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Amla Fruit Extract and Vitamin C in Bio C: An Ingredient-Based Narrative Review of Phytochemistry, Antioxidant Mechanisms and Domain-Specific Evidence

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Abstract:

Background. Oxidative stress contributes to cellular damage across many tissues. *Phyllanthus emblica L.* (amla; *Phyllanthaceae*) fruit is distinctive in combining ascorbate with a hydrolysable tannin fraction — emblicanin A, emblicanin B, punigluconin and pedunculagin — whose antioxidant activity exceeds the contribution of the fruit's vitamin C alone.

Objective. To appraise the phytochemistry, antioxidant mechanisms and domain-specific evidence relevant to Bio C, which supplies 900 mg of dried amla fruit extract with 80 mg of vitamin C per serving, separating ingredient-level from finished-product evidence throughout.

Review approach. PubMed, Web of Science, Scopus, Google Scholar and the Cochrane Library were searched for systematic reviews, randomised trials, pharmacokinetic studies and mechanistic reports, each graded against a five-tier hierarchy ending in product-specific evidence.

Principal findings. The antioxidant and metabolic domain is most mature: randomised trials of standardised extract lowered malondialdehyde and raised nitric oxide and glutathione at 250–500 mg twice daily, reduced 8-hydroxy-2′-deoxyguanosine at 500 mg/day, and improved the lipid profile over 12 weeks, with a meta-analysis of nine trials reporting lipid and inflammatory benefit that its authors qualified for substantial heterogeneity. A double-blind placebo-controlled trial of amla monotherapy at 2000 mg/day reduced heartburn and regurgitation in non-erosive reflux disease. Skin and hair rest on mechanistic work with an oral randomised trial of a lingonberry–amla combination and an uncontrolled topical serum study. Ocular relevance is confined to ascorbate physiology; the AREDS base requires 500 mg vitamin C with vitamin E, zinc, copper and carotenoids and is not transferable.

Limitations. Finished-product randomised trials are largely absent across this category, so the appraisal is ingredient-level; extract chemistry varies widely, making marker standardisation the principal quality requirement.

Conclusion. Within the Food Safety and Standards Authority of India framework, supplements of this composition are well positioned for daily antioxidant and nutritional support, with the digestive, hair, skin and eye

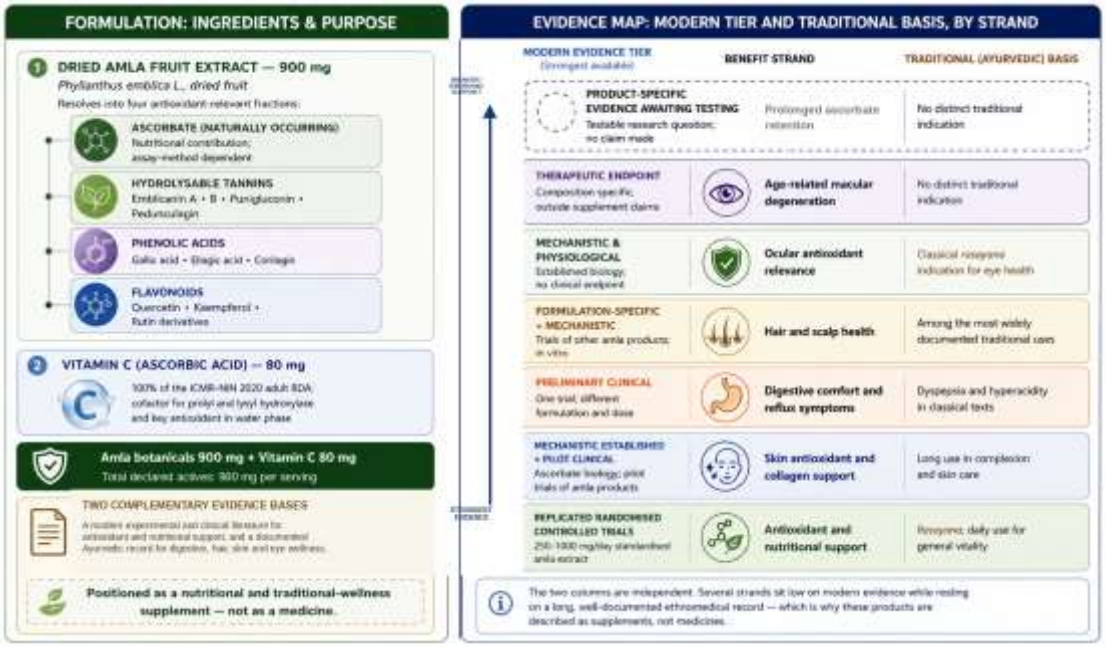
associations communicable as documented in Ayurvedic traditional use. Disease-specific claims remain a separate category requiring product-specific trials.

Keywords: Phyllanthus emblica; amla; vitamin C; hydrolysable tannins; antioxidant; nutraceutical claim substantiation

Highlights

- Amla pairs ascorbate with a hydrolysable tannin fraction, not vitamin C alone.
- Only the antioxidant domain rests on randomised trials and a meta-analysis of amla.
- Marker standardisation, not dose, is the principal quality-control gap.
- Ayurvedic tradition underpins the domains where modern trial evidence is thinnest.

Graphical abstract



Graphical abstract. Left: the two Bio C ingredients arranged by formulation purpose — dried amla fruit extract 900 mg, resolved into its ascorbate, hydrolysable tannin, phenolic acid and flavonoid fractions, and vitamin C 80 mg as the nutritional ascorbate contribution — together with the principal quality-control gap. Right: an evidence ladder placing each proposed benefit domain at the single tier corresponding to the strongest evidence available for it, from randomised trials at the base to not establish at the upper bands. The apex tier's product-specific evidence for Bio C is uncoloured and outlined with a broken line to indicate it is empty.

Abbreviations

8-OHdG, 8-hydroxy-2′-deoxyguanosine; AMD, age-related macular degeneration; ApoA1, apolipoprotein A1; ApoB, apolipoprotein B; ARE, antioxidant response element; AREDS, Age-Related Eye Disease Study; CAT, catalase; FSSAI, Food Safety and Standards Authority of India; GERD, gastroesophageal reflux disease; GPx, glutathione peroxidase; GSH, reduced glutathione; HDL, high-density lipoprotein; HPLC, high-performance liquid chromatography; HPTLC, high-performance thin-layer chromatography; hs-CRP, high-sensitivity C-reactive protein; ICMJE, International Committee of Medical Journal Editors; ICMR-NIN, Indian Council of Medical Research–National Institute of Nutrition; LDL-C, low-density lipoprotein cholesterol; MDA, malondialdehyde; MMP, matrix metalloproteinase; NERD, non-erosive reflux disease; NO, nitric oxide; Nrf2, nuclear factor erythroid 2–related factor 2; PK, pharmacokinetics; QC, quality control; RCT, randomised controlled trial; RDA, recommended dietary allowance; RNS, reactive nitrogen species; ROS, reactive oxygen species; RPE, retinal pigment epithelium; SIRT1, sirtuin

1; SOD, superoxide dismutase; SVCT, sodium-dependent vitamin C transporter; TC, total cholesterol; TG, triglycerides; UL, tolerable upper intake level; UV, ultraviolet; vWF, von Willebrand factor.

1. Introduction

1.1 Oxidative stress and nutritional antioxidant defence

Reactive oxygen species (ROS) and reactive nitrogen species (RNS) are continuously generated through mitochondrial respiration, inflammatory signalling, xenobiotic metabolism and, in surface tissues, environmental insults such as ultraviolet radiation and air pollutants. Macromolecular damage accrues once ROS production exceeds endogenous defences, including superoxide dismutase, catalase, glutathione peroxidase, glutathione, urate and bilirubin reservoirs [1, 2]. Lipid peroxidation in cellular and lipoprotein membranes, oxidative protein modification, and accumulation of oxidative DNA lesions such as 8-hydroxy-2′-deoxyguanosine (8-OHdG) collectively drive the pathobiology of atherosclerosis, neurodegeneration, photoageing and retinal degeneration. Dietary antioxidants — ascorbate, polyphenols and carotenoids — are routinely investigated as adjuncts that may shift the redox balance back towards physiological equilibrium.

1.2 Nutraceutical importance of amla and vitamin C

Phyllanthus emblica L. (syn. *Emblica officinalis Gaertn.*; amla, Indian gooseberry; family *Phyllanthaceae*) is widely studied in modern nutraceutical research and is recognised as more than a vitamin C reservoir because of its hydrolysable tannin fraction [2–4]. The fruit simultaneously delivers ascorbate and a polyphenol–tannin complex, an arrangement that produces documented antioxidant responses in metabolic syndrome, dyslipidaemia and healthy adults at daily doses of 500–1000 mg of standardised extract [5–8]. Vitamin C contributes directly as a reductant, recycles the α-tocopheroxyl radical and supports enzymatic cofactor functions including prolyl and lysyl hydroxylase activity in collagen biosynthesis [9]. The two constituents are therefore conceptually complementary rather than redundant.

1.3 Rationale for the Bio C formulation

Bio C supplies 900 mg of dried amla fruit extract together with 80 mg of vitamin C (ascorbic acid) per serving. The combination is designed to leverage the polyphenol-driven antioxidant activity of amla and to reinforce the nutritional ascorbate pool that supports collagen cofactor functions and glutathione recycling. The formulation is positioned as a daily nutraceutical supporting antioxidant defence and general nutritional adequacy.

1.4 Objective and scope of the review

The review centres on Bio C and evaluates six evidence domains: antioxidant activity; gastroesophageal symptom support, particularly non-erosive reflux disease; vitamin C stability, absorption, bioavailability and retention; ocular antioxidant defence and age-related macular degeneration (AMD) relevance; skin health; and hair biology. In the critical appraisal of Section 14, these six domains resolve into seven appraisal strands, because the ocular domain is graded separately for general ocular antioxidant relevance and for AMD-specific protection, and the vitamin C disposition domain is graded for prolonged systemic retention as a distinct claim. Safety, quality control and regulatory positioning are addressed separately. Throughout, ingredient-level evidence is rigorously distinguished from finished-product evidence; only the antioxidant and nutritional-support domain rests on randomised trials at doses near the 900 mg amla fraction that Bio C delivers. The remaining domains are framed as biologically plausible, mechanistically supported, or supported only at preliminary clinical level until product-specific studies are completed.

2. Literature Search Strategy and Evidence Evaluation

2.1 Databases and search period

Published literature was searched in PubMed, Web of Science, Scopus, Google Scholar and the Cochrane Library, with supplementary hand-searching of the reference lists of identified review articles. Full texts of the retrieved records were assembled and screened as a single working corpus covering amla, *Phyllanthus*

emblica, *Emblica officinalis* and related reviews. The search window covered primarily 2000 to the present, while seminal works on amla polyphenol chemistry and ascorbate metabolism were retained regardless of date.

2.2 Search terms

Search strings combined *Phyllanthus emblica*, *Emblica officinalis*, "amla" and "Indian gooseberry" with domain-specific descriptors including "antioxidant", "malondialdehyde", "MDA", "glutathione", "8-OHdG", "gastroesophageal reflux", "non-erosive reflux disease", "NERD", "age-related macular degeneration", "AMD", "AREDS", "bioavailability", "pharmacokinetics", "skin ageing", "collagen", "SIRT1", "tyrosinase", "melanogenesis", "hair growth", "5α-reductase", "alopecia", "androgenetic alopecia", "metal chelation", "polyphenols", "safety" and "drug interaction". Vitamin C–specific searches also included "ascorbic acid bioavailability", "vitamin C retention", "stability", "oxalate" and "tolerable upper intake level".

2.3 Eligibility criteria

Included were systematic reviews and meta-analyses, randomised controlled trials, controlled observational studies, pharmacokinetic studies, mechanistic experiments on cells, and animal studies where these directly informed human biology. Editorials, conference abstracts without full text, and non-English publications without translation were excluded. Animal and *in vitro* studies were retained only where they provided mechanistic context for human endpoints. Multicomponent formulation studies were retained with explicit acknowledgement that the amla contribution cannot be isolated. Studies of *Phyllanthus* species other than *P. emblica* were admitted only as congeneric supporting evidence and are identified as such wherever cited.

2.4 Evidence hierarchy

Evidence was grouped into five tiers: clinical (human RCTs), preclinical (animal models), mechanistic (cell-based or biochemical), formulation-specific (trials of standardised amla extracts with disclosed composition), and product-specific (trials of the actual Bio C finished product). This hierarchy is used throughout the review to prevent experimental findings from being presented as established clinical efficacy for Bio C. The hierarchy operates within a wider framework of four claim-substantiation pillars — phytochemical plausibility, standardisation and bioavailability, clinical evidence for the ingredient class, and regulatory compliance — which is set out in Figure 3 and applied in Section 13.

3. Bio C: Formulation Profile and Product Rationale

3.1 Product composition

Bio C delivers two principal ingredients per serving: 900 mg of dried amla fruit extract and 80 mg of vitamin C (ascorbic acid). The amla extract provides the polyphenol and tannin foundation that distinguishes the formulation from a vitamin C–only product, while the added ascorbate reinforces nutritional antioxidant status and supports enzymatic cofactor activity. The declared composition is summarised in Table 1, and the marketed presentation and label declaration are shown in Figure 1.

Table 1: Declared composition of Bio C per single daily serving.

Active ingredient	Quantity per serving	Principal rationale
Amla dried fruit extract	900 mg	Polyphenols, hydrolysable tannins and botanical antioxidant activity[2,3,10]
Vitamin C (ascorbic acid)	80 mg	Nutritional antioxidant activity and collagen-formation cofactor[9,11,12]

Fig 1: Bio C as marketed: composition per serving and label declaration. The product supplies 900 mg of dried *Phyllanthus emblica L.* fruit extract, providing hydrolysable tannins (emblicanin A and B, punigluconin, pedunculagin), phenolic acids (gallic and ellagic acid) and flavonoids (quercetin, kaempferol), together with 80 mg of vitamin C (ascorbic acid). The label declares the 80 mg of ascorbate as 100% of the ICMR-NIN 2020 recommended dietary allowance and carries the statement "not for medicinal use", consistent with the nutraceutical positioning argued throughout this review.

3.2 Functional rationale for combining amla and vitamin C

The combination is intended to support complementary activity. Ascorbate donates electrons directly to neutralise ROS and recycles other antioxidants, including the α-tocopheroxyl radical, while amla hydrolysable tannins — emblicanins, punigluconin, pedunculagin, gallic acid, ellagic acid and corilagin — show radical-scavenging behaviour that contributes to tissue antioxidant protection *in vivo* beyond what the fruit's ascorbate alone achieves[10,13] with metal-chelating and protein-binding activity described for hydrolysable tannins as a chemical class[2,4]. Flavonoid constituents such as quercetin and kaempferol derivatives further diversify the antioxidant profile [4]. The pairing is hypothesised, but not directly demonstrated in product-specific trials, to broaden redox defence and to support the regenerative ascorbate cycle [2, 3].

