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BEETROOT (BETA VULGARIS) EXTRACT-ENRICHED HERBAL LIP BALM: FORMULATION STRATEGIES, OPTIMIZATION PARAMETERS, EVALUATION METHODS AND FUTURE PROSPECTS—A REVIEW

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ABSTRACT

Lip balms are semisolid cosmetic preparations intended to lubricate the lip surface, improve application comfort and help reduce excessive moisture loss. Beetroot (Beta vulgaris L.) is a source of betalain pigments, particularly betacyanins such as betanin, that may contribute a red-violet tint to herbal lip-care products. Its phytochemical profile and pigment stability vary with cultivar, plant part, extraction method and storage conditions. This review critically examines the scientific rationale and practical development of beetroot extract-enriched lip balm, including raw-material characterization, extraction approaches, excipient selection, formulation and processing principles, optimization strategies, evaluation methods, stability, safety and regulatory considerations. Particular attention is paid to challenges arising from the polarity of betalain-rich extracts and their incorporation into predominantly anhydrous wax–oil systems. Evaluation topics include appearance, colour uniformity, homogeneity, softening behaviour, mechanical strength, spreadability, payoff, packaging compatibility, pigment retention and risk-based microbiological assessment. The review identifies a small but relevant direct evidence base on beetroot lip balm and discusses reported limitations, including inadequate spreadability and the need to interpret pH measurements cautiously in

anhydrous preparations. Evidence from food chemistry, extract studies and other botanical lip products provides useful formulation context but cannot establish clinical benefit or finished-product safety by itself. Future work should prioritize standardized extract specifications, validated pigment assays, design-of-experiments approaches, suitable delivery formats, reproducible testing, stability-indicating methods and product-specific safety assessment. Beetroot-enriched lip balm is a plausible botanical tinting concept, but successful development depends on measured quality and stability rather than natural origin alone.

KEYWORDS: Beetroot extract; *Beta vulgaris*; Herbal lip balm; Betalains; Formulation optimization; Cosmetic stability.

INTRODUCTION

The vermilion of the human lip differs from ordinary cutaneous skin in structure and barrier function. The lips are exposed to air, wind, temperature variation, ultraviolet radiation, saliva and repeated mechanical contact, while their surface characteristics can change with age and environmental conditions. Dryness, tightness, scaling and fissuring may consequently arise when barrier function is impaired or environmental water loss exceeds replenishment. A lip-care product is therefore designed primarily to improve surface lubrication, reduce friction and help limit excessive moisture loss rather than to treat every cause of lip inflammation. Formulation design should account for the distinctive lip surface and the fact that a product applied repeatedly may be incidentally ingested in small quantities.[1,2]

Lip balms are semisolid cosmetic preparations commonly made from waxes, oils, butters and optional colourants, flavours or other ingredients. Waxes help provide structure and resistance to deformation, while liquid and semisolid emollients influence glide, film formation and the perception of softness. The balance is critical: a product that is too hard may drag or require excessive pressure during application, whereas a product that is too soft may deform, sweat, melt in a warm environment or transfer excessively. Performance also depends on the package, use temperature and formulation history, meaning that a composition cannot be judged solely from ingredient identity or appearance.[2-4]

Plant-derived ingredients are increasingly investigated in cosmetic formulations because they can contribute colour, sensory characteristics and potentially useful chemical functionality. However, the label ‘natural’ does not establish purity, suitability for lip application, absence of allergens or superior performance. Extract composition is influenced by botanical source, cultivar, growing environment, plant part, harvest maturity and processing. For an ingredient

intended to impart colour, reproducibility and stability may be more important than a broad claim of biological activity; for an emollient product, botanical origin must be considered alongside oxidation, odour, variability and compatibility with the other excipients.[2,4-6]

