

Article

White-Tomato Colorless Carotenoid Microcapsules and Skin Barrier Resilience: Physicochemical Performance and Human Evidence

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Abstract: The stratum corneum limits water loss and helps the skin tolerate environmental stress. We evaluated a BCLC® white-tomato microcapsule enriched in phytoene and phytofluene, with attention to free oil, water activity and active-carotenoid retention, and compared these formulation data with human barrier studies. The optimized powders contained 6.31–7.58% phytoene plus phytofluene, had water activity of 0.29–0.34 and free oil of 1.3–1.7%. The non-encapsulated ethanol-extract comparator had 6.8% free oil. In a double-blind human study of a tomato-derived supplement predominantly containing phytoene and phytofluene, barrier strength increased by 59.9% after 12 weeks, barrier recovery was 38.8% faster, firmness improved by 9.34% and elasticity by 11.6%. A separate 16-week study reported lower TEWL among participants with higher baseline TEWL. The formulation measurements and human evidence identify TEWL, barrier-disruption/recovery testing, mechanical skin measures and circulating carotenoids as suitable endpoints for direct study of the BCLC® microcapsule.

Keywords: Skin Barrier, Phytoene, Phytofluene, TEWL, Elasticity, Firmness, Microencapsulation, White Tomato

Introduction

The stratum corneum is the main permeability barrier between the body and the external environment. Its performance depends on corneocyte organization, intercellular lipids and an appropriate hydration state, and loss of barrier integrity is commonly reflected by an increase in transepidermal water loss (TEWL) [1]-[3]. That functional perspective is important when oral interventions are studied, because dryness, recovery after disruption and mechanical properties such as firmness or elasticity do not necessarily move in parallel. Repeated ultraviolet and environmental exposure can add oxidative and inflammatory stress to the same barrier system.

Phytoene and phytofluene are colorless carotenoids that have been discussed in relation to human nutrition, tissue exposure and skin-focused applications [4]-[7]. Their weak visible pigmentation distinguishes them from more intensely colored carotenoids and makes them practical candidates for a low-color oral ingredient. For formulation work, however, the relevant question is not only whether these compounds are present in the raw concentrate, but whether a repeatable amount can be delivered after conversion of the lipophilic material into a dry powder.

Human tomato-carotenoid studies provide a useful set of barrier measurements. In a 12-week double-blind study, a phytoene/phytofluene-predominant tomato-derived supplement was evaluated

with TEWL, tape-stripping recovery and Cutometer measurements [8]. A 16-week golden-tomato study used TEWL and reported a response that was more evident among participants with higher baseline water loss [9]. Another 12-week study combined skin assessments with plasma phytoene and phytofluene measurements [10]. These designs are relevant here because they connect repeated oral exposure with objective or semi-objective skin endpoints rather than relying on a single appearance score.

The broader carotenoid literature adds a second layer of context. Controlled tomato- or carotenoid-supplementation studies have followed ultraviolet responses, serum carotenoid accumulation and pigmentation-related outcomes [11]-[14]. An oral carotenoid-rich intervention has also been examined with collagen/elastin-related skin measurements [15]. Taken together, these studies show that the choice of endpoint matters: barrier water loss, recovery after disruption, mechanical properties, circulating carotenoids and light-response measures describe different parts of the skin response.

The BCLC® system was developed to make that exposure question more controlled. A white-tomato carotenoid concentrate is incorporated into a dry microcapsule using sodium starch octenyl succinate, a secondary polysaccharide wall material and hydroxypropyl methylcellulose, with tocopherol-based antioxidant protection. The present work therefore examined free oil, water activity and short-term carotenoid retention before using the published human studies to identify practical barrier endpoints. The human evidence is used as study-design context, not as a substitute for direct testing of the BCLC® formulation.

Materials and Method

Three optimized formulations and three process comparators were tested. The optimized process used selective adsorption to reduce colored carotenoids, followed by addition of wall materials, high-shear dispersion, homogenization and spray drying or freeze drying. Free oil was measured by a centrifugation/filter-paper method. Water activity and moisture were measured instrumentally, carotenoids by HPLC-DAD, and 30-day accelerated stability at 40°C/75% relative humidity.

The human evidence review prioritized oral tomato-carotenoid studies with objective barrier or mechanical endpoints. TEWL, tape-stripping disruption threshold, post-disruption recovery and Cutometer measurements were the principal outcomes [8]-[10]. General barrier physiology and hydration references were used to interpret TEWL and stratum-corneum function [1]-[3], while other human carotenoid studies supplied systemic-exposure and photooxidative context [11]-[13], [14].