3.3 Dose relevance

Published randomised trials of amla in metabolic syndrome and dyslipidaemia have used 250–500 mg twice daily, equivalent to 500–1000 mg per day, of standardised aqueous or ethyl acetate extracts over 12 weeks[6,7]; a further 18-week crossover trial in healthy adults used 500 mg once daily[5]. The multicentre symptomatic GERD trial of an Ayurvedic multi-herbal formulation containing amla administered a higher total daily dose over 28 days [14]. The 900 mg amla fraction in Bio C is therefore within the active dose envelope of the metabolic syndrome literature, provided the extract is standardised to defined polyphenol markers [3, 7].

3.4 Ingredient evidence versus finished-product evidence

A critical premise of this review is that no clinical trial of the finished Bio C formulation was identified in PubMed, Web of Science, Scopus or the Cochrane Library. All antioxidant, GERD, ocular, skin and hair findings discussed below derive from trials of amla extract, isolated ascorbate or related polyphenols. They are informative but cannot be assumed to transfer to Bio C without confirmation in product-specific RCTs.

3.5 Intended nutraceutical positioning

Bio C is appropriately positioned as an antioxidant and nutritional-support formulation for adults seeking daily redox support. It is not positioned as a treatment for active gastroesophageal reflux disease, AMD, alopecia or dermatological disease. Holding to this positioning protects consumers from over-interpretation of indirect evidence and aligns with the FSSAI provisions that govern health supplements and nutraceuticals in India [15, 16].

4. Botanical Identity, Traditional Use and Nutritional Importance of Amla

4.1 Taxonomy and nomenclature

The accepted botanical name is *Phyllanthus emblica L.*, with *Emblica officinalis Gaertn.* as a primary synonym. Amla is now placed in the family *Phyllanthaceae*, having formerly been classified within *Euphorbiaceae* [2, 17]. Common names include amla, amlaki, Indian gooseberry, anwala, nellikka and usiri. The pharmacologically and nutritionally relevant plant part is the fruit, particularly the dried whole fruit and its aqueous, ethanolic or ethyl-acetate extracts [4].

4.2 Traditional applications

Amla has been used for centuries across the Ayurvedic, Siddha and Unani traditions. Classical Ayurvedic texts describe amla as a *rasayana*, a rejuvenative category associated with general vitality, digestive function, ocular health, hair and scalp care, and tissue integrity [17, 18]. Documented traditional indications include dyspepsia, hyperacidity, colic and flatulence, alongside uses for respiratory comfort, hair and scalp health, eye function and skin complexion [17]. Experimental support for the antistress *rasayana* framing comes from rodent work in which the amla tannoid fraction normalised stress-induced perturbations of brain superoxide dismutase, catalase and glutathione peroxidase activity and reduced lipid peroxidation [19]. Traditional application nevertheless does not constitute modern clinical evidence: dose, extract type and outcome measures differ substantially between traditional practice and contemporary research.

4.3 Nutritional composition

Amla fruit is rich in vitamin C relative to most common fruits and is a meaningful source of carbohydrates, dietary fibre, minerals (notably calcium, phosphorus, iron and potassium), organic acids (malic, citric, mucic and tartaric) and a diverse polyphenol fraction[2,4,18]. Reported vitamin C content of fresh fruit varies widely across cultivars, commonly cited in the range of 200–900 mg per 100 g fresh weight by HPLC, and is substantially higher than in most other common fruits. The fruit is low in fat, contains appreciable mucilage and pectin, and offers considerable nutritional density per 100 g edible portion [4].

4.4 Factors affecting phytochemical composition

Phytochemical content in amla varies with cultivar, maturity at harvest, geographic and climatic conditions during growth, soil mineral composition, post-harvest drying method, extraction solvent and conditions, and storage stability [3, 4]. Aqueous and hydroalcoholic extracts differ in tannin yield, while drying temperature influences retention of heat-labile ascorbate and certain flavonoids. These factors materially affect the antioxidant content of any dried amla extract and complicate direct dose translation between studies. Recent metabolomic and quality-marker reviews of *P. emblica* identify this chemical variability and the prevalence of non-standardised formulations as the principal quality-control gap in the published literature [3, 4].

5. Phytochemical Profile and Standardisation of Amla Extract

5.1 Vitamin C and related analytical considerations

Vitamin C in amla exists partly as free ascorbic acid and partly as a heat-stable, protein-associated ascorbate complex that resists degradation during drying. Reported vitamin C values differ widely between studies and between preparations of the same fruit: validated HPLC with diode-array detection gives 0.4% (w/w) ascorbic acid in the raw fruit, rising to 1.28% (w/w) after classical Ayurvedic processing, with ascorbate accounting for only part of the measured antioxidant activity [20]. Commercial extracts differ correspondingly, and in one comparative analysis ascorbic acid was undetectable in one of four marketed preparations [21]. Modern HPLC-based assays with ultraviolet or mass spectrometric detection provide more reliable quantification. Any reference to the “vitamin C content” of an amla extract should therefore specify the analytical method. Functional-beverage stability work has additionally shown that processing method, extraction solvent and storage temperature materially affect the ascorbate titre in finished amla products [22].

5.2 Hydrolysable tannins

The hallmark tannin fraction of amla comprises emblicanin A, emblicanin B (a pedunculagin-type ellagitannin), and their hydrolysis products including punigluconin and pedunculagin. A tannoid fraction characterised as emblicanin A 37%, emblicanin B 33%, punigluconin 12% and pedunculagin 14% has been the basis of much of the primary antioxidant work on the fruit [10]. These tannins undergo hydrolysis to release gallic acid, ellagic acid and glucose moieties; the parent molecules and their hydrolysis products contribute differentially to radical scavenging, metal chelation and protein binding [2–4]. Emblicanin A and B are frequently used as quantitative markers for extract standardisation. The dyslipidaemia trial used an ethyl acetate extract standardised to not less than 35% polyphenols, 8% triterpenoids and 10% oil [7] whereas the metabolic syndrome trial used an aqueous extract standardised by high-performance liquid chromatography to its low-molecular-weight hydrolysable tannins [6].

5.3 Phenolic acids

Gallic acid and ellagic acid are the dominant low-molecular-weight phenolic acids in amla. Both are well characterised for antioxidant, anti-inflammatory and protein-binding behaviour, and ellagic acid in particular has been investigated for dermal, mucosal and metabolic effects [4]. Corilagin, an ellagitannin glucoside, has been confirmed by RP-HPLC alongside gallic and ellagic acids in commercial *P. emblica* fruit extracts, which show DPPH, superoxide-anion and hydroxyl-radical scavenging activity that varies markedly between preparations [21]; the tannoid fraction as a whole is the principal carrier of the fruit's antioxidant activity [10].

5.4 Flavonoids and additional phytochemicals

Amla contains flavonoid constituents including quercetin, kaempferol and rutin derivatives, along with smaller amounts of additional polyphenols, organic acids, sugars and amino acids [4]. Although present at lower concentrations than the hydrolysable tannins, flavonoids contribute complementary radical-scavenging and metal-chelating behaviour. *In vitro* characterisation of *Phyllanthus* extracts indicates that quercetin content varies with extraction method and that quercetin may contribute to stimulation of collagen biosynthesis in human dermal fibroblasts, activation of SIRT1 and activation of the FOXO1 transcription factor; it should be noted that this particular characterisation was performed on *Phyllanthus indofischeri Bennet*, a congeneric Indian gooseberry species, and not on *P. emblica*, so it is cited here as congeneric supporting evidence only[23]. Minor constituents include mucic acid, certain lignans, carotenoids and ascorbate oxidase–related proteins that influence product stability during processing [4].

5.5 Relationship between phytochemical composition and antioxidant activity

Multiple studies have demonstrated that the antioxidant capacity of amla extracts cannot be explained by ascorbate content alone. The primary tannoid work on the fruit concluded explicitly that the antioxidant activity of *E. officinalis* resides in the tannoids of the fruit, which possess vitamin C–like properties, rather than in vitamin C itself: the tannoid fraction raised frontal cortical and striatal superoxide dismutase, catalase and glutathione peroxidase activity with a concomitant fall in lipid peroxidation [10]. The implication for Bio C is that the 900 mg amla fraction contributes antioxidant activity through tannin and phenolic-acid constituents over and above its intrinsic ascorbate, and that the 80 mg of added vitamin C should be regarded as a nutritional adjunct rather than the principal antioxidant driver [3, 10, 13].

5.6 Extract standardisation requirements

For Bio C to be interpretable to clinicians and consumers, the dried amla fruit extract should be characterised by:

- a declared native extract ratio (for example 10:1 or 20:1);
- the extraction solvent (typically water, ethanol or a hydroalcoholic mixture);
- declared total hydrolysable tannin or polyphenol content, as gallic acid or tannic acid equivalents;
- quantitative emblicanin A and B, gallic acid and ellagic acid markers by HPLC;
- an HPLC or HPTLC fingerprint;
- Moisture content and stability data across shelf life.

Without this information, "900 mg of amla extract" is scientifically incomplete and dose translation from published studies remains approximate [3, 4, 7].

6. Antioxidant Mechanisms and Clinical Evidence

6.1 Oxidative stress and cellular injury

Oxidative stress arises from an imbalance between ROS production and antioxidant defences. The superoxide anion, hydrogen peroxide and the hydroxyl radical target polyunsaturated lipids in cellular and lipoprotein membranes, generating lipid hydroperoxides and downstream aldehydes such as malondialdehyde and 4-hydroxynonenal. Proteins undergo oxidative modification of cysteine, methionine and aromatic residues, often with loss of enzymatic activity. Nuclear and mitochondrial DNA accumulate oxidative lesions, of which 8-OHdG is the most studied. Mitochondrial dysfunction perpetuates ROS production, establishing a feed-forward loop. The retina is among the most metabolically active and most environmentally exposed tissues in the body, which makes retinal oxidative damage a leading candidate mechanism in AMD pathogenesis[24–26].

6.2 Direct radical-scavenging mechanisms

Ascorbate donates a hydrogen atom or electron to a variety of radical species, yielding the ascorbyl radical, which is regenerated by NADH-dependent reductases or by interaction with other small-molecule antioxidants [9]. In the presence of free, catalytically active transition-metal ions, ascorbate can reduce metal centres and generate hydrogen peroxide and hydroxyl radicals *in vitro*; systematic appraisal of the *in vivo* data nevertheless finds consistent antioxidant rather than pro-oxidant behaviour at nutritional intakes [27]. Amla polyphenols scavenge radicals through hydrogen donation from phenolic hydroxyl groups, with the resulting phenoxyl radical stabilised by the conjugated tannin scaffold. Isolated gallate and catecholate phenolics chelate redox-active iron and copper and thereby limit hydroxyl-radical generation, although whole amla extracts have been reported not to chelate iron(II) appreciably at achievable concentrations, so the contribution of chelation to the activity of a whole-fruit extract should not be overstated[4,21].

6.3 Inhibition of lipid peroxidation

Lipid peroxidation in low-density lipoprotein and cellular membranes is a key mediator of atherosclerosis and membrane dysfunction. Ascorbate protects lipids by intercepting peroxyl radicals at the aqueous–lipid interface; amla polyphenols demonstrate complementary behaviour, with tannin binding to apolipoprotein and membrane domains. In an isolated rat heart ischaemia–reperfusion model, an emblicanin-A– and emblicanin-B–enriched fraction of amla fruit juice given at 50 and 100 mg/kg prevented the reperfusion-induced fall in cardiac superoxide dismutase, catalase and glutathione peroxidase activity and the accompanying rise in lipid peroxidation, with vitamin E at 200 mg/kg as the comparator antioxidant [13]. Together these complementary activities suggest broader membrane protection than either class provides alone, although direct synergy in human physiology remains to be demonstrated in product-specific trials.

6.4 Endogenous antioxidant defence

Beyond direct scavenging, antioxidant nutrients support the enzymatic defence system. Ascorbate contributes to the maintenance of reduced glutathione by serving as a cofactor in redox recycling [9]. Amla tannoids have been reported in preclinical studies to raise the activity of superoxide dismutase, catalase and glutathione peroxidase [10, 13] and amla feeding improves hepatic and renal antioxidant status in high-fat-fed rats [28]. In the randomised metabolic-syndrome trial of 250 mg and 500 mg *P. emblica* aqueous extract twice daily for 12 weeks, the change in reduced glutathione at 12 weeks was +24.31% (250 mg twice daily) and +53.22% (500 mg twice daily), with corresponding MDA reductions of −21.02% and −31.44% and NO increases of +41.89% and +50.70%, each statistically significant versus placebo [6]. The 18-week crossover study of 500 mg/day amla extract additionally reported significant reductions in 8-OHdG and von Willebrand factor alongside an increase in HDL cholesterol [5].

6.5 Nrf2–ARE–mediated cytoprotection

The nuclear factor erythroid 2–related factor 2–antioxidant response element pathway regulates a battery of cytoprotective genes, including phase II detoxification enzymes such as heme oxygenase-1, NAD(P)H-quinone dehydrogenase 1 and glutathione S-transferase. Dietary polyphenols, including quercetin, resveratrol and curcumin, have been documented to induce Nrf2 nuclear translocation and downstream transcription in retinal pigment epithelium [25]. Selected *Phyllanthus* polyphenol fractions have similarly induced activation of the SIRT1 longevity pathway and the FOXO1 transcription factor *in vitro*, although in the study reporting the largest effects the material tested was *P. indofischeri* rather than *P. emblica* [23]. The inference is that amla may upregulate endogenous defences over hours to days, complementing its direct scavenging; this pathway is plausible but remains to be confirmed at clinical dose and duration in humans for the Bio C formulation.

6.6 Interaction between vitamin C and amla polyphenols

Ascorbate is well known to recycle the α-tocopheroxyl radical at the membrane surface [9]. By analogy, ascorbate may also regenerate oxidised polyphenol intermediates in solution and at the mucosal interface, although the quantitative significance of any such recycling within a single supplement dose is not established. Mixed antioxidant formulations used as adjuncts in ophthalmology operate on the same complementary principle: each component supplies its own mechanism of action without evidence of interference [24, 25]. It is appropriate to frame the ascorbate–polyphenol interaction in Bio C as complementary rather than as proven pharmacological synergy. The two mechanistic arms and their convergent biomarker outputs are summarised in Figure 2.

