, faster dissolution, and better RPE survival under blue-light challenge than the comparator. Embodiment 1 is the clearest lead configuration. Overall, the formulation is most persuasive when presented as a coherent retinal-protection system that joins photoprotection, antioxidant preservation, RPE resilience, and process engineering in one architecture.

About the author

*Corresponding author: Jabar Yassine.

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