Results

Table 1. Physicochemical and carotenoid characteristics of the evaluated formulations.

Formulation	Phytoene + phytofluene (%)	Colored carotenoids / colorless carotenoids (%)	Moisture (%)	Water activity	Free oil (%)	30-d retention (%)
BCLC formulation 1	7.58	2.77	4.1	0.29	1.3	88.6
BCLC formulation 2	6.79	3.53	4.3	0.31	1.5	85.2
BCLC formulation 3	6.31	4.12	4.8	0.34	1.7	82.7

Comparator 1: ordinary freeze-dried powder	0.62	29.03	5.8	0.42	0.2	59.4
Comparator 2: non- encapsulated ethanol-extract powder	9.84	7.32	4.6	0.27	6.8	62.8
Comparator 3: encapsulated without colored- carotenoid reduction	8.10	8.52	4.8	0.31	1.4	86.2

Free oil was 1.3%, 1.5% and 1.7% in the three optimized BCLC® microcapsules. The non-encapsulated ethanol-extract comparator contained 6.8%. Ordinary freeze-dried powder contained 0.2% free oil, but it also had only 0.62% phytoene plus phytofluene and retained 59.4% after accelerated storage. Water activity in the optimized powders was 0.29–0.34, and 30-day active retention was 82.7–88.6%.

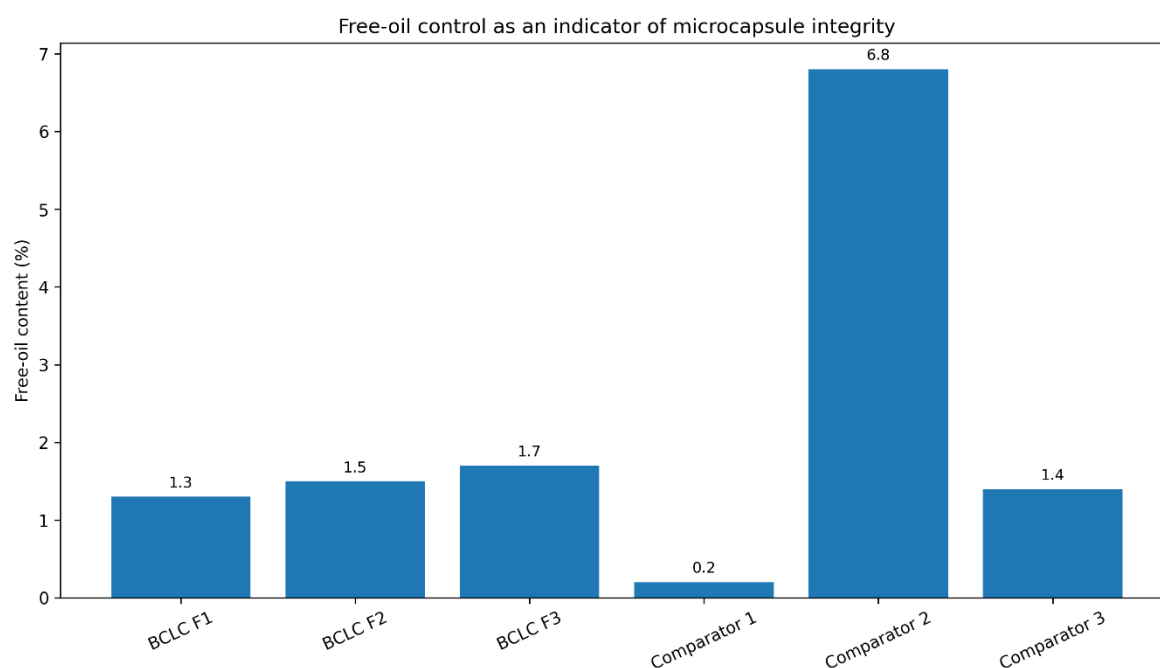


Figure 1. Free-oil control across formulation designs.

Tarshish et al. conducted a double-blind study in women aged 35–55 years. Fifty-nine participants completed 12 weeks of supplementation with a tomato-derived carotenoid product or placebo. The active supplement contained a proprietary tomato-carotene mixture standardized to 10 mg total carotenoids and predominantly composed of phytoene and phytofluene. Barrier strength

increased significantly by 59.9% from baseline, barrier recovery after tape stripping was 38.8% faster, and Cutometer measurements showed improvements of 9.34% in firmness and 11.6% in elasticity [8].

A separate 16-week golden-tomato study included 65 subjects who consumed one capsule per day. TEWL decreased significantly among participants with higher baseline TEWL [9]. In another 12-week study, participants reported improvements in hydration, elasticity, firmness and skin texture while plasma phytoene and phytofluene increased [10]. These studies used different protocols, but each links repeated oral tomato-carotenoid exposure with a measurable skin outcome.

Human Evidence Synthesis

Table 2. Key human studies relevant to the principal outcome.

Study	Design	Intervention	Endpoints	Main findings
Tarshish et al., 2023	Double-blind, 59 completed	12 weeks, tomato carotenoid supplement, 10 mg total carotenoids, predominantly phytoene/phytofluene	TEWL, tape stripping, recovery, Cutometer	Barrier strength +59.9%, recovery 38.8% faster, firmness +9.34%, elasticity +11.6%
Tarshish et al., 2022 (GTE)	Human oral study, 65 participants	16 weeks, golden tomato extract	TEWL, skin appearance	TEWL improved in participants with high baseline TEWL
Tarshish et al., 2022 (visual attributes)	Human oral study, 60 women completed visual-attribute part	12 weeks, tomato carotenoid supplement	Hydration, texture, elasticity, firmness, appearance	Significant perceived improvements, plasma phytoene/phytofluene increased

The human studies were used to define barrier endpoints and study duration rather than as direct results of the BCLC® formulation. Their value lies in the measurements they used: TEWL, tape stripping, recovery kinetics, Cutometer parameters and circulating carotenoids. Formulation differences were kept explicit when interpreting the evidence.

Discussion

The low free-oil fraction is a practical measure of microcapsule integrity. Carotenoid-rich lipid outside the wall matrix is more exposed to oxygen, moisture and physical migration. BCLC® formulations 1–3 contained 1.3–1.7% free oil, compared with 6.8% in the non-encapsulated ethanol-extract comparator. The same optimized powders retained 82.7–88.6% of phytoene plus phytofluene after 30 days, giving a reproducible powder matrix for oral dosing.

Barrier responses in the human studies developed over weeks, not hours. In the 12-week trial, the largest barrier-strength changes were recorded after sustained supplementation [8]. The 16-week golden-tomato study also showed that baseline TEWL affected the observed response [9]. For a BCLC® trial, enrollment criteria and baseline barrier status should therefore be specified before treatment begins, participants with elevated TEWL may provide a more sensitive model for water-loss endpoints.

Phytoene and phytofluene are bioavailable despite their lack of visible color [4]-[7]. Their relevance to barrier research is most plausibly linked to the environment in which the stratum corneum operates: oxidative stress, inflammatory signaling, tissue carotenoid exposure and lipid organization. Core barrier physiology depends on the corneocyte/lipid structure and controlled water flux [1]-[3]. Human carotenoid trials have also documented systemic accumulation and changes in UV-related skin responses [11]-[13], [14], while carotenoid-rich supplementation has been studied against collagen/elastin indices [15].

Low free oil, low water activity and high short-term active retention make the BCLC® powder suitable for repeated oral dosing in an objective barrier study. Those measurements are formulation attributes rather than clinical outcomes, but they help standardize the exposure delivered to participants. TEWL and tape-stripping recovery can then be interpreted against a defined carotenoid composition rather than against an unstable or poorly encapsulated powder.

Current Scope and Future Directions

A BCLC®-specific randomized study can combine plasma phytoene/phytofluene with facial and forearm TEWL, corneometry, tape-stripping disruption threshold, barrier-repair kinetics and Cutometer parameters. Baseline TEWL and sensitive/dry-skin status can be prespecified for stratification. Repeated measurements across the intervention would show when the barrier response begins and whether it tracks systemic carotenoid exposure.

Conclusion

The BCLC® white-tomato microcapsules combined 6.31–7.58% phytoene plus phytofluene with low free oil (1.3–1.7%), water activity of 0.29–0.34 and 82.7–88.6% active retention after 30 days of accelerated storage. Human studies of phytoene/phytofluene-predominant tomato supplements have reported changes in barrier strength, repair, firmness, elasticity and TEWL over repeated oral intake. The formulation data support direct BCLC® evaluation using standardized barrier measurements and circulating colorless-carotenoid exposure.

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