Red beetroot, *Beta vulgaris* L., is a notable source of betalain pigments, especially red-violet betacyanins and yellow-orange betaxanthins. Betanin and related pigments contribute to the characteristic red-purple colour. Beetroot also contains phenolic compounds and other constituents whose reported levels vary among varieties and analytical methods. The chemistry of beetroot is well described in food and phytochemical research, but evidence from foods, extracts or in-vitro antioxidant assays cannot be transferred directly to a finished lip balm. The composition that reaches the finished product depends on the extraction format, residual moisture, concentration, processing temperature and the physical environment created by the wax–oil base.[5-18]

Direct literature specifically addressing beetroot-enriched lip balm remains limited. One published formulation study used ethanolic beetroot extract at 0%, 5%, 10% and 15% and observed an increase in red colour intensity with increasing extract concentration; its reported spreadability remained low, and its pH-related result requires careful interpretation because pH is not directly defined for a conventional anhydrous balm without a specified aqueous measurement procedure. The authors reported greater preference for the 10% formulation, but this does not establish a universally optimum concentration, clinical effectiveness or commercial stability. The present review therefore examines formulation principles, extraction, optimization, evaluation and regulatory questions while separating direct lip-balm evidence from indirect beetroot chemistry and general cosmetic formulation evidence.[20-24]

MATERIALS

Targeted searches were conducted using combinations of concepts including: ‘Beta vulgaris phytochemistry,

- Red beet betalains,
- Betanin stability,
- Beetroot extract topical formulation,
- Beetroot lip balm,
- Herbal lip balm formulation,
- Natural pigments in cosmetics,
- Lip balm evaluation,
- Cosmetic product stability,

- Cosmetic microbiological risk.

Priority was given to peer-reviewed primary studies, established reviews on betalain chemistry and beetroot composition, the direct published study of an ethanolic beetroot extract in lip balm, studies on related botanical lip products, and official standards or regulatory documents. Older foundational reports were retained when they described pigment chemistry or stability mechanisms that continue to inform current development. Sources were not treated as equivalent: observations from a finished lip balm were distinguished from data in purified pigment, aqueous extract, food matrices, cell systems or general cosmetic products. Where accessible metadata did not fully substantiate a strong claim, the claim was qualified or omitted. [5-13]

The evidence was organized into botanical identity and phytochemistry; cosmetic relevance; extract production and characterization; excipient selection and manufacturing; optimization design; evaluation; stability; safety and regulation; limitations; and future priorities. Direct findings are attributed to their original formulation study, whereas conceptual development suggestions are described as proposed approaches requiring confirmation. The review did not conduct a formal risk-of-bias tool, independent duplicate screening or meta-analysis, and it does not report a PRISMA flow diagram. These limitations are consistent with the narrative design and should be considered when interpreting the breadth of the evidence. [7,10]

1. BOTANICAL OVERVIEW OF BEETROOT (BETA VULGARIS)

Beetroot is the fleshy storage root of Beta vulgaris L., a species cultivated in multiple forms and valued for food use, pigment content and phytochemical diversity. The most relevant raw material for a red lip balm is typically the red-purple table beet, although the pigment profile can vary with cultivar and plant material. Peel, flesh and processing by-products may differ in phenolics and pigments, so use of a non-standardized by-product should be supported by identity testing and a compositional rationale. For cosmetic development, botanical identity, traceability, harvest and post-harvest handling, microbial quality and agricultural contamination controls form part of raw-material qualification. [5,11-13,16]

Beetroot is not a chemically uniform ingredient. Differences among varieties and production settings can affect pigment ratios, colour strength, phenolic content and the amount of material recovered by a particular solvent. Storage of intact raw roots and processing history can also change measurable constituents. As a result, formulation studies should identify the plant part, source, preparation state and extraction conditions and, where feasible, use a

marker-based specification rather than relying only on the visual redness of the extract. Colour appearance alone is not a quantitative substitute for pigment assay because turbidity, other coloured constituents and measurement conditions can influence the result. [11-13,20]

2. PHYTOCHEMICAL COMPOSITION OF BEETROOT

Betalains are nitrogen-containing, water-soluble pigments structurally distinct from anthocyanins. They are generally classified as betacyanins, which produce red to violet hues, and betaxanthins, which tend to produce yellow to orange hues. Betanin and isobetanin are commonly reported betacyanins in red beetroot. The actual composition of a beetroot extract depends on cultivar, extraction selectivity, processing and storage, so a formulation paper should not assume a fixed betanin content without analytical measurement. Because these pigments are relatively polar, direct incorporation of an aqueous extract into a nonpolar base presents a formulation challenge. [6-14,17]

Phenolic constituents, including phenolic acids and flavonoid-related compounds, have been reported in beetroot and its peel or root tissues. These compounds are of interest because they can contribute to in-vitro antioxidant assay responses, but their amounts and recovery depend on the solvent and analytical technique. A result expressed as total phenolic content or radical-scavenging capacity is method-dependent and does not establish the quantity of a specific active constituent, the amount delivered to lip tissue, or a cosmetic benefit. In formulation work, phytochemical screening can be an initial descriptive step, but specific chromatographic or spectrophotometric marker analysis provides stronger evidence of batch consistency.[5,13-16]

TABLE 1. MAJOR BEETROOT CONSTITUENTS AND THEIR RELEVANCE TO LIP BALM DEVELOPMENT.

Constituent / group	Typical relevance in literature	Potential relevance to lip balm	Key caution
Betacyanins (including betanin / isobetanin)	Red-violet pigments; widely reported in red beetroot	Primary candidates for visible tint; marker candidates for standardization	Pigment content and stability vary with cultivar, extraction and storage [6-13]
Betaxanthins	Yellow-orange pigment group	May influence overall hue and shade balance	Relative abundance differs by raw material and processing [7,9,12]
Phenolic	Reported in beetroot	May justify exploratory	Total phenolics are

Constituent / group	Typical relevance in literature	Potential relevance to lip balm	Key caution
compounds / phenolic acids	tissues and extracts; may contribute to assay-based antioxidant responses	characterization if relevant to product rationale	method-dependent and do not identify individual compounds [5,13-16]
Flavonoid-related constituents	Some flavonoids have been reported in beetroot-related analyses	Potential supporting phytochemical profile	Presence and abundance should be confirmed for the specific extract [5,14-16]

For finished-product development, a useful minimum characterization package would document extract appearance, odour, dry matter or solids content, solvent identity, residual solvent where relevant, water content, and a pigment-related measure such as absorbance at a justified wavelength or chromatographic marker. Absorbance can support lot-to-lot comparisons only when sample preparation, dilution, path length and blank correction are fixed. High-performance liquid chromatography or another suitably selective method can provide more specific information than an unvalidated colour reading. The method should be selected according to available facilities and claims intended for the final product.[9-11,19,20]

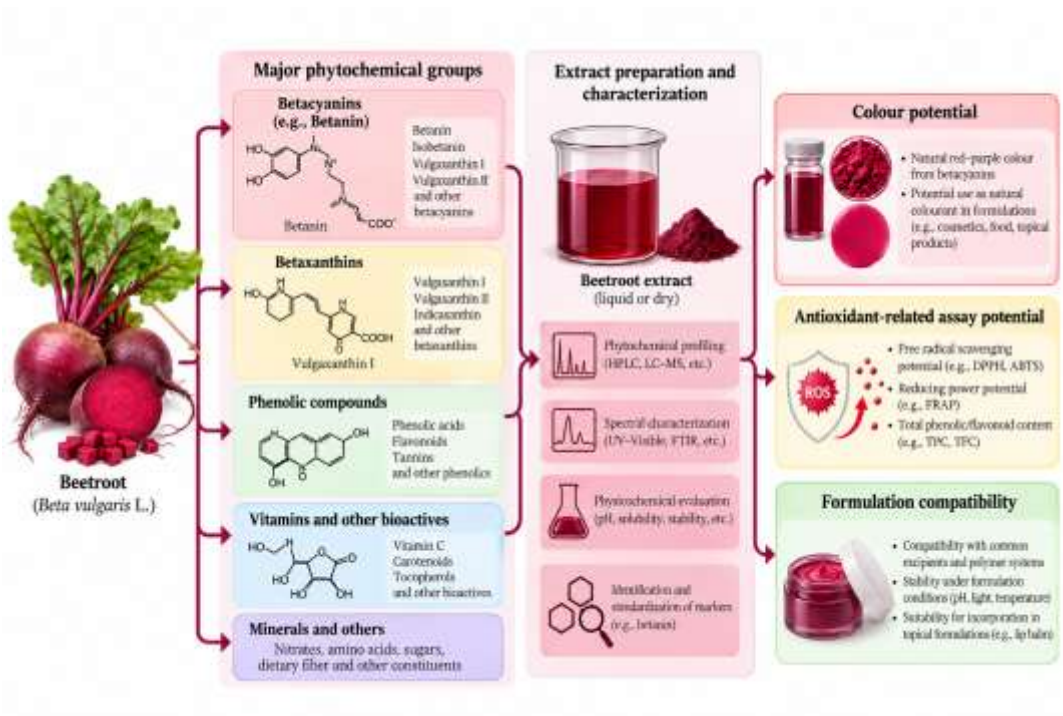


Figure 1. Phytochemical Profile of Beetroot and Its Relevance to Herbal Lip Balm.

4. RATIONALE FOR BEETROOT-ENRICHED HERBAL LIP BALM

An extract-enriched lip balm integrates two separate formulation purposes: the wax–oil base must provide acceptable film formation and glide, while the beetroot-derived material may contribute colour and selected measurable phytochemical characteristics. These purposes can conflict. Increasing extract load may intensify colour but can also increase polarity, water content, particulate matter, odour or incompatibility with the continuous lipid phase. The correct selection is therefore an experimental balance rather than a presumption that more extract produces a better product.[2,9,10,21]

A sound rationale should define primary and secondary target product attributes before formulation begins. Primary attributes might include an even visible tint, smooth glide, adequate mechanical integrity and acceptable storage stability. Secondary attributes may include preference, minimal odour and packaging convenience. A developer should also state the intended product category and market, distinguish cosmetic appearance from therapeutic objectives, and predefine conditions that would require reformulation or rejection. Without explicit product targets, choosing a 'best' batch after testing many options can become subjective and difficult to reproduce.[2,21,24]

5. STABILITY STUDIES

Stability testing determines whether the product retains acceptable attributes during storage in its intended package. ISO/TR 18811 provides a framework for developing a cosmetic stability protocol but does not prescribe one universal set of conditions or acceptance criteria for every product. The manufacturer or developer must justify test conditions and relevant parameters for the product. For beetroot balm, the protocol should be designed around the expected sensitivity of betalains, the lipid base, the package and the anticipated transport and consumer-use environment.[7,8,20]

Light and oxygen can contribute to betalain degradation and can also affect the oxidation of oils. Packaging that limits light exposure and unnecessary headspace may be worth investigating, but its benefit should be demonstrated by comparing appropriate alternatives under the same conditions. The chemical nature and permeability of the container, closure integrity and the repeated opening of a package can influence exposure. If a colour change is observed, a marker assay can help distinguish pigment degradation from a visual shift caused by surface appearance or background ingredients.[7-11]

TABLE 2. STABILITY CHALLENGES AND POTENTIAL CONTROL STRATEGIES.

Challenge	Possible contributor	Evidence / limitation
Pigment fading or hue shift	Light, oxygen, heat, matrix conditions	Betalain sensitivity is documented, but finished balm response requires testing [7-11,14,20]
Uneven colour / speckling	Poor dispersion, agglomeration, phase incompatibility	Specific solution depends on extract and base [9-11,21]
Softening / deformation	Wax–oil ratio, temperature and package geometry	Must be confirmed for selected formula [2,23,24]
Sweating / oil separation	Crystallization, base incompatibility, process history or added liquid extract	Water-bearing extracts can change an anhydrous design [9-11,21]
Odour change / lipid oxidation	Oxidation of oils or interactions with the botanical extract	Stabilizer effects are formulation-specific [2,3,8]
Microbial concern	Introduced water, contamination or inadequate process hygiene	Use product-specific risk assessment and applicable standards [23]

A defensible stability protocol should state the batch number, number of units, package, storage conditions, time points, analytical methods, acceptance criteria and any deviations. Tests may include initial characterization, room-temperature real-time storage, justified accelerated exposure and relevant cycling or transport conditions. Numerical shelf-life claims should be reserved for data that support them. For early-stage academic research, results should be framed as preliminary stability observations rather than commercial shelf-life validation when the study duration or conditions are limited.[23]

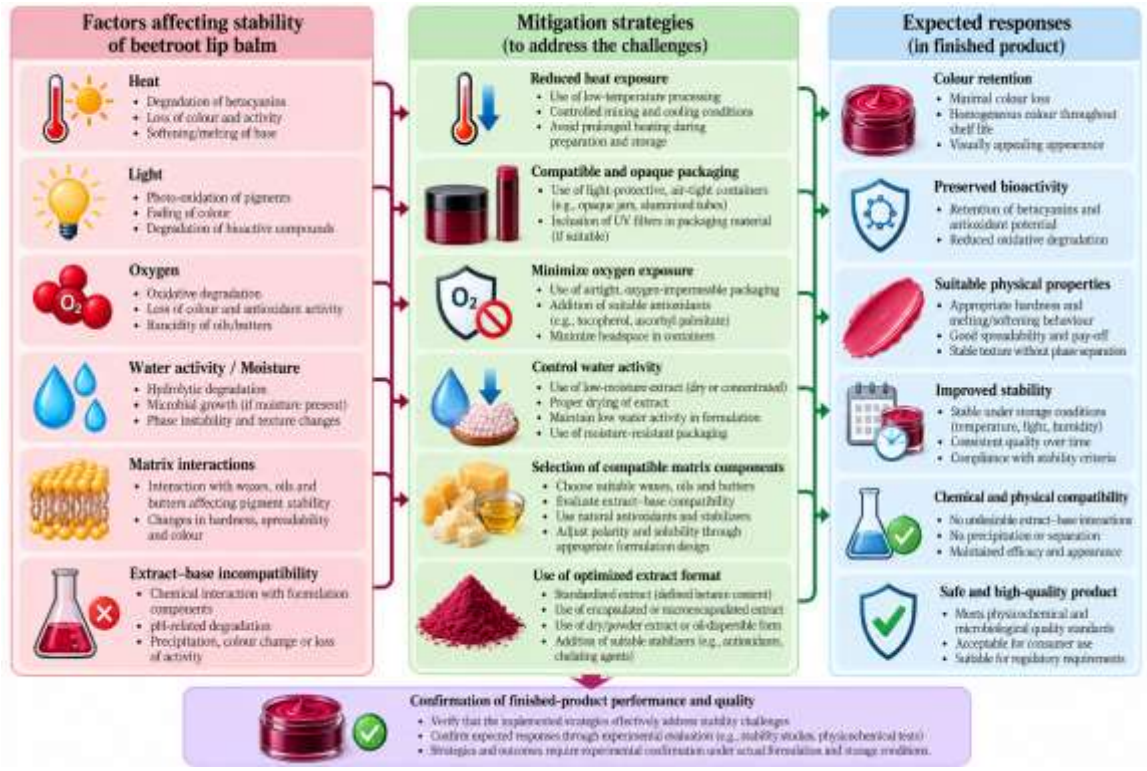


Figure 2. Stability Challenges and Future Development Strategies.

6. SAFETY, QUALITY AND REGULATORY CONSIDERATIONS

Safety assessment must address the finished formulation, not just the reputation of a plant ingredient. Beetroot extract quality can be affected by botanical identity, agricultural contaminants, microbial burden, processing hygiene, residual solvent and the chemical profile of the selected raw material. Oils, waxes, flavours and other additives also need appropriate cosmetic-grade specifications and traceability. A formulation described as natural can still produce irritation or sensitization, and a raw material used in