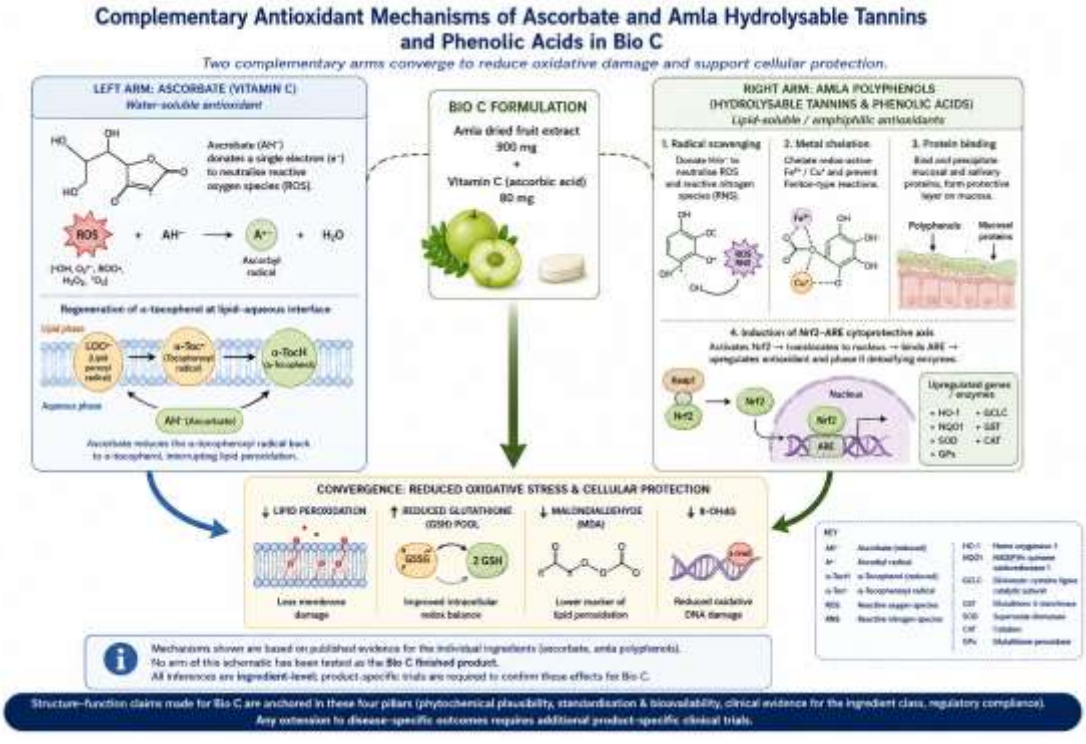


Fig 2: Complementary antioxidant mechanisms of ascorbate and amla hydrolysable tannins and phenolic acids in Bio C. Ascorbate (left arm) donates single electrons to neutralise reactive oxygen and nitrogen species and regenerates the α-tocopheroxyl radical at the lipid–aqueous interface. Amla polyphenols (right arm) scavenge radicals, chelate redox-active Fe^{2+} and Cu^{+}, bind mucosal proteins and induce the Nrf2–ARE cytoprotective axis. The two arms converge on reduced lipid peroxidation, an improved reduced-glutathione pool and lower malondialdehyde and 8-hydroxy-2′-deoxyguanosine. The four claim-substantiation pillars named in the lower banner are defined in Figure 3. No arm of this schematic has been tested as the Bio C finished product; all inferences are ingredient-level.

6.7 Preclinical antioxidant evidence

In vitro studies consistently show that amla extracts scavenge DPPH, ABTS and superoxide radicals and register high ferric-reducing antioxidant power [4, 21]; an *E. officinalis* extract also improved viability and mitochondrial membrane potential and lowered reactive oxygen species in human retinal pigment epithelial cybrids derived from patients with age-related macular degeneration [29]. In rats fed a high-fat diet, amla supplementation reduced hepatic and renal oxidative stress and the accompanying inflammatory response[28]; tannoid fractions likewise normalised brain and myocardial antioxidant enzyme activity and lipid peroxidation under stress and ischaemia-reperfusion challenge[13,19]. The mechanistic finding that *P. emblica* fruit extract raises type I procollagen in primary mouse fibroblasts by 1.65-fold on immunocytochemistry and 6.78-fold on Western blot at 0.1 mg/mL, while inhibiting collagenase activity by up to 78.67 ± 3.51% at 1 mg/mL [30] is reproduced in human skin fibroblasts, where amla extract promotes procollagen production and inhibits matrix metalloproteinase-1[31, 32].

6.8 Human clinical evidence

Randomised controlled trials of standardised amla extract in metabolic syndrome, dyslipidaemia and healthy adults show:

- • 250 mg and 500 mg *P. emblica* aqueous extract twice daily for 12 weeks decreased reflection index and increased NO and GSH, and reduced MDA, in subjects with metabolic syndrome versus placebo, with statistically significant between-group differences favouring the higher dose[6];
- • 500 mg/day amla for 18 weeks improved blood fluidity and lowered von Willebrand factor and 8-OHdG alongside an increase in HDL cholesterol in a crossover healthy-volunteer study[5];
- • 500 mg amla ethyl-acetate extract standardised to not less than 35% polyphenols, 8% triterpenoids and 10% oil, administered twice daily for 12 weeks, reduced TC, TG, LDL-C and VLDL-C versus placebo in 98 dyslipidaemic adults, with favourable safety data; the fall in the ApoB/ApoA1 ratio was significant within-group but not between groups ($p = 0.087$)[7];
- • a 2023 systematic review and meta-analysis of *E. officinalis* fruit consumption concluded that the fruit reduces cardiovascular-disease risk factors across multiple small-to-moderate trials[33];
- • A 2024 narrative review describes *E. officinalis* as a promising nutraceutical candidate for metabolic syndrome prevention, with mechanistic concordance across preclinical and clinical findings [8].

These trials use daily amla doses spanning 500–2000 mg, a range that brackets the 900 mg fraction of Bio C by weight; the studies are summarised in Table 2. Comparability by weight is not the same as comparability by potency, because the trial extracts were standardised to declared marker content and the corresponding characterisation for this class of finished product is generally not published (Section 15.1). The 80 mg of ascorbate in Bio C delivers 100% of the ICMR-NIN 2020 recommended dietary allowance for Indian adults, the reference value declared on the product label, and is comparable to the United States allowances of 75 mg for women and 90 mg for men; it is nevertheless well below the 200 mg/day proposed as the optimum adult intake based on combined metabolic, pharmacokinetic, observational and phase II randomised evidence [11].

Table 2: Randomised controlled trials and evidence syntheses of standardised *Phyllanthus emblica* extract at daily doses of 500–2000 mg, spanning and exceeding the Bio C amla fraction.

Source	Design	Daily dose	Duration	Participants	Primary efficacy endpoint	Key biomarker changes	Safety findings
Usharani 2019[6]	Randomised, double-blind, placebo-controlled	250 mg b.i.d. and 500 mg b.i.d. aqueous extract	12 weeks	59 adults with metabolic syndrome	Reflection index; NO, GSH, MDA	GSH +24.31% (250 mg) and +53.22% (500 mg);	Favourable; no clinically significant laborator

						MDA −21.02% and −31.44%; NO +41.89% and +50.70%	y changes
Kapoor 2019[5]	Randomised, double-blind, crossover, placebo-controlled	500 mg/day	18 weeks	15 healthy volunteers	Blood fluidity; vWF, 8-OHdG, HDL	Significant reductions in vWF and 8-OHdG; significant increase in HDL cholesterol	Favourable; no adverse events or tolerance issues
Upadya 2019[7]	Randomised, double-blind, placebo-controlled, multicentre	500 mg b.i.d. ethyl-acetate extract, ≥35% polyphenols, 8% triterpenoids, 10% oil	12 weeks	98 dyslipidaemic adults	TC, TG, LDL-C, ApoB, ApoB/ApoA1	Significant reductions in TC, TG, LDL-C and VLDL-C versus placebo; the ApoB/ApoA1 fall was significant within-group only (p = 0.087 between groups)	4 mild adverse events in 98 participants (3 placebo, 1 amla)
Brown 2023[33]	Systematic review and meta-analysis of 9 RCTs	500–1500 mg/day across included trials	14–84 days	535 pooled participants	Cardiovascular-disease risk factors	Reductions in LDL-C (−15.08 mg/dL), VLDL-C, triglycerides and hs-CRP; authors caution that heterogeneity limits confidence	Acceptable across pooled trials
Karkon Varnosfaderani 2018[34]	Randomised, double-blind,	500 mg tablets, two twice daily	4 weeks	68 adults with non-erosive reflux	Heartburn and regurgitation frequency	Significantly greater reduction in all four	Well tolerated; no safety signal

	placebo-controlled	(2000 mg/day), after meals		disease	and severity	measures versus placebo (P < 0.001)	reported
Prabhakar 2024[8]	Narrative review of metabolic syndrome prevention	500–1000 mg/day in the cited clinical evidence	Various	Multiple cited preclinical and clinical studies	Mechanistic concordance across studies	Concordance for antioxidant, anti-inflammatory and lipid-modulating actions	Acceptable across cited evidence

6.9 Relevance to the Bio C formulation

The strongest direct support for the antioxidant rationale of Bio C is the convergence of replicated human RCT biomarker improvements at standardised doses overlapping 900 mg/day[5–7,33]. The 80 mg of added ascorbate reinforces nutritional ascorbate status and supports collagen cofactor activity. The amla fraction contributes polyphenol-driven antioxidant activity that cannot be replicated by ascorbate alone [10].

Suggested structure–function claim: Provides a botanical polyphenol matrix and vitamin C that contribute to the protection of cells from oxidative stress.

Evidence tier: Clinical — multiple randomised trials and a meta-analysis of standardised amla extract at doses bracketing the Bio C amla fraction for the ingredient; the product-specific tier is empty[5–7,33].

7. Gastroesophageal Reflux and Digestive Symptom Relevance

7.1 Pathophysiology of GERD and non-erosive reflux disease

GERD develops when gastric contents reflux into the oesophagus with sufficient frequency or volume to produce symptoms or mucosal injury. Acid exposure, pepsin activity, transient lower oesophageal sphincter relaxation and impaired oesophageal clearance all contribute. Non-erosive reflux disease is the predominant symptomatic phenotype, characterised by heartburn and regurgitation without visible mucosal breaks on endoscopy. Oesophageal mucosal sensitivity, low-grade inflammation and oxidative stress are increasingly recognised as contributors to NERD symptom generation, providing a conceptual bridge to antioxidant nutraceuticals.

7.2 Traditional gastrointestinal use of amla

Ethnopharmacological reviews of *P. emblica* fruit record traditional use for dyspepsia, hyperacidity, colic, flatulence, peptic ulcer, diarrhoea and dysentery across the Ayurvedic, Siddha and Unani systems [17]. This traditional use is empirical and predates modern diagnostic categorisation; it does not map directly onto GERD as defined today, but it establishes the cultural and historical context for investigating amla in reflux-related symptoms.

7.3 Clinical evidence in non-erosive reflux disease and symptomatic GERD

The strongest published evidence for amla in reflux symptoms is a double-blind, randomised, placebo-controlled trial of amla monotherapy in non-erosive reflux disease. Sixty-eight adults with at least three months of classic reflux symptoms received two 500 mg amla tablets twice daily after meals, a total of 2000 mg/day, or matching placebo for four weeks. Reductions in the frequency and the severity of both heartburn and regurgitation were significantly greater in the amla arm than in the placebo arm ($P < 0.001$ for each) on the reflux-associated quality-of-life instrument [34]. A separate open-label multicentre comparative study of a multi-herbal Ayurvedic capsule containing amla versus omeprazole 20 mg in 63 adults over 28 days reported within-group improvement in heartburn, acid-regurgitation and GERD health-related quality-of-life scores in both arms[14]; being open-label and multi-herbal, it cannot isolate the amla

contribution. Additional preclinical support comes from a rodent gastroprotective and motility study of an amla plus honey combination alongside pantoprazole and rebamipide [35].

7.4 Possible mechanisms

Mechanistic hypotheses that may explain a symptomatic benefit of amla in reflux include: (i) antioxidant activity at the oesophageal mucosa, reducing oxidative damage to epithelial cells; (ii) mucosal cytoprotection through polyphenol–protein interactions at the epithelial surface; (iii) anti-inflammatory activity reducing low-grade neutrophilic infiltration; and (iv) modulation of mucosal sensitivity to acid. None of these mechanisms was measured in the cited clinical or preclinical studies [34, 35], and none has been demonstrated clinically for Bio C or for the specific formulation used in the published trial; they are best framed as plausible biological mechanisms warranting investigation.

7.5 Relevance and limitations for Bio C

The placebo-controlled trial that isolates amla used 2000 mg/day, more than twice the 900 mg/day amla fraction in Bio C, and enrolled patients with diagnosed non-erosive reflux disease rather than general consumers[34]; the comparative trial used a different multi-herbal formulation altogether[14]. The animal-model doses used to generate motility and gastroprotection data do not translate directly to a 900 mg/day human serving. A supplement of this composition should therefore be described as offering potential support for digestive comfort, not as a treatment for reflux disease [34].

7.6 Gastrointestinal tolerability of vitamin C

Ascorbic acid is well tolerated across a broad range of intakes; the only consistently reported adverse effect is occasional gastrointestinal upset or mild diarrhoea arising from the osmotic effect of unabsorbed ascorbate at doses far above the amount in a nutritional supplement [36]. At the 80 mg dose in Bio C, such effects are uncommon and usually mild. Consumers with known ascorbate sensitivity or a prior history of intolerance should be advised to take the product with food.

Suggested structure–function claim: Traditionally used in Ayurveda to support digestive comfort; not indicated for the treatment of reflux disease.

Evidence tier: Clinical, at a higher dose than this formulation — one double-blind placebo-controlled trial of amla monotherapy at 2000 mg/day in non-erosive reflux disease, a comparative trial of a different multi-herbal formulation, supporting rodent data, and a long classical record for dyspepsia and hyperacidity[14,17,34,35].

8. Vitamin C Stability, Absorption, Bioavailability and Retention

8.1 Intestinal absorption and renal handling of vitamin C

Ascorbate is absorbed in the small intestine and handled in the kidney by the sodium-dependent vitamin C transporters SVCT1 and SVCT2, encoded by SLC23A1 and SLC23A2. SVCT1 is the absorptive isoform, expressed in the intestine, renal proximal tubule and liver, where it mediates dietary uptake and renal reabsorption; SVCT2 is distributed throughout the body and transports ascorbate into tissues [37]. In *Slc23a1*-null mice, the dominant phenotype is renal: fractional ascorbate excretion rises up to 18-fold and hepatic portal accumulation is nearly abolished, whereas intestinal absorption is only marginally affected [38]. The transporter's principal contribution to whole-body ascorbate economy is therefore renal reabsorption rather than intestinal uptake, a distinction that matters when interpreting claims about ascorbate retention.

8.2 Plasma saturation and renal regulation

Plasma vitamin C concentrations are tightly regulated. Depletion–repletion pharmacokinetics in healthy volunteers describe a steep sigmoid relationship between dose and plasma concentration: there is no urinary excretion below about 100 mg/day, the plateau is approached at 200 mg/day, and above 500 mg single doses bioavailability falls while the absorbed fraction is excreted[37,39]. The ICMR-NIN 2020 recommended dietary allowance for adults is 80 mg/day, the reference value against which the Bio C label declares 100% RDA; comprehensive review of the scientific evidence base has proposed an optimum adult

intake of 200 mg/day based on plasma saturation kinetics and dose-dependent health benefit, and intakes providing at least adequate, if not saturating, plasma levels of approximately 100–200 mg/day have been recommended for cellular and tissue sufficiency [9, 11]. The 80 mg level in Bio C therefore meets the Indian nutritional reference value while sitting at the lower end of the range proposed for optimal antioxidant benefit, and is best understood as supporting maintenance of plasma ascorbate.

8.3 Effect of the food or botanical matrix

Co-ingestion of polyphenol-rich foods and beverages can affect ascorbate stability and absorption. Phytochemical analysis of a functional Indian gooseberry beverage containing turmeric, ginger, lime and black pepper showed that nutrient-matrix interactions significantly influence vitamin C retention during storage, with ascorbate loss tied to dissolved oxygen, processing temperature and container headspace [22]. Polyphenols may in principle protect ascorbate during gastrointestinal transit by scavenging oxidants in the lumen, although this has not been quantified for Bio C.

8.4 Vitamin C stability in amla preparations

In amla, vitamin C exists partly in a heat-stable, protein-associated form that survives drying better than free ascorbate. Finished-product vitamin C content is nevertheless sensitive to drying temperature, oxygen exposure during manufacture, light, residual moisture, extraction solvent polarity and storage conditions. Storage studies of *P. emblica* fruit preparations show progressive ascorbate loss over months even in sealed containers, with degradation accelerating in oxygen-exposed and unfilled containers; in one herbal-drink study ascorbate fell from an initial 61.0 mg/100 g to 54.47 mg/100 g after the first month, 42.36 mg/100 g after the second and 36.39 mg/100 g after the third month of refrigerated storage [22]. Vitamin C loss during storage is driven by photolysis, oxidation, peroxides, thermolability and the action of ascorbate oxidase and peroxidase enzymes [4, 22].

8.5 Evidence for prolonged vitamin C retention

Reports suggesting that amla-derived polyphenols may prolong ascorbate half-life or reduce its rate of post-ingestion decline, plausibly through antioxidant protection during absorption, derive primarily from rodent work and a small number of human pharmacokinetic observations. Given that plasma ascorbate is constrained by absorption and renal handling in humans [39], that the transporter evidence locates the principal determinant of retention in renal reabsorption [38] and that no human pharmacokinetic study of a dual-component amla plus ascorbate product has been published, the question is untested rather than settled.

8.6 Stability versus biological retention

A consistent terminological distinction is essential when describing vitamin C disposition in Bio C. Stability refers to preservation of ascorbate in the finished product over shelf life. Absorption refers to entry into the circulation. Bioavailability refers to the fraction of ingested ascorbate reaching the systemic circulation. Retention refers to persistence of ascorbate concentrations in plasma or tissues over time. These four descriptors are independent and should not be conflated.

8.7 Implications for Bio C

The defensible phrasing for Bio C is “potential influence of the amla matrix on vitamin C stability and disposition” rather than “longer retention time”. Bio C provides 80 mg of ascorbate in a nutritional dose sufficient to support plasma ascorbate concentrations, alongside a polyphenol fraction that may aid stability during storage and gastrointestinal transit. Any assertion of prolonged systemic retention is not currently defensible from clinical evidence on the finished Bio C formulation.

9. Ocular Antioxidant Defence and Age-Related Macular Degeneration

9.1 Oxidative stress in retinal ageing

The retina is among the most metabolically active tissues in the body. Continuous photon absorption by photoreceptor outer segments, high mitochondrial density in the retinal pigment epithelium, and a uniquely

high oxygen tension at the choroidal interface create a sustained oxidant load. Photochemical reactions, lipofuscin accumulation within RPE cells and progressive mitochondrial inefficiency together drive chronic oxidative stress, while oxidative damage to the retinal antioxidant enzyme system — including superoxide dismutase and glutathione peroxidase, together with small-molecular-weight antioxidants such as carotenoids and ascorbate — is implicated in AMD pathogenesis[25,26].

9.2 Physiological role of vitamin C in ocular tissues

Ascorbate is concentrated in the aqueous and vitreous humour at many times the plasma concentration, a gradient attributed to SVCT2 expressed in the ciliary epithelium and retinal pigment epithelium [37]. Within the eye, ascorbate has been shown in ex vivo and animal models to attenuate ultraviolet light by absorption, and its depletion increases ultraviolet-B-induced lens epithelial damage [24]. It scavenges the superoxide anion radical, hydrogen peroxide, the hydroxyl radical, singlet oxygen and reactive nitrogen species, and contributes to the prevention of membrane lipid peroxidation [24, 26]. Vitamin C deficiency has long been associated with increased cataract risk, supporting a role for ascorbate in long-term lens and ocular health.

9.3 Evidence from AREDS and AREDS2

The Age-Related Eye Disease Study and AREDS2 provide the principal reference for antioxidant-based AMD risk reduction. The original AREDS formulation comprised 500 mg of vitamin C, 400 IU (approximately 270 mg) of vitamin E, 15 mg of beta-carotene, 80 mg of zinc as zinc oxide and 2 mg of copper as cupric oxide. AREDS2 refined this by largely replacing beta-carotene with 10 mg of lutein plus 2 mg of zeaxanthin — particularly for current and former smokers, given the lung-cancer signal associated with beta-carotene — while leaving vitamin C, vitamin E and copper unchanged and re-evaluating the zinc dose at 25 mg against the original 80 mg[40–43]. In exploratory analysis, lutein and zeaxanthin versus beta-carotene was associated with a hazard ratio of 0.82 (95% CI 0.69–0.96) for progression to late AMD [40]. In the AREDS2 randomised trial itself (4203 participants, median follow-up five years), lutein and zeaxanthin supplementation was not associated with excess adverse events, whereas beta-carotene was associated with more lung cancers, predominantly among former smokers [43, 44].

9.4 Limitations of extrapolating AREDS evidence

AREDS supplements deliver 500 mg of vitamin C, several-fold higher than the 80 mg in Bio C, alongside vitamin E, zinc, copper and macular carotenoids — none of which are ingredients in Bio C. The published AREDS benefit cannot be transferred to a formulation lacking these components. The component-by-component comparison is set out in Table 3. Any health communication suggesting AREDS-equivalent benefit for Bio C is therefore untenable [40–42].

Table 3: AREDS [45] and AREDS2 [40, 41] formulations compared with Bio C, showing why the AREDS evidence base is not transferable.

Component	AREDS (original)	AREDS2	Bio C
Vitamin C (ascorbic acid)	500 mg	500 mg	80 mg
Vitamin E (α-tocopherol)	400 IU (~270 mg)	400 IU (~270 mg)	Not present
Beta-carotene	15 mg	Largely replaced by lutein and zeaxanthin	Not present
Zinc (as zinc oxide)	80 mg	80 mg, with 25 mg also evaluated	Not present
Copper (as cupric oxide)	2 mg	2 mg	Not present
Lutein	Not present	10 mg	Not present
Zeaxanthin	Not present	2 mg	Not present
Docosahexaenoic acid	Not present	350 mg (tested; no additional AMD	Not present

		benefit)	
Eicosapentaenoic acid	Not present	650 mg (tested; no additional AMD benefit)	Not present
Dried amla (*P. emblica*) fruit extract	Not present	Not present	900 mg
Transferability of the AMD risk-reduction finding	Reference formulation	Reference formulation (modified)	Not transferable; formulation lacks the required components and dose

9.5 Evidence for amla in ocular health

Several *in vitro* and preclinical studies report that polyphenols, including quercetin and other flavonoids, protect retinal pigment epithelial cells against oxidative stress and can suppress vascular endothelial growth factor expression. Quercetin, fisetin, luteolin, resveratrol and curcumin each have documented cytoprotective activity in RPE models, acting through direct ROS scavenging, Nrf2 activation, modulation of A2E photo-oxidation, inhibition of lipid peroxidation — with quercetin protecting ARPE-19 cells against 4-hydroxynonenal-induced stress and decreasing mRNA expression of IL-6, IL-8 and MCP-1 — and autophagy induction[25]. Amla-specific ocular work is preclinical but does exist: an *E. officinalis* extract improved cell viability and mitochondrial membrane potential and reduced reactive oxygen species and apoptosis in human retinal pigment epithelial cybrids derived from patients with age-related macular degeneration [29]. Amla-specific ocular trials at the clinical level remain absent.

9.6 Relevance to Bio C

Bio C supports ocular antioxidant physiology through its ascorbate and polyphenol content. Bio C is not an AMD-preventive formulation, is not a substitute for AREDS or AREDS2 in patients with intermediate AMD, and has not been demonstrated to alter AMD progression. Mendelian randomisation analysis of circulating micronutrients found no causal effect of circulating vitamin C on age-related macular degeneration, cataract, glaucoma or diabetic retinopathy[46] and a cross-sectional national survey of nutritional intake reinforces the importance of overall dietary micronutrient patterns without establishing a causal role for any single ingredient[47]. Observational data on sunlight exposure and antioxidant status point the same way[48]; earlier reviews of carotenoids and antioxidant vitamins argued for a protective effect, but that literature has not resolved into a single-nutrient conclusion[49]. Defensible language for a supplement of this composition is therefore "ocular antioxidant support as part of daily nutrition", alongside the traditional Ayurvedic association of amla with eye health [17] rather than any AMD-specific claim [24, 25, 40, 43].

Suggested structure–function claim: Provides vitamin C, which contributes to normal collagen formation and to the protection of cells from oxidative stress, and is traditionally used in Ayurveda in support of eye health.

Evidence tier: Established ocular ascorbate physiology with a classical traditional indication; AMD risk reduction is a therapeutic endpoint tied to the AREDS composition and lies outside the claim space of a general supplement [18, 24, 40–42].

10. Skin Health and Healthy Ageing

10.1 Vitamin C and collagen biosynthesis

Ascorbate is an essential cofactor for prolyl hydroxylase and lysyl hydroxylase, the enzymes that hydroxylate proline and lysine residues during procollagen synthesis. Hydroxylation stabilises the procollagen triple helix and enables proper fibril assembly. In vitamin C deficiency, hydroxylation fails, and scurvy develops with impaired wound healing and dermal fragility; at nutritional doses, ascorbate supports normal collagen turnover, and normal skin maintains high ascorbate concentrations in support of this function [12]. Skin-protective polyphenols, including those found in *Phyllanthus* extracts, have been documented with anti-melanogenic, pro-collagen and photoprotective activities *in vitro*[30,32,50].

10.2 Cutaneous antioxidant defence

The skin is exposed to ultraviolet radiation, environmental pollutants and thermal stress, all of which generate ROS. Cutaneous ascorbate is concentrated in the epidermis relative to the dermis and can be depleted by ultraviolet exposure [12]. Ascorbate also supports epithelial barrier function and the oxidant-scavenging activity of the skin[9]. Polyphenols from amla taken orally may reach the dermal microvasculature and contribute to plasma antioxidant capacity with downstream benefit to cutaneous tissues, although direct dermal delivery and clinical efficacy remain modest at nutritional doses.

10.3 Vitamin C and skin-barrier and wound-healing physiology

Beyond collagen biosynthesis, ascorbate supports keratinocyte differentiation and fibroblast proliferation and migration during wound healing[12]. Amla extract protects human skin fibroblasts against ultraviolet-B-induced photoageing, preserving procollagen 1 through inhibition of matrix metalloproteinase-1, inhibiting hyaluronidase and scavenging reactive oxygen species[31,32].

10.4 Anti-photoageing potential of amla phytochemicals

Amla polyphenols have been investigated *in vitro* for inhibition of matrix metalloproteinases that degrade dermal collagen and for reduction of melanogenesis[32,50,51]. *P. emblica* fruit extract raises type I procollagen in primary mouse fibroblasts by 1.65-fold on immunocytochemistry and 6.78-fold on Western blot at 0.1 mg/mL — approximately 7.75-fold greater induction than the reference herbal collagen enhancer asiaticoside at the same concentration — and inhibits collagenase activity dose-dependently to a maximum of 78.67 ± 3.51% at 1 mg/mL[30]; the procollagen effect is reproduced in human skin fibroblasts[31]. A standardised *P. emblica* branch extract inhibited tyrosinase and tyrosinase-related protein-2 activity, suppressed melanin formation and inhibited matrix metalloproteinase-2 in cellular assays at 0.1 mg/mL[50]. Congeneric work on *P. indofischeri* reports SIRT1 and FOXO1 activation and collagen stimulation comparable to vitamin C, and is cited here only as supporting evidence from a related species[23].

10.5 Human evidence involving oral and topical amla-containing preparations

Three published studies inform this domain. A randomised, double-blind, placebo-controlled trial of an oral lingonberry plus amla fruit extract in 99 healthy female subjects over 12 weeks reported dose-dependent improvements in skin elasticity ($P < 0.01$), skin thickness, stratum corneum water content and the degree of wrinkles around the eyes ($P < 0.001$)[52]. A 90-day open-label pilot study of a multi-herbal adjuvant skin-supplement liquid in 40 women aged 35–50 years reported improvements in Cutometer elasticity parameters (23–54%), hydration (30% forehead, 34% cheek) and wrinkle reduction by Antera 3D analysis, with no product-related adverse events[53]. A randomised, double-blind, placebo-controlled study of a topical gel containing 0.1% standardised *P. emblica* branch extract in 20 volunteers over 84 consecutive days reported skin lightening, improved elasticity and hydration, and wrinkle reduction on instrumental assessment, with no irritation on single closed patch testing[50]. All three used formulations, routes and doses that differ from Bio C.

10.6 Implications for Bio C

A defensible conclusion is that Bio C supplies the vitamin C required for normal collagen formation together with an amla-derived polyphenol antioxidant matrix. Bio C should not be claimed to reverse wrinkles, lighten hyperpigmentation or treat dermatological disease; such claims require product-specific clinical substantiation. Where dermal claims are made, the phrasing should make clear that biological plausibility for the amla polyphenol contribution is anchored *in vitro*, while human dermal evidence currently derives from studies of other amla-containing formulations rather than from Bio C itself[30,32,50–53].

Suggested structure–function claim: Supports skin health and normal collagen formation.

Evidence tier: Mechanistically established with pilot clinical confirmation in different formulations[30,50,52,53].

11. Hair and Scalp Health

11.1 Oxidative stress and hair-follicle biology

Hair follicles are highly proliferative mini-organs sensitive to oxidative stress. ROS have been implicated in premature catagen entry, follicle miniaturisation, perifollicular inflammation in androgenetic alopecia, and altered melanocyte activity in greying. Follicular redox balance is part of the normal hair cycle, and antioxidant nutrients have been proposed as supportive factors in androgenetic alopecia and other forms of hair thinning.

11.2 Nutritional role of vitamin C

Vitamin C contributes to hair biology through three principal mechanisms: support of collagen biosynthesis in the dermal sheath, antioxidant protection of the follicular environment[12] and enhancement of non-haem iron absorption. Polyphenols and phytate inhibit non-haem iron uptake in a dose-dependent manner[54] and ascorbate overcomes that inhibition: 30 mg reversed the effect of maize-bran phytate and 50 mg or more was required against meals containing over 100 mg of tannic acid[55]. The iron-absorption role is particularly relevant for menstruating women and individuals at risk of iron deficiency. All three actions are nutritional rather than pharmacological and operate at adequate intake rather than at supra-physiological doses.

11.3 Amla and the hair-growth cycle

In a screen of seventeen traditional hair-treatment plants, *P. emblica* was the second most potent inhibitor of 5α-reductase, with a finasteride-equivalent activity of 18.99 ± 0.40 mg/g extract, and enzyme inhibition across the panel correlated with hair-growth promotion in C57BL/6 mice[56]. Preclinical reports also describe amla extracts and vesicular delivery formulations promoting follicular proliferation[57,58]. Dose-dependent cell proliferation has been reported in human dermal papilla cells at concentrations around 50 µg/mL, alongside dose-dependent reduction in 5α-reductase expression and dose-dependent increases in insulin-like growth factor 1 and vascular endothelial growth factor supporting follicular differentiation and growth[57]. Further *in vitro* enzymatic screening of Ayurvedic herbs places *E. officinalis* among the more active 5α-reductase inhibitors[59].

11.4 Clinical evidence in amla-containing hair products

A 90-day TrichoScan-based clinical study of a hair serum formulation containing amla, coconut water and selenium in 42 healthy male and female volunteers showed statistically significant improvement from baseline in hair growth rate, hair density, vellus density and terminal density (each $P < 0.0001$), and significant reductions in hair fall and hair thinning (each $P < 0.0001$)[60]. A 90-day assessment of a different serum combining biotinoyl tripeptide-1 with *P. emblica* fruit extract in 40 participants showed improved hair density and quality, with a significant reduction in transepidermal water loss in women ($P < 0.05$)[61]. A prospective open-label assessment of an oral amla tablet in 300 participants over three months reported a reduction in hair-fall visual analogue score from 6.2 ± 1.7 to 3.4 ± 1.5 ($P = 0.001$) alongside increases in vitamin D and antioxidant biomarkers[62].

11.5 Translational limitations

Several differences separate these hair studies from Bio C. The serum or oral-tablet vehicles, daily amla dose, accompanying actives, study population characteristics and intervention duration all differ from the intended use of Bio C as a once- or twice-daily oral tablet delivering 900 mg of dried amla extract plus 80 mg of vitamin C. Two of the three clinical studies used topical serums rather than an oral route. Without a Bio C–specific trial in hair biology, the proper level of inference is biological plausibility rather than demonstrated clinical benefit.

11.6 Relevance to Bio C

Healthy-hair support is biologically plausible for Bio C given its combined ascorbate and amla polyphenol content, with the polyphenols contributing 5α-reductase inhibition, antioxidant protection and pro-

follicular growth signalling *in vitro*, and ascorbate contributing collagen cofactor activity and iron-absorption enhancement. Bio C should be framed as supporting normal hair biology through nutritional and antioxidant contributions rather than as an alopecia treatment[57–62].

Suggested structure–function claim: Provides nutrients that support normal hair biology, and is traditionally used in Ayurveda for hair and scalp care; not a treatment for hair loss.

Evidence tier: Mechanistic and formulation-specific, on a well-documented traditional base[17,57,59–62].

12. Safety, Tolerability and Herb–Drug Interaction Considerations

12.1 Safety of amla preparations

Standardised amla extracts at 250–500 mg twice daily for 12 weeks[6,7] and at 500 mg daily for 18 weeks[5] have shown acceptable safety profiles in randomised trials. No substantial changes in liver safety tests, urinalysis or haematology have been reported, and no adverse events of clinical significance have been documented relative to placebo[5–7]. In the multicentre dyslipidaemia trial of 500 mg amla extract twice daily, only four mild adverse events were recorded among 98 participants over 12 weeks — one mild fever, one mild headache and two of mild gastritis; three were in the placebo group and one in the amla group, all resolving with routine management[7]. Toxicological review of *P. emblica* fruit reports an absence of adverse effect even at high oral doses in animal studies[17]. The Ayurvedic *rasayana* classification of amla is consistent with a strong overall safety record.

12.2 Safety of vitamin C at the Bio C dose

At 80 mg per serving, the ascorbate component of Bio C is firmly within the nutritional range and well below the threshold at which gastrointestinal symptoms become clinically meaningful. The contribution of Bio C to total daily vitamin C intake should be considered alongside dietary sources. The tolerable upper intake level for adults, commonly cited as 2000 mg/day, is the relevant benchmark for cumulative intake, and the only consistently reported adverse effect at high intakes is transient gastrointestinal upset from unabsorbed ascorbate[36]. Pro-oxidant chemistry requires free, catalytically active transition metals; whether it occurs *in vivo* at nutritional intakes is not established, the evidence showing consistent antioxidant protection of lipids but inconsistent findings for DNA oxidation[27].

12.3 Populations requiring caution

Several populations merit targeted caution. Individuals with a history of recurrent calcium oxalate kidney stones may be advised to monitor vitamin C intake. Patients with iron-overload disorders such as hereditary haemochromatosis should be aware that ascorbate enhances non-haem iron absorption. Chronic kidney disease alters vitamin C metabolism and oxalate handling. Pregnant and breastfeeding women should follow medical guidance on supplement use, and children should not receive adult formulations without professional advice. Patients receiving multiple medicines should review any new supplement with their prescriber or pharmacist, consistent with the rational-use and nutrivigilance principles set out for nutraceuticals in India[15].

12.4 Potential herb–drug interactions

The most important interaction signal is antiplatelet rather than theoretical. In a randomised crossover study in ten patients with type 2 diabetes, *P. emblica* extract produced statistically significant inhibition of platelet aggregation both after a single 500 mg dose and after 500 mg twice daily for ten days, alone and in combination with clopidogrel 75 mg or aspirin 75 mg, and bleeding and clotting times were prolonged relative to baseline with all treatments; all regimens were well tolerated[63]. This is a small, open-label, single-centre study, but it is direct human evidence of a pharmacodynamic effect at a dose close to the amla fraction of a typical supplement, and it should inform counselling rather than be discounted. Caution and, where appropriate, clinical review are therefore warranted in consumers taking anticoagulants or antiplatelet agents, and before elective surgery.

Amla has additionally been studied in people with type 2 diabetes, where 250 and 500 mg twice daily improved endothelial function and oxidative-stress biomarkers[64]; no human interaction study with

metformin, sulfonylureas, insulin or antihypertensives has been published, so monitoring remains a precaution rather than a documented requirement. The dyslipidaemia trial recorded no clinically significant adverse events or safety laboratory changes, although participants were required to be free of lipid-lowering therapy for at least four weeks before enrolment, so it does not address concomitant use[7]. Because polyphenol- and tannin-rich preparations reduce non-haem iron absorption in humans by 50-90% in a dose-dependent manner, separating administration from iron supplements by approximately two hours is a prudent precaution[54].

12.5 Gastrointestinal tolerability and administration

Gastrointestinal upset from ascorbate is an osmotic effect of unabsorbed quantities far above the amount in a nutritional supplement[36]; taking the product with food is nonetheless a reasonable precaution, and the amla dose in the published reflux trial was given after meals[34].

13. Quality Control, Regulatory Positioning and Claim Substantiation

13.1 Botanical authentication

Identity testing by macroscopic and microscopic examination, complemented by molecular or chemotaxonomic markers, should confirm that the dried amla extract in Bio C derives from *P. emblica* L. fruit and not from related species or adulterants. Closely related Indian gooseberry species are cultivated commercially and studied for cosmetic and nutraceutical use, *P. indofischeri* among them[23]; in the authors' view this makes species-level authentication a substantive rather than a formal requirement, and marketed amla extracts are known to differ substantially in phenolic and ascorbate content[4,21]. Plant part, drying method and extraction provenance should be traceable to lot records.

13.2 Phytochemical quality control

Routine quality control should include HPLC determination of ascorbic acid content against validated standards, marker-based polyphenol fingerprinting by HPLC or HPTLC, quantitative assay of marker tannins (emblicanin A and B, gallic acid and ellagic acid), total hydrolysable tannin or polyphenol assay, and ash, moisture and microbial content checks[3,4]. Release specifications should set minimum and maximum limits for each marker compound.

13.3 Contaminant testing

Routine testing should address heavy metals (lead, cadmium, arsenic and mercury), pesticide residues conforming to relevant pharmacopoeial limits, aflatoxin screening, total microbial count and absence of specified pathogens, and residual solvents where applicable. These requirements are consistent with the FSSAI provisions applying to health supplements and nutraceuticals, under which the Authority sets approval, labelling and quality standards for the category[15,16].

13.4 Stability testing

Stability studies should track vitamin C content, marker tannin content, total polyphenol content and physical parameters such as moisture and disintegration across accelerated and real-time storage conditions. Ascorbate in amla-based products declines measurably during storage, with retention better at low temperature[22]; ascorbate is additionally labile to oxygen, light and residual moisture, so these sensitivities should be reflected in the declared storage conditions and the assigned shelf life.

13.5 Appropriate claim categories for amla–ascorbate supplements

In India, nutraceuticals and health supplements are regulated as foods under the Food Safety and Standards Act, 2006, with the FSSAI responsible for approvals, permitted claims and labelling standards; the categorisation of products that resemble pharmaceuticals in form and implied therapeutic effect remains an area of active regulatory tightening[15,16]. Within that framework, communications for an amla–ascorbate supplement of this composition fall naturally into two distinct and complementary categories, and the practical task for any manufacturer in this category is to keep the two apart rather than to blend them.

The first category comprises evidence-based structure–function statements, which rest on the modern experimental and clinical literature reviewed in Sections 6 to 11 and are supportable for any product of this class delivering a comparable dose:

- "supports antioxidant defence";
- "provides vitamin C, contributing to normal collagen formation";
- "contributes to the protection of cells from oxidative stress";
- "supports skin health";
- "supports general wellness".

The second category comprises traditional-use statements. It is important to recognise that the benefit areas for which modern controlled-trial evidence is thinnest — digestive comfort, hair and scalp health, eye health and general vitality — are precisely the areas in which amla has the longest and best-documented ethnomedical record. These are Ayurvedic *rasayana* indications, described in classical texts and sustained by centuries of continuous use across the Ayurvedic, Siddha and Unani systems, and they are recorded in the modern ethnopharmacological literature as traditional applications rather than as demonstrated pharmacological effects[4,17–19]. Their present status is therefore not that of a disproven claim but of a traditional claim awaiting modern confirmation, and this distinction is what allows them to be communicated responsibly.

Statements of this kind can legitimately be presented as heritage of use — for example, that amla has been used traditionally in Ayurveda as a *rasayana* associated with digestive comfort, hair and scalp care, eye health and general vitality — provided three conditions are met. The traditional origin is stated explicitly, so that the consumer understands the basis of the statement. The wording remains descriptive of use rather than of effect. And the product is not positioned as a treatment for, or a substitute for medical management of, any diagnosed condition. On that basis, a supplement of this class is properly understood as a general nutritional and traditional-wellness product rather than as a medication, which is both the accurate scientific position and the appropriate commercial one.

What remains outside both categories is the therapeutic claim: the assertion that the product treats, prevents or cures a defined disease. Statements such as "treats GERD", "prevents age-related macular degeneration", "prolongs vitamin C retention in the body", "prevents hair loss" or "reverses skin ageing" are disease claims, and a disease claim requires a randomised controlled trial of the finished product with endpoints matched to the claim, irrespective of how strong the traditional or mechanistic rationale may be; this is the substantiation standard implied by the FSSAI framework for the category[15,16]. The four pillars that determine which category a given statement belongs to are set out in Figure 3, and the claim-by-claim framework, including the traditional basis available for each benefit area, is given in Table 4.

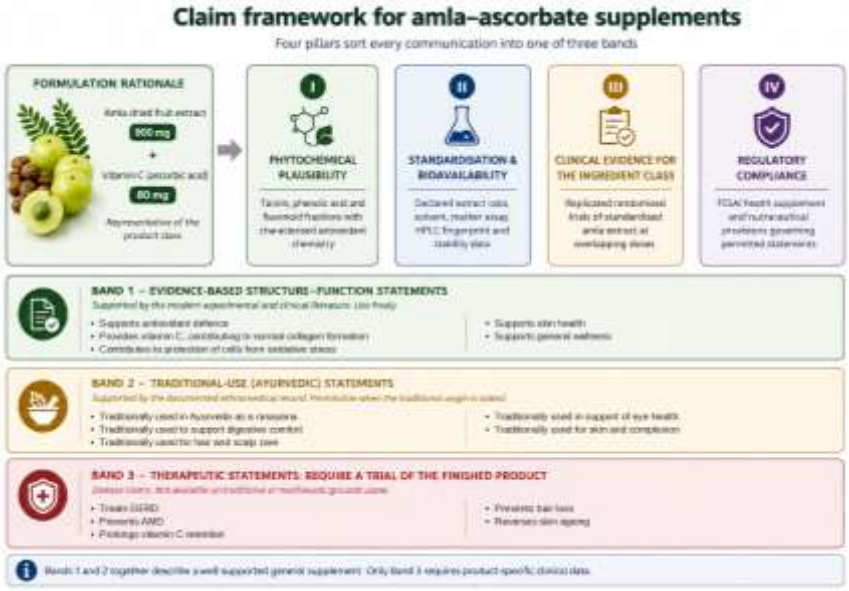


Fig 3: Claim framework for amla–ascorbate supplements. The formulation rationale (left) is assessed against four pillars — phytochemical plausibility, standardisation and bioavailability, clinical evidence for

the ingredient class, and regulatory compliance — which together sort communications into three bands. Evidence-based structure–function statements are supported by the modern literature; traditional-use statements are supported by the documented Ayurvedic record and may be presented as heritage of use when the traditional origin is stated; therapeutic statements require a randomised controlled trial of the finished product regardless of how strong the traditional or mechanistic rationale is.

Table 4: Claim framework for amla–ascorbate supplements: evidence-based structure–function statements, traditional-use statements, and therapeutic statements that require product-specific trials.

Benefit area	Evidence-based structure–function statement	Traditional (Ayurvedic) basis available	Statement reserved for future clinical trials
Antioxidant and cellular protection	"Contributes to the protection of cells from oxidative stress"; "supports antioxidant defence"	Rasayana classification; long use for vitality and resilience[17,19]	"Neutralises free radicals and prevents disease" — a disease-prevention claim[15]
Vitamin C nutrition	"Provides vitamin C, contributing to normal collagen formation"	Amla is the classical dietary source of the vitamin C principle[4,18]	"High-potency vitamin C for immune protection" — 80 mg meets the ICMR-NIN allowance[65] but is a nutritional, not therapeutic, dose[11]
Skin	"Supports skin health"; "supports normal collagen formation"	Long-standing use in complexion and skin care[17,50]	"Reverses skin ageing"; "removes wrinkles" — the supporting trials used different combination formulations, and the elasticity and wrinkle data include a topical route[50,52,53]
Digestive comfort	General digestive comfort as part of daily nutrition	Dyspepsia, hyperacidity, colic and flatulence are explicitly recorded classical indications[4,17]	"Treats GERD"; "replaces antacids or PPIs" — the placebo-controlled trial used 2000 mg/day amla, more than twice this dose[34]
Hair and scalp	Provides nutrients that support normal hair biology	Among the most widely documented traditional uses of the fruit[17,18]	"Prevents hair loss"; "treats alopecia" — the controlled clinical data are from topical serums, the oral human reports are uncontrolled, and the supporting mechanistic evidence is preclinical[56,60,62]
Eye health	Ocular antioxidant support as part of daily nutrition	Classical *rasayana* indication for eye health[17,18]	"Prevents AMD"; "protects the macula" — a therapeutic endpoint tied to the AREDS composition[40–42]
Ascorbate disposition	Nothing beyond the declared vitamin C content	None	"Prolongs vitamin C retention in the body" — never tested in humans; plasma ascorbate is constrained by absorption and renal handling[38,39]
General	"Supports general wellness"	Rasayana tradition of daily use for general vitality[17]	Any treatment, cure or prevention wording — requires specific regulatory authorisation[15,16]

13.6 Evidence expectations for this product class

The hierarchy of evidence used throughout this review places ingredient-level evidence below formulation-specific evidence, and formulation-specific evidence below product-specific evidence. The published

evidence for amla–ascorbate supplements as a class, Bio C included, currently sits at the ingredient level for the botanical component and at the nutrient level for ascorbate, which is the normal position for nutraceuticals in this category and is not peculiar to any single brand. Very few marketed botanical supplements of any kind carry finished-product randomised trials, and the absence of one is therefore a description of the category's evidence maturity rather than a deficiency of a particular product.

Two consequences follow. First, within the nutritional and traditional-use categories set out in Section 13.5, a product of this composition is well supported: the antioxidant and nutritional rationale rests on several randomised trials of the ingredient, and a meta-analysis of them, at doses bracketing this one, and the traditional indications rest on a documented ethnomedical record. Second, any move from those categories into disease-specific territory requires the manufacturer to generate product-specific data — a properly designed clinical trial with full disclosure of extract standardisation, dose justification, endpoints consistent with the claim category, and complete adverse-event reporting. Manufacturers who invest in that work convert a well-founded general supplement into a substantiated health-claim product; until then, positioning the product as a daily antioxidant and traditional-wellness supplement is both defensible and commercially sufficient[3,15,16].

14. Evidence Integration and Critical Appraisal

14.1 Strength of evidence by health domain

When the six review domains defined in Section 1.4 are appraised together, they resolve into seven strands — the ocular domain separating into general ocular antioxidant relevance and AMD-specific protection, and the vitamin C disposition domain contributing prolonged systemic retention as a distinct claim. Each strand is graded here on two axes that are often conflated: the modern experimental and clinical evidence available for it, and the traditional Ayurvedic record that stands behind it. A strand may be weak on the first axis and strong on the second, and the two together determine how a supplement of this composition should be described. Figure 4 maps each strand onto the tier corresponding to the strongest modern evidence available, and Table 5 gives the full appraisal, including the traditional basis and the resulting wording, together with a final cross-cutting row on finished-product performance that is not itself a benefit strand.

- Antioxidant and nutritional support — strongest modern evidence. Randomised trials of standardised amla extract across several populations, and a meta-analysis of nine randomised trials in 535 participants at 500–1500 mg/day over 14–84 days, place this strand at the top of the hierarchy; that dose range brackets the 900 mg/day amla fraction. The trials differ in population and primary endpoint, rather than being replications of one another, and the pooled analysis reports reductions in low-density lipoprotein cholesterol, very-low-density lipoprotein cholesterol, triglycerides and high-sensitivity C-reactive protein while cautioning that heterogeneity limits confidence[5–7,33].
- Skin antioxidant and collagen support — biologically established. The dependence of prolyl and lysyl hydroxylase on ascorbate, together with *in vitro* photoprotection, melanin-modulatory and collagen-biosynthesis data for amla polyphenols, supports a meaningful biological contribution; the 12-week lingonberry plus amla trial, the 90-day multi-herbal supplement study and the 84-day topical branch-extract trial provide pilot clinical confirmation for the amla polyphenol matrix in skin physiology, and amla's use in skin and complexion care is a long-standing Ayurvedic application[12,17,30,50,52,53].
- Gastroesophageal reflux and digestive comfort — clinical evidence at a higher dose, on a strong traditional base. A double-blind placebo-controlled trial of amla monotherapy at 2000 mg/day for four weeks significantly reduced the frequency and severity of heartburn and regurgitation in 68 adults with non-erosive reflux disease[34]; an open-label comparative trial of a different multi-herbal formulation and preclinical rodent data provide supporting context[14,35]. This sits on top of one of amla's best-documented classical indications, dyspepsia and hyperacidity being explicitly recorded as traditional uses[17]. Because the trial dose is more than twice the amla fraction of a typical supplement, the appropriate description remains digestive comfort rather than treatment of reflux disease.

- Hair and scalp health — mechanistic and formulation-specific evidence on a strong traditional base. *P. emblica* is a potent *in vitro* 5α-reductase inhibitor and promotes hair growth in mice[56,59]; a 90-day trichoscopy-based clinical study of a topical amla-containing serum reported significant improvement in hair growth rate and density[60] with further preclinical and uncontrolled reports of oral and topical amla preparations[57,58,61,62]. Hair and scalp care is among the most widely documented traditional uses of the fruit[17]. Vehicle, dose and accompanying ingredients differ between those studies and an oral amla–ascorbate tablet, so the supportable description is nutritional and traditional support for normal hair biology.
- Ocular antioxidant relevance — established physiology, traditional endorsement, no clinical endpoint. Ascorbate physiology in ocular fluids, carotenoid biology and polyphenol cytoprotection in retinal pigment epithelial cells provide a strong mechanistic case, and eye health is a classical *rasayana* indication for amla; what is absent is amla-specific clinical ocular-endpoint data, so the wording should stay at the level of ocular antioxidant support as part of daily nutrition[18,24–26,43].
- Age-related macular degeneration — a therapeutic endpoint, not a supplement claim. The AREDS evidence base requires 500 mg of vitamin C together with vitamin E, zinc, copper and macular carotenoids, a composition no amla–ascorbate supplement matches. This is a disease endpoint requiring a specific formulation and dose, and it lies outside the claim space of a general supplement irrespective of traditional use[40–42,46–49].
- Prolonged vitamin C retention — an untested hypothesis, not a claim. Human plasma ascorbate is tightly constrained by absorption and renal handling[39] and transporter evidence locates the dominant determinant of retention in renal reabsorption[38]. No human pharmacokinetic study of a dual-component amla plus ascorbate product has been published, so the question is untested rather than merely unproven. It is well defined and readily testable.

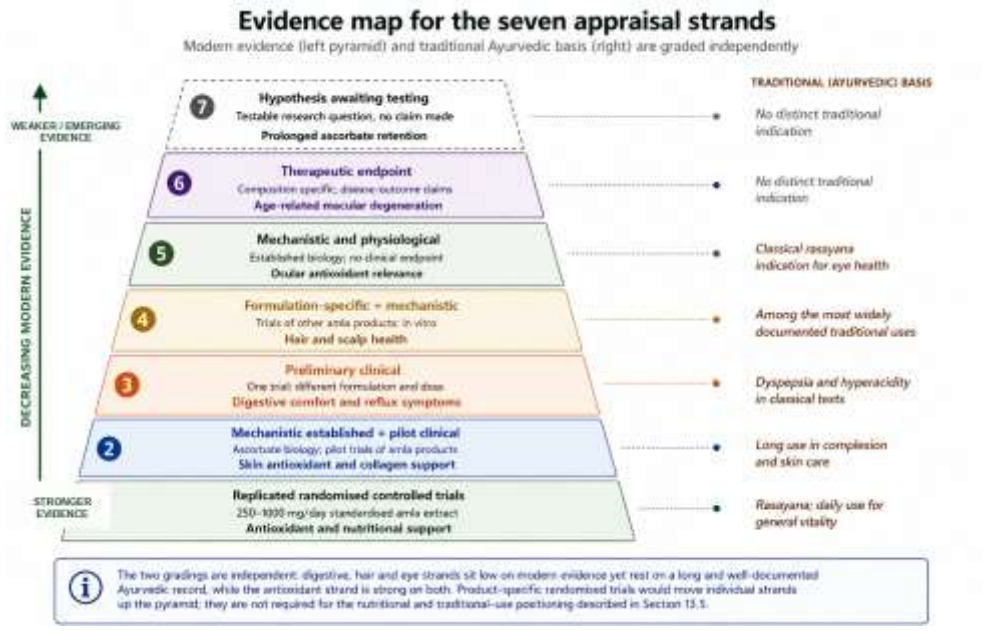


Fig 4: Evidence map for the seven appraisal strands of amla–ascorbate supplements. Each strand is placed at the tier corresponding to the strongest modern evidence available for it, from replicated randomised controlled trials of standardised amla extract at the base to hypothesis-level at the top. The right-hand column records the traditional Ayurvedic basis for the same strand, which is independent of the modern tier: several strands sit low on modern evidence while resting on a long and well-documented ethnomedical record. Read together, the two columns show why these products are properly described as nutritional and traditional-wellness supplements rather than as medicines, and where product-specific trials would add the most.

Table 5: Strength-of-evidence summary for the proposed benefit strands of amla–ascorbate supplements, graded on both modern evidence and traditional basis, with the resulting supportable wording.

Appraisal strand	Best available modern evidence	Modern evidence tier	Traditional (Ayurvedic) basis	Supportable wording
Antioxidant and nutritional support	RCTs across several populations at 500–1000 mg/day, and a meta-analysis of 9 RCTs (n = 535) at 500–1500 mg/day[5–7,33]	Clinical (RCT + meta-analysis)	Rasayana; general vitality[17]	Primary structure–function rationale
Skin antioxidant and collagen support	Ascorbate-dependent hydroxylase biology; *P. emblica* procollagen and anti-collagenase data; 12-week oral and 84-day topical randomised trials plus a 90-day pilot[12,30,50,52,53]	Mechanistically established + pilot clinical	Complexion and skin care[17]	"Supports skin health and normal collagen formation"
Digestive comfort and reflux symptoms	Double-blind placebo-controlled trial of amla monotherapy, 2000 mg/day for 4 weeks, in 68 adults with non-erosive reflux disease[34]; open-label comparative trial of a multi-herbal capsule and rodent data[14,35]	Clinical, at a higher dose	Dyspepsia, hyperacidity, colic explicitly recorded[17]	Traditional digestive comfort; not a reflux treatment
Hair and scalp health	*P. emblica* among the most potent *in vitro* 5α-reductase inhibitors with hair growth in mice[56]; 90-day trichoscopy study of a topical amla serum[60]; preclinical and uncontrolled oral reports[57,59,61,62]	Formulation-specific + mechanistic	Widely documented hair and scalp use[17]	Nutritional and traditional support for normal hair biology
Ocular antioxidant relevance	Ascorbate physiology in ocular fluids; polyphenol cytoprotection in retinal pigment epithelium[24–26,43]	Mechanistic and physiological	Classical *rasayana* eye-health indication[18]	Ocular antioxidant support as part of daily nutrition
Age-related macular degeneration	AREDS and AREDS2 require 500 mg vitamin C with vitamin E, zinc, copper and carotenoids[40–42,46,47]	Therapeutic endpoint; composition-specific	Not a distinct traditional indication	Outside the claim space of a general supplement
Prolonged vitamin C retention	No human study of a combined amla–ascorbate product; plasma ascorbate is constrained by absorption and renal handling[38,39]	Untested hypothesis	None	Research question; no claim at present
Finished-product performance	Product-specific randomised trials are largely absent across this category	Product-specific tier open	Not applicable	Positioned as a supplement, not a medicine

(cross-cutting, not a benefit strand)				

14.2 Major limitations of the literature

Several recurring limitations constrain the evidence base. Clinical samples are small: total enrolment ranges from 15 in the crossover study to 98 in the dyslipidaemia trial, roughly 20 to 50 participants per arm, with 68 in the reflux trial[5–7,34]. Intervention periods are short — 14 to 84 days across the pooled randomised trials[33] and four to eighteen weeks in the studies reviewed here[5,34]. Amla extracts used across studies vary in format — fresh juice, aqueous extract, hydroalcoholic extract, ethyl acetate extract and dried powder — and most are reported without adequate standardisation to polyphenol or tannin markers[3,4]. Doses range widely across trials, hampering dose translation. Many published studies evaluate combination formulations in which the contribution of any single ingredient cannot be isolated, for example the lingonberry plus amla drink and the multi-herbal skin supplement[52,53]. Part of the frequently cited mechanistic literature was generated in congeneric *Phyllanthus* species rather than in *P. emblica*, which requires care in attribution[23]. Finished-product randomised trials are largely absent across this product category rather than for any one brand. Mechanistic and preclinical findings are over-represented relative to clinical endpoints, and long-term safety data beyond twelve months of continuous use are limited.

14.3 Overall benefit–evidence relationship

Taken together, a supplement combining a standardised amla fruit extract at a dose within the studied envelope with a nutritionally complete quantity of ascorbate is a scientifically coherent formulation, and Bio C is a representative example of the class. Its antioxidant and nutritional rationale rests on the strongest evidence available in this field — several randomised trials of the botanical ingredient and a meta-analysis of them, supported by well-characterised ascorbate biology — and its remaining benefit areas rest on a documented Ayurvedic record together with consistent mechanistic and pilot clinical data. The appropriate positioning follows directly: a daily nutritional and traditional-wellness supplement supporting antioxidant defence, normal collagen biosynthesis and general skin, hair, digestive and ocular wellbeing, presented as a supplement rather than as a medicine, with disease-specific outcomes held back for product-specific trials. Framed this way, the product class is well supported on its own terms, and the outstanding research questions are opportunities to strengthen it rather than deficiencies in it.

15. Research Gaps and Future Directions

15.1 Analytical characterisation of Bio C

Priority should be given to a complete analytical profile of the finished Bio C product, including the native extract ratio of the amla component, total hydrolysable tannin content, quantitative emblicanin A and B content, gallic and ellagic acid content, true ascorbic acid content, residual moisture, and shelf-life stability under accelerated and real-time storage conditions. Species-level botanical authentication should be documented alongside the chemical profile. This characterisation is the prerequisite for any subsequent clinical interpretation[3,4].

15.2 Bio C pharmacokinetic study

A single-dose and steady-state pharmacokinetic study comparing Bio C with a reference 80 mg conventional vitamin C preparation would clarify whether the amla polyphenol matrix alters the absorption, plasma profile or urinary excretion of ascorbate. Because renal reabsorption is the dominant determinant of ascorbate economy, the design should include urinary fractional excretion alongside plasma kinetics[38,39] and parallel biomarkers of polyphenol absorption such as ellagic acid metabolites and gallic acid conjugates to confirm that the tannin fraction is biologically available.

15.3 Antioxidant biomarker trial

A randomised, placebo-controlled trial measuring plasma vitamin C, reduced glutathione, malondialdehyde, 8-OHdG and high-sensitivity C-reactive protein over 8–12 weeks would provide direct Bio C–specific evidence

for the formulation's core antioxidant rationale, building on the design strengths of the 18-week crossover and 12-week parallel-group metabolic-syndrome trials[5,6]. Endpoint selection should be governed by what each marker can actually detect. Ascorbate is a poor candidate for lipid-peroxidation endpoints: in a controlled depletion–repletion study, plasma and urinary F2-isoprostanes and a major urinary F2-isoprostane metabolite were unchanged at every vitamin C dose from 30 to 2500 mg/day[66]. F2-isoprostanes therefore belong in such a trial only as a test of the hydrolysable tannin fraction, which that null result does not govern, and should be powered and interpreted on that basis rather than as a general oxidative-stress readout. The markers that have responded to standardised amla extract in published trials — malondialdehyde, glutathione, nitric oxide and 8-OHdG — remain the more defensible primary choices[5,6]. Endothelial function endpoints such as reflection index or flow-mediated dilatation would add value.

15.4 GERD or NERD clinical study

A product-specific randomised study in non-erosive reflux disease, using the validated reflux-symptom instruments already applied in this indication and comparing symptom improvement against placebo over 8–12 weeks, would establish whether the 900 mg/day amla fraction produces measurable symptomatic benefit at less than half the 2000 mg/day dose used in the published placebo-controlled trial[34].

15.5 Skin-health study

A controlled study measuring corneometer hydration, cutometer elasticity, transepidermal water loss and serum or urinary biomarkers of collagen metabolism, such as procollagen type I C-terminal propeptide or urinary collagen crosslinks, over 12–24 weeks would quantify the skin-relevant contribution of Bio C[12,30,52].

15.6 Hair-health exploratory trial

An exploratory trial measuring trichoscopy-derived hair density, shaft diameter, anagen-to-telogen ratio and patient-reported outcomes in women with self-perceived thinning or female-pattern hair loss would generate an initial signal of clinical effect in hair biology, building on the 90-day trichoscopy study of a topical amla-containing serum[60] and on the preclinical 5α-reductase and follicular data[56,57].

15.7 Ocular-health research

Initial research should focus on oxidative biomarkers and general ocular nutritional status rather than on AMD treatment endpoints. A study measuring plasma ascorbate concentrations together with non-invasive retinal imaging markers over 6–12 months would generate foundational data for any subsequent AMD-targeted evaluation[24,25].

16. Practice Points and Clinical Takeaways

- For adults seeking daily antioxidant and nutritional support. This is the domain with randomised-trial support at doses that bracket the 900 mg amla fraction by weight — comparability by potency depends on marker standardisation that is generally not published for finished products in this category — and it is the appropriate primary positioning for Bio C[5–7,33].
- For consumers expecting a high-dose vitamin C product. The 80 mg of ascorbate meets 100% of the ICMR-NIN 2020 recommended dietary allowance for Indian adults[65] but is well below the 200 mg/day proposed as optimal for antioxidant benefit; Bio C should not be presented as a high-potency ascorbate supplement[9,11].
- For consumers with reflux symptoms. The placebo-controlled evidence comes from amla monotherapy at 2000 mg/day over four weeks in diagnosed non-erosive reflux disease[34] — more than twice the amla fraction of a typical supplement. Such a product should not be substituted for prescribed acid-suppressive therapy, and persistent or alarm symptoms warrant medical assessment.
- For consumers seeking macular protection. The original AREDS formulation contained 500 mg of vitamin C with vitamin E, beta-carotene, zinc and copper[45]; AREDS2 replaced beta-carotene with the macular carotenoids lutein and zeaxanthin[40,41]. Bio C contains neither the dose nor the additional components, and consumers with established AMD should be directed to an AREDS-compliant product on ophthalmological advice.

- For consumers with a history of renal oxalate stones. Ascorbate is metabolised in part to oxalate, and supplementation at 1000 mg twice daily raised urinary oxalate and calcium-oxalate stone risk in about 40% of participants in a controlled crossover study[67]. At 80 mg the contribution is small and within the ordinary dietary range, but consumers with recurrent calcium-oxalate nephrolithiasis should seek clinical advice before regular use of any ascorbate supplement.
- For consumers taking antiplatelet or anticoagulant medicines. *P. emblica* extract 500 mg inhibited platelet aggregation and prolonged bleeding and clotting times, alone and with clopidogrel or aspirin, in a small crossover study in type 2 diabetes[63]. Consumers on these medicines, and those approaching elective surgery, should seek clinical advice before regular use.
- Administration and tolerability. Gastrointestinal upset from ascorbate is an osmotic effect of unabsorbed quantities well above a nutritional dose[36]; taking the product with food remains a reasonable precaution.
- Expectation setting. Consumers are best served by a plain two-part message: the antioxidant and nutritional rationale rests on randomised trials of the botanical ingredient, while the digestive, hair, skin and eye associations rest on a long Ayurvedic record that modern trials have not yet reproduced in full. Presented that way, the product is an honest general supplement rather than a medicine, which in a category marked by widespread over-claiming is also the stronger commercial position[15,17].

17. Conclusion

Bio C is a scientifically plausible nutraceutical formulation combining 900 mg of dried amla fruit extract with 80 mg of vitamin C per serving. Its strongest evidence-based rationale is antioxidant and nutritional support, anchored by randomised trials at doses that bracket the 900 mg fraction by weight, although comparability by potency depends on standardisation data that this category does not routinely publish: individual trials reported lower malondialdehyde with higher glutathione and nitric oxide[6] reduced 8-hydroxy-2′-deoxyguanosine and improved high-density lipoprotein cholesterol[5] improved lipid profile[7] and were well tolerated. A meta-analysis of nine randomised trials reported pooled reductions in low-density lipoprotein cholesterol, triglycerides and high-sensitivity C-reactive protein, which its authors cautioned should be interpreted conservatively given substantial statistical and clinical heterogeneity[33]. The vitamin C component supports normal collagen formation[12] and contributes to systemic antioxidant defence[9,11] while the amla component supplies hydrolysable tannins to which the fruit's antioxidant activity was attributed in primary rodent work, rather than to its ascorbate[10] alongside gallic and ellagic acids[4]. Placebo-controlled clinical evidence supports a role for amla monotherapy in reflux-symptom modulation, but at 2000 mg/day, more than twice the 900 mg/day amla fraction of this formulation[34]; supporting reports of polyherbal and adjunctive amla preparations are open-label[14,35]. Skin and hair findings are biologically supported by *in vitro* collagen-biosynthesis[30,31] tyrosinase-inhibition data for a topically applied amla branch extract[50] and 5α-reductase data[56] and by a randomised oral trial of a lingonberry–amla combination supplying far less amla extract than a 900 mg fraction[52] together with an uncontrolled study of a topical amla-containing serum[60] but require product-specific confirmation. Age-related macular degeneration risk reduction is tied to the AREDS composition and dose[40,44] and prolonged vitamin C retention has never been tested in humans for a combined amla–ascorbate product[38,39]; neither should be claimed. Formulation-specific clinical trials spanning pharmacokinetics, antioxidant biomarkers and the principal target domains remain the necessary next step before any expansion of the current nutraceutical positioning.

Declarations

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Competing interests. All authors are employees of Biotex Life Solutions Pvt. Ltd., the manufacturer of Bio C, the formulation that is the subject of this review. This affiliation constitutes a potential conflict of interest and is disclosed here in full. To mitigate it, the review appraises ingredient-level evidence graded

against an explicit five-tier hierarchy, relies on primary and meta-analytic sources, states explicitly where evidence is preliminary, formulation-specific, derived from a congeneric species or absent, identifies four proposed benefit domains as not supportable on present evidence, and makes no clinical-efficacy claim for the finished product. The authors declare no other financial or non-financial competing interests.

Author contributions. All authors contributed to the conception and design of the review, to the literature search and evidence appraisal, and to the drafting and critical revision of the manuscript for important intellectual content. All authors read and approved the final version to be published, meet all four International Committee of Medical Journal Editors authorship criteria, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of it are appropriately investigated and resolved.

Data availability. Data sharing does not apply to this article: no new datasets were generated or analysed. All sources cited are publicly available and listed in the References.

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Use of generative artificial intelligence. During the preparation of this manuscript, the authors used generative artificial-intelligence tools to assist with literature retrieval, reference verification, language editing and formatting. All content was subsequently reviewed, verified against the primary sources and edited by the authors, who take full responsibility for the content of the published article.

Disclaimer. This article is an ingredient-based narrative review summarising evidence relevant to Bio C, a formulation of Biotex Life Solutions Pvt. Ltd. Its findings apply to *Phyllanthus emblica* fruit extract and to ascorbic acid as classes of nutraceutical ingredients, and not to the finished Bio C product, which has not been evaluated in any clinical trial. No claim is made that Bio C has been shown to diagnose, treat, cure or prevent any disease. Structure–function statements must remain within the framework of applicable Food Safety and Standards Authority of India regulations for health supplements and nutraceuticals, and be supported by the certificate of analysis for each production batch[15,16].

References

1. Sies H, Berndt C, Jones DP. Oxidative stress. Annu Rev Biochem. 2017;86:715-48. doi:10.1146/annurev-biochem-061516-045037. PMID:28441057.
2. Gul M, Liu ZW, Iahtisham-Ul-Haq, Rabail R, Faheem F, Walayat N, Nawaz A, Shabbir MA, Munekata PES, Lorenzo JM, Aadil RM. Functional and nutraceutical significance of amla (*Phyllanthus emblica L.*): a review. Antioxidants (Basel). 2022;11(5):816. doi:10.3390/antiox11050816. PMID:35624683.
3. Ruhela G, Dhama K, Shanker K, Ding X, Sharma A. Exploration of metabolomics of *Phyllanthus emblica*: from ayurveda food to modern prospectives in quality control. Food Chem Adv. 2023;3:100330. doi:10.1016/j.focha.2023.100330.
4. Ma QG, Wang L, Liu RH, Yuan JB, Xiao H, Shen ZY, Li JX, Guo JZ, Cao L, Huang HL, Wei RR. *Phyllanthus emblica* Linn: a comprehensive review of botany, traditional uses, phytonutrients, health benefits, quality markers, and applications. Food Chem. 2024;446:138891. doi:10.1016/j.foodchem.2024.138891. PMID:38432135.
5. Kapoor MP, Suzuki K, Derek T, Ozeki M, Okubo T. Clinical evaluation of *Emblica officinalis* Gaertn (amla) in healthy human subjects: health benefits and safety results from a randomized, double-blind, crossover placebo-controlled study. Contemp Clin Trials Commun. 2019;17:100499. doi:10.1016/j.conctc.2019.100499. PMID:31890983.

6. Usharani P, Merugu PL, Nutalapati C. Evaluation of the effects of a standardized aqueous extract of *Phyllanthus emblica* fruits on endothelial dysfunction, oxidative stress, systemic inflammation and lipid profile in subjects with metabolic syndrome: a randomised, double blind, placebo controlled clinical study. BMC Complement Altern Med. 2019;19(1):97. doi:10.1186/s12906-019-2509-5. PMID:31060549.

7. Upadya H, Prabhu S, Prasad A, Subramanian D, Gupta S, Goel A. A randomized, double blind, placebo controlled, multicenter clinical trial to assess the efficacy and safety of *Emblica officinalis* extract in patients with dyslipidemia. BMC Complement Altern Med. 2019;19(1):27. doi:10.1186/s12906-019-2430-y. PMID:30670010.

8. Prabhakar P, Marakala V, Sacheendran D, D'souza RK, D'souza RT, Jayandran M, Pavankumar GS, Palatty PL, Baliga MS. *Emblica officinalis* in preventing metabolic syndrome: a first review addressing the benefits and the mechanism of action. In: Recent progress in medicinal plants. Bentham Science Publishers; 2024. p. 117-41. doi:10.2174/9789815274103124010012.

9. Carr AC, Maggini S. Vitamin C and immune function. Nutrients. 2017;9(11):1211. doi:10.3390/nu9111211. PMID:29099763.

10. Bhattacharya A, Chatterjee A, Ghosal S, Bhattacharya SK. Antioxidant activity of active tannoid principles of *Emblica officinalis* (amla). Indian J Exp Biol. 1999;37(7):676-80. PMID:10522157.

11. Frei B, Birlouez-Aragon I, Lykkesfeldt J. Authors' perspective: what is the optimum intake of vitamin C in humans? Crit Rev Food Sci Nutr. 2012;52(9):815-29. doi:10.1080/10408398.2011.649149. PMID:22698272.

12. Pullar JM, Carr AC, Vissers MCM. The roles of vitamin C in skin health. Nutrients. 2017;9(8):866. doi:10.3390/nu9080866. PMID:28805671.

13. Bhattacharya SK, Bhattacharya A, Sairam K, Ghosal S. Effect of bioactive tannoid principles of *Emblica officinalis* on ischemia-reperfusion-induced oxidative stress in rat heart. Phytomedicine. 2002;9(2):171-4. doi:10.1078/0944-7113-00090. PMID:11995952.

14. Tamoli S, Pande S, Deshpande S, Mundhe N, Doiphode M, Kolhe G, Upasani S. Evaluation of efficacy and safety of Ayucid capsule in subjects suffering from chronic symptomatic gastroesophageal reflux disease. Int J Pharm Investig. 2018;8(2):100-6. doi:10.4103/jphi.jphi_35_18.

15. Malve H, Bhalerao P. Past, present, and likely future of nutraceuticals in India: evolving role of pharmaceutical physicians. J Pharm Bioallied Sci. 2023;15(2):68-74. doi:10.4103/jpbs.jpbs_96_23. PMID:37469644.

16. Haripriya G, Harigovind PC, Sankar UV. Nutraceutical market in India: thoughts on a right-based regulatory approach. Indian J Pharmacol. 2026;58(3):196-204. doi:10.4103/ijp.ijp_862_25. PMID:42060803.

17. Saini R, Sharma N, Oladeji OS, Sourirajan A, Dev K, Zengin G, El-Shazly M, Kumar V. Traditional uses, bioactive composition, pharmacology, and toxicology of *Phyllanthus emblica* fruits: a comprehensive review. J Ethnopharmacol. 2021;282:114570. doi:10.1016/j.jep.2021.114570. PMID:34480995.

18. Saroj N, Kundu MKM, Misra S, Pal R. Aonla (Indian gooseberry) (*Emblica officinalis Gaertn.*): the vitamin C powerhouse for immunity. In: Fruit crops for nutritional security. Springer; 2025. p. 303-27. doi:10.1007/978-981-95-2762-5_13.

19. Bhattacharya A, Ghosal S, Bhattacharya SK. Antioxidant activity of tannoid principles of *Emblica officinalis* (amla) in chronic stress induced changes in rat brain. Indian J Exp Biol. 2000;38(9):877-80. PMID:12561944.

20. Scartezzini P, Antognoni F, Raggi MA, Poli F, Sabbioni C. Vitamin C content and antioxidant activity of the fruit and of the Ayurvedic preparation of *Emblica officinalis Gaertn.* J Ethnopharmacol. 2005;104(1-2):113-8. doi:10.1016/j.jep.2005.08.065. PMID:16226416.

21. Poltanov EA, Shikov AN, Dorman HJD, Pozharitskaya ON, Makarov VG, Tikhonov VP, Hiltunen R. Chemical and antioxidant evaluation of Indian gooseberry (*Emblica officinalis Gaertn.*, syn. *Phyllanthus emblica L.*) supplements. Phytother Res. 2009;23(9):1309-15. doi:10.1002/ptr.2775. PMID:19172666.

22. Gomez S, Anjali C, Kuruvila B, Maneesha PK, Joseph M. Phytochemical constitution and antioxidant activity of functional herbal drink from Indian gooseberry (*Emblica officinalis Gaertn.*) fruits containing spices and condiments. Food Prod Process Nutr. 2023;5:12. doi:10.1186/s43014-022-00127-8.

23. Boonpisuttinant K, Taka T, Ruksiriwanich W, Chutoprapat R, Udompong S, Kansawang R, Sangsee J, Chompoo W, Samothai K, Srisuttee R. Assessment of *in vitro* anti-skin aging activities of *Phyllanthus indofischeri Bennet* extracts for dermatological and aesthetic applications. Sci Rep. 2023;13(1):18661. doi:10.1038/s41598-023-45434-3. PMID:37907639.

24. Maiuolo J, Bulotta RM, Oppedisano F, Bosco F, Scarano F, Nucera S, Guarnieri L, Ruga S, Macri R, Caminiti R, Musolino V, Gliozzi M, Carresi C, Cardamone A, Coppoletta A, Nicita M, Carnevali A, Scorcia V, Mollace V. Potential properties of natural nutraceuticals and antioxidants in age-related eye disorders. Life (Basel). 2023;13(1):77. doi:10.3390/life13010077. PMID:36676026.

25. Pawlowska E, Szczepanska J, Koskela A, Kaarniranta K, Blasiak J. Dietary polyphenols in age-related macular degeneration: protection against oxidative stress and beyond. Oxid Med Cell Longev. 2019;2019:9682318. doi:10.1155/2019/9682318. PMID:31019656.

26. Tokarz P, Kaarniranta K, Blasiak J. Role of antioxidant enzymes and small molecular weight antioxidants in the pathogenesis of age-related macular degeneration (AMD). Biogerontology. 2013;14(5):461-82. doi:10.1007/s10522-013-9463-2. PMID:24057278.

27. Carr A, Frei B. Does vitamin C act as a pro-oxidant under physiological conditions? FASEB J. 1999;13(9):1007-24. doi:10.1096/fasebj.13.9.1007. PMID:10336883.

28. Muthu PR, Bobby Z, Sankar P, Vickneshwaran V, Jacob SE. Amla (*Emblica officinalis*) improves hepatic and renal oxidative stress and the inflammatory response in hypothyroid female Wistar rats fed with a high-fat diet. J Basic Clin Physiol Pharmacol. 2018;29(2):175-84. doi:10.1515/jbcpp-2017-0116. PMID:29267168.

29. Nashine S, Kanodia R, Nesburn AB, Soman G, Kuppermann BD, Kenney MC. Nutraceutical effects of *Emblica officinalis* in age-related macular degeneration. Aging (Albany NY). 2019;11(4):1177-88. doi:10.18632/aging.101820. PMID:30792375.

30. Chanvorachote P, Pongrakhananon V, Luanpitpong S, Chanvorachote B, Wannachaiyasit S, Nimmannit U. Type I pro-collagen promoting and anti-collagenase activities of *Phyllanthus emblica* extract in mouse fibroblasts. J Cosmet Sci. 2009;60(4):395-403. PMID:19691935.

31. Fujii T, Wakaizumi M, Ikami T, Saito M. Amla (*Emblica officinalis Gaertn.*) extract promotes procollagen production and inhibits matrix metalloproteinase-1 in human skin fibroblasts. J Ethnopharmacol. 2008;119(1):53-7. doi:10.1016/j.jep.2008.05.039. PMID:18588964.

32. Adil MD, Kaiser P, Satti NK, Zargar AM, Vishwakarma RA, Tasduq SA. Effect of *Emblica officinalis* (fruit) against UVB-induced photo-aging in human skin fibroblasts. J Ethnopharmacol. 2010;132(1):109-14. doi:10.1016/j.jep.2010.07.047. PMID:20688142.

33. Brown PDS, Ketter N, Vis-Dunbar M, Sakakibara BM. Clinical effects of *Emblica officinalis* fruit consumption on cardiovascular disease risk factors: a systematic review and meta-analysis. BMC Complement Med Ther. 2023;23(1):190. doi:10.1186/s12906-023-03997-8. PMID:37296402.

34. Karkon Varnosfaderani S, Hashem-Dabaghian F, Amin G, Bozorgi M, Heydarirad G, Nazem E, Nasiri Toosi M, Mosavat SH. Efficacy and safety of amla (*Phyllanthus emblica L.*) in non-erosive reflux disease: a double-blind, randomized, placebo-controlled clinical trial. J Integr Med. 2018;16(2):126-31. doi:10.1016/j.joim.2018.02.008. PMID:29526236.

35. Mazumder A, Kumar N, Das S, Kumar SY. A comparative study on mono-therapy and combination therapy of additive drugs (rebamipide and pantoprazole) with amla and honey combination for the treatment of gastroesophageal reflux disease and intestinal motility. Res J Pharm Technol. 2022;15(9):4144-50. doi:10.52711/0974-360x.2022.00696.

36. Hathcock JN, Azzi A, Blumberg J, Bray T, Dickinson A, Frei B, Jialal I, Johnston CS, Kelly FJ, Kraemer K, Packer L, Parthasarathy S, Sies H, Traber MG. Vitamins E and C are safe across a broad range of intakes. Am J Clin Nutr. 2005;81(4):736-45. doi:10.1093/ajcn/81.4.736. PMID:15817846.

37. Padayatty SJ, Levine M. Vitamin C: the known and the unknown and Goldilocks. Oral Dis. 2016;22(6):463-93. doi:10.1111/odi.12446. PMID:26808119.

38. Corpe CP, Tu H, Eck P, Wang J, Faulhaber-Walter R, Schnermann J, Margolis S, Padayatty S, Sun H, Wang Y, Nussbaum RL, Espey MG, Levine M. Vitamin C transporter *Slc23a1* links renal reabsorption, vitamin C tissue accumulation, and perinatal survival in mice. J Clin Invest. 2010;120(4):1069-83. doi:10.1172/JCI39191. PMID:20200446.

39. Levine M, Conry-Cantilena C, Wang Y, Welch RW, Washko PW, Dhariwal KR, Park JB, Lazarev A, Graumlich JF, King J, Cantilena LR. Vitamin C pharmacokinetics in healthy volunteers: evidence for a recommended dietary allowance. Proc Natl Acad Sci U S A. 1996;93(8):3704-9. doi:10.1073/pnas.93.8.3704. PMID:8623000.

40. Chew EY, Clemons TE, SanGiovanni JP, Danis RP, Ferris FL, Elman MJ, Antoszyk AN, Ruby AJ, Orth D, Bressler SB, Fish GE, Hubbard GB, Klein ML, Chandra SR, Blodi BA, Domalpally A, Friberg T, Wong WT, Rosenfeld PJ, Agrón E, Toth CA, Bernstein PS, Sperduto RD. Secondary analyses of the effects of lutein/zeaxanthin on age-related macular degeneration progression: AREDS2 report No. 3. JAMA Ophthalmol. 2014;132(2):142-9. doi:10.1001/jamaophthalmol.2013.7376. PMID:24310343.

41. Chew EY, Clemons T, SanGiovanni JP, Danis R, Domalpally A, McBee W, Sperduto R, Ferris FL. The Age-Related Eye Disease Study 2 (AREDS2): study design and baseline characteristics (AREDS2 report number 1). Ophthalmology. 2012;119(11):2282-9. doi:10.1016/j.ophtha.2012.05.027. PMID:22840421.

42. Sobrin L, Seddon JM. Nature and nurture — genes and environment — predict onset and progression of macular degeneration. Prog Retin Eye Res. 2014;40:1-15. doi:10.1016/j.preteyeres.2013.12.004. PMID:24374240.

43. Bernstein PS, Li B, Vachali PP, Gorusupudi A, Shyam R, Henriksen BS, Nolan JM. Lutein, zeaxanthin, and meso-zeaxanthin: the basic and clinical science underlying carotenoid-based nutritional interventions against ocular disease. Prog Retin Eye Res. 2016;50:34-66. doi:10.1016/j.preteyeres.2015.10.003. PMID:26541886.

44. Age-Related Eye Disease Study 2 (AREDS2) Research Group. Lutein + zeaxanthin and omega-3 fatty acids for age-related macular degeneration: the Age-Related Eye Disease Study 2 (AREDS2) randomized clinical trial. JAMA. 2013;309(19):2005-15. doi:10.1001/jama.2013.4997. PMID:23644932.

45. Age-Related Eye Disease Study Research Group. A randomized, placebo-controlled, clinical trial of high-dose supplementation with vitamins C and E, beta carotene, and zinc for age-related macular degeneration and vision loss: AREDS report no. 8. Arch Ophthalmol. 2001;119(10):1417-36. doi:10.1001/archopht.119.10.1417. PMID:11594942.

46. Cao X, Xu Z, Zhang B, Jiang Z, Yuan X. Exploring causal relationships between circulating micronutrients and age-related eye diseases: a Mendelian randomization study. Genes Nutr. 2025;20(1):8. doi:10.1186/s12263-025-00767-8. PMID:40148774.

47. Kong M, Lee MY, Yang W, Bae JH, Kim JM. Obesity, nutritional intake, and age-related macular degeneration: a cross-sectional study using nationwide survey data from Korea. Ophthalmic Epidemiol. 2025;32(6):660-70. doi:10.1080/09286586.2025.2500023. PMID:40322902.

48. Fletcher AE, Bentham GC, Agnew M, Young IS, Augood C, Chakravarthy U, de Jong PT, Rahu M, Seland J, Soubrane G, Tomazzoli L, Topouzis F, Vingerling JR, Vioque J. Sunlight exposure, antioxidants, and age-related macular degeneration. Arch Ophthalmol. 2008;126(10):1396-403. doi:10.1001/archopht.126.10.1396. PMID:18852418.

49. Snodderly DM. Evidence for protection against age-related macular degeneration by carotenoids and antioxidant vitamins. Am J Clin Nutr. 1995;62(6 Suppl):1448S-61S. doi:10.1093/ajcn/62.6.1448S. PMID:7495246.

50. Chaikul P, Kanlayavattanakul M, Somkumnerd J, Lourith N. *Phyllanthus emblica L.* (amla) branch: a safe and effective ingredient against skin aging. J Tradit Complement Med. 2021;11(5):390-9. doi:10.1016/j.jtcme.2021.02.004. PMID:34522633.

51. Prabhakar P, Dadibhavi AH, Marakala V, Pavankumar GS, Palatty PL, Baliga MS. Indian gooseberry (*Emblica officinalis*) and its phytochemicals as modulators of matrix metalloproteinase in skin. In: Treatments, nutraceuticals, supplements, and herbal medicine in neurological and dermatological disorders. Elsevier; 2025. p. 369-79. doi:10.1016/b978-0-443-26635-5.00032-8.

52. Uchiyama T, Tsunenaga M, Miyanaga M, Ueda O, Ogo M. Oral intake of lingonberry and amla fruit extract improves skin conditions in healthy female subjects: a randomized, double-blind, placebo-controlled clinical trial. Biotechnol Appl Biochem. 2019;66(5):870-9. doi:10.1002/bab.1800. PMID:31342566.

53. Janaki C, Sachdev M, Ritambhara KR. A pilot, exploratory study to demonstrate the efficacy of a novel adjuvant herbal liquid supplement for skin rejuvenation and anti-aging. Int J Res Dermatol. 2021;7(6):792-8. doi:10.18203/issn.2455-4529.intjresdermatol20214203.

54. Hurrell RF, Reddy M, Cook JD. Inhibition of non-haem iron absorption in man by polyphenolic-containing beverages. Br J Nutr. 1999;81(4):289-95. PMID:10999016.

55. Siegenberg D, Baynes RD, Bothwell TH, Macfarlane BJ, Lamparelli RD, Car NG, MacPhail P, Schmidt U, Tal A, Mayet F. Ascorbic acid prevents the dose-dependent inhibitory effects of polyphenols and phytates on nonheme-iron absorption. Am J Clin Nutr. 1991;53(2):537-41. doi:10.1093/ajcn/53.2.537. PMID:1989423.

56. Kumar N, Rungseevijitprapa W, Narkkhong NA, Suttajit M, Chaiyasut C. 5α-reductase inhibition and hair growth promotion of some Thai plants traditionally used for hair treatment. J Ethnopharmacol. 2012;139(3):765-71. doi:10.1016/j.jep.2011.12.010. PMID:22178180.

57. Jang SH, Kim M, Wee JH, Kim J, Choi W. Effects of amla (*Phyllanthus emblica L.*) extract on hair growth promoting. KSBB J. 2018;33(4):299-305. doi:10.7841/ksbbj.2018.33.4.299.

58. Laovachirasuwan P, Fuangbangluang W, Phanichanaphan A, Nasomroop I, Phadungkit M. The development of *Phyllanthus emblica* extract in ethosomes for hair loss prevention. Pharmacogn J. 2020;12(4):905-10. doi:10.5530/pj.2020.12.128.

59. Chakrabarty AK, Banerjee D, Kumar R, Katiyar CK, Dubey SK. *In vitro* 5α-reductase inhibition by selected Ayurvedic herbs for androgenic disorders. Int J Ayurveda Res. 2024;5(4):266-71. doi:10.4103/ijar.ijar_26_24.

60. Majeed M, Majeed S, Nagabhushanam K, Mundkur L, Neupane P, Shah K. Clinical study to evaluate the efficacy and safety of a hair serum product in healthy adult male and female volunteers with hair fall. Clin Cosmet Investig Dermatol. 2020;13:691-700. doi:10.2147/CCID.S271013. PMID:33061509.

61. Wu C, Yang CY, So PB, Hu H, Yang SH, Hsueh HW, Wu T, Yen FL. Safety profile and efficacy of Biosea Revive serum for hair growth through *in vitro* assessment and clinical evaluation. Cosmetics. 2025;12(4):139. doi:10.3390/cosmetics12040139.

62. Mote D, Mali S, Maurya MN. To evaluate the safety and efficacy of Vedistry Amla+ tablets as a supplement for healthy hair. J Ayurveda Integr Med Sci. 2025;10(4):4-9. doi:10.21760/jaims.10.4.2.

63. Fatima N, Pingali U, Muralidhar N. Study of pharmacodynamic interaction of *Phyllanthus emblica* extract with clopidogrel and ecosprin in patients with type II diabetes mellitus. Phytomedicine. 2014;21(5):579-85. doi:10.1016/j.phymed.2013.10.024. PMID:24291054.

64. Usharani P, Fatima N, Muralidhar N. Effects of *Phyllanthus emblica* extract on endothelial dysfunction and biomarkers of oxidative stress in patients with type 2 diabetes mellitus: a randomized, double-blind, controlled study. Diabetes Metab Syndr Obes. 2013;6:275-84. doi:10.2147/DMSO.S46341. PMID:23935377.

65. Indian Council of Medical Research – National Institute of Nutrition, Expert Group on Nutrient Requirements for Indians. Recommended Dietary Allowances and Estimated Average Requirements: Nutrient Requirements for Indians. Hyderabad: ICMR-NIN; 2020.

66. Levine M, Wang Y, Padayatty SJ, Morrow J. A new recommended dietary allowance of vitamin C for healthy young women. Proc Natl Acad Sci U S A. 2001;98(17):9842-6. doi:10.1073/pnas.171318198. PMID:11504949.

67. Massey LK, Liebman M, Kynast-Gales SA. Ascorbate increases human oxaluria and kidney stone risk. J Nutr. 2005;135(7):1673-7. doi:10.1093/jn/135.7.1673. PMID:15987848.