

Article

A Fruit-Derived Vitamin C–Polyphenol Matrix for Collagen Formation and Tissue Integrity: Stability Characteristics and Human Healing Evidence

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Abstract: The NVTIA® fruit-derived vitamin C-polyphenol powder was evaluated as a stable nutritional input for collagen- and tissue-repair research. The optimized powders contained 16.8-18.4% L-ascorbic acid and 7.9-8.8% corrected total polyphenols, with water activity of 0.23-0.25. After 30 days of accelerated storage, L-ascorbic acid retention was 87.5-89.1%; direct dry mixing, removal of the protective matrix, and a conventional carrier gave lower retention and higher hygroscopicity. Human healing studies are not uniform. A small double-blind trial reported better foot-ulcer healing with 500 mg/day slow-release vitamin C, whereas a pressure-ulcer trial using 500 mg twice daily did not improve wound closure. Multi-nutrient pressure-ulcer studies and collagen-synthesis experiments show that baseline nutrition, wound type, co-interventions, and exposure context materially affect the observed response. The stable fruit-derived matrix is therefore suited to direct studies that pair measured vitamin C exposure with collagen or tissue-integrity endpoints.

Keywords: vitamin C; collagen; wound healing; skin integrity; connective tissue; acerola; polyphenols; stability

Introduction

Vitamin C is required for collagen prolyl and lysyl hydroxylation and also contributes to fibroblast and skin redox biology [1]. Severe deficiency impairs connective-tissue integrity, but supplementation studies are more variable once overt deficiency is absent. A recent systematic review of tissue-healing studies likewise found different effects across wound types, baseline status, and co-interventions [2]. Ascorbic acid can also be lost before a participant takes the product. Extraction, concentration, drying, oxygen exposure, and storage humidity all affect the remaining amount. The fruit-derived formulation was therefore built around low-temperature oxygen-isolated extraction, liquid-phase compounding with *Phyllanthus emblica* polyphenols, and a low-methoxyl-pectin-gum-arabic-resistant-dextrin matrix.

The analysis focused first on stability: L-ascorbic acid content, polyphenols, moisture, water activity, 30-day retention, and hygroscopicity. Human collagen and wound studies were then considered as a separate evidence layer so that formulation stability was not treated as a clinical healing endpoint.

Materials and Methods

Three optimized powders and seven process comparators were assessed for L-ascorbic acid, corrected total polyphenols, moisture, water activity, processing retention, 30-day accelerated-storage retention, and 24-hour hygroscopicity. The optimized formulations used approximately 15-16% protective matrix and an ascorbate-to-corrected-polyphenol ratio of 1:0.43-0.52.

Human studies were included when collagen formation, skin or wound integrity, pressure- or foot-ulcer healing, or musculoskeletal collagen biology was a principal endpoint. Randomized trials were prioritized. Multi-nutrient interventions containing arginine, zinc, protein, or other components were kept as multi-component evidence rather than assigned to vitamin C alone.

Result

Moisture in the optimized powders was 3.8-4.1% and water activity 0.23-0.25. Thirty-day L-ascorbic acid retention was 88.1%, 89.1%, and 87.5%. The direct dry-mix comparator retained 77.2%, the no-protective-matrix comparator 75.3%, and the conventional carrier 80.2%. Hygroscopicity was 5.8-6.3% for the optimized powders and 10.6-13.6% in several comparators.

Table 1. Accelerated-storage retention and hygroscopicity of selected formulation conditions.

Condition	30-d retention (%)	24-h hygroscopicity (%)
Optimized 1	88.1	5.8
Optimized 2	89.1	6.1
Optimized 3	87.5	6.3
No protective matrix	75.3	13.6
Dry-mixed fruit powders	77.2	12.8
Conventional carrier	80.2	10.6

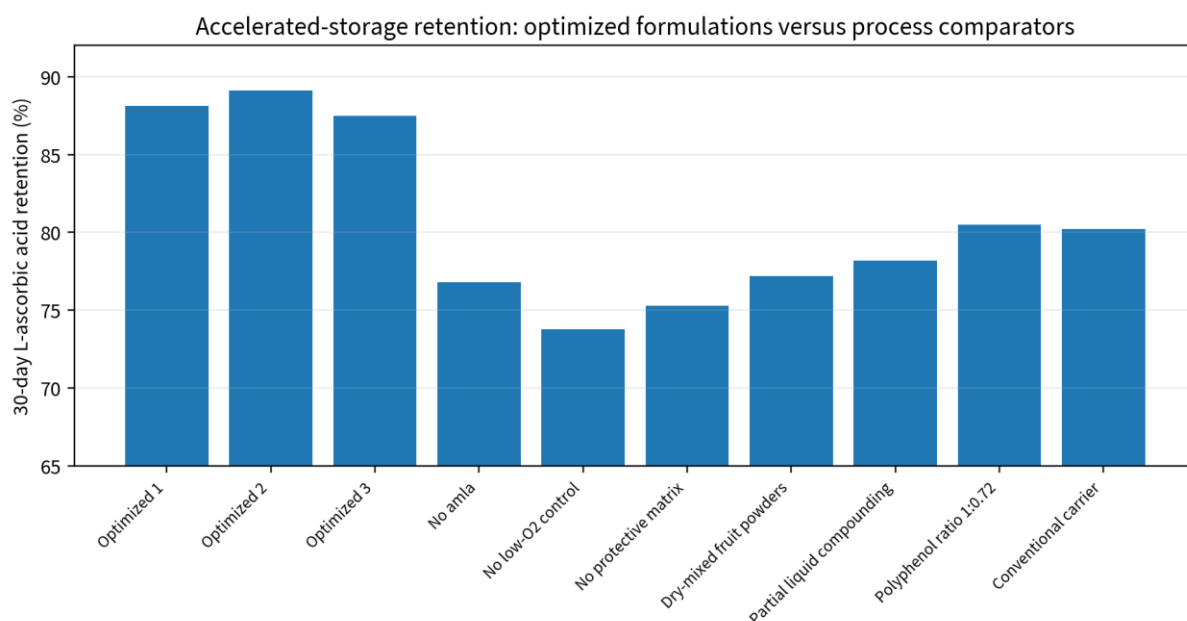


Figure 1. Accelerated-storage L-ascorbic acid retention across optimized and comparator conditions.

Clinical wound responses differed by setting. Gunton et al. randomized 16 people with foot ulcers to 500 mg/day slow-release vitamin C or an inactive comparator; median 8-week change in ulcer size was 100% healing in the vitamin C group versus -14% in control [3]. Ter Riet et al. used 500 mg vitamin C twice daily in pressure-ulcer patients and did not find a higher wound-closure rate than with the low-dose control [4]. Desneves et al. tested a high-protein supplement enriched with arginine, vitamin C, and zinc and reported faster pressure-ulcer healing, although the contribution of vitamin C cannot be separated from the other nutrients [5].

The broader literature shows the same dependence on context. Bechara et al. found favorable healing signals in some pathologies but substantial variation across study size, wound type, baseline status, and accompanying nutrients [2]. DePhillipo et al. reviewed collagen and musculoskeletal-injury research and found strong mechanistic support with more limited controlled human evidence [6].

Clinical Evidence Synthesis

Table 2. Summary of human evidence on vitamin C, collagen formation, and tissue healing.

Study	Design / population	Intervention	Main outcome	Interpretation
Gunton et al., 2021 [3]	Randomized double-blind trial; 16 people with foot ulcers	500 mg/day slow-release vitamin C	Median 8-week ulcer healing 100% vs -14% in control	Positive signal, especially relevant to baseline deficiency
ter Riet et al., 1995 [4]	Multicenter blinded RCT; pressure ulcers	500 mg vitamin C twice daily vs 10 mg twice daily	No higher wound-closure rate in the high-dose group	Demonstrates clinical heterogeneity across wound contexts
Desneves et al., 2005 [5]	Small randomized trial; pressure ulcers	High-protein/energy supplement with arginine, vitamin C and zinc	Improved healing rate in enriched-supplement group	Supports combined nutrition approach; vitamin C-specific contribution not separable
Bechara et al., 2022 [2]	Systematic review of human tissue-healing studies	Vitamin C supplementation across conditions	Improvement reported in selected pathologies, particularly pressure ulcers	Provides broader context while emphasizing study heterogeneity
DePhillipo et al., 2018 [6]	Systematic review; musculoskeletal injury/collagen evidence	Vitamin C	Strong mechanistic/preclinical rationale; controlled human findings limited and mixed	Supports collagen mechanism and guides future direct endpoints

Discussion

For a collagen-oriented ingredient, storage stability is part of dose definition. The optimized powders remained low in water activity and hygroscopicity, while removal of the protective matrix was accompanied by lower ascorbate retention. The formulation variable is therefore not cosmetic: it changes how much vitamin C remains available in the finished powder.

Clinical outcomes cannot be expected to move uniformly because wound repair is constrained by perfusion, infection, glycemic control, protein-energy status, zinc status, vitamin C status, and wound chronicity. In the positive foot-ulcer trial, vitamin C deficiency was common at baseline [3]. The neutral pressure-ulcer trial [4] points in the opposite direction and makes baseline biochemical status an important stratification variable rather than an after-the-fact explanation.

Several mechanistic and nutrition studies help define what to measure next. Boyera et al. reported vitamin-C-dependent increases in collagen deposition and matrix contraction in human fibroblast models [7]. Uchida et al. showed that an acerola matrix altered ascorbate handling compared with isolated vitamin C [8]. In a randomized crossover study, vitamin-C-enriched gelatin taken before

exercise increased a circulating marker of collagen synthesis [9]. Pressure-ulcer nutrition trials by Cereda et al. in 2009 and 2015, and by van Anholt et al., reported faster healing with formulas enriched in protein, arginine, zinc, vitamin C, and antioxidants in defined populations [10]-[12]. Tajima and Pinnell showed preferential enhancement of type I and III collagen gene transcription by ascorbic acid in human skin fibroblasts [13]. Human vitamin C pharmacokinetics are saturable and highly dose dependent [14], consistent with the dose-response work of Levine et al. [15].

6. Research Scope and Future Directions

A direct study of the complete fruit-derived powder could measure plasma vitamin C together with a prespecified collagen or tissue endpoint. In wound populations, standardized wound-area measurements and baseline vitamin C status are essential. In non-wound populations, collagen-turnover markers or skin-barrier measures would allow the nutritional exposure to be tested without importing disease-specific outcomes from unrelated trials.

Conclusion

The optimized fruit-derived powder maintained 87.5-89.1% L-ascorbic acid after 30 days of accelerated storage while remaining low in water activity and hygroscopicity. Human tissue-healing evidence includes both positive and neutral randomized results, and multi-nutrient trials show that the surrounding nutritional state matters. The formulation supplies a defined ascorbate-polyphenol exposure for direct collagen and tissue-integrity studies with baseline status and endpoint selection specified in advance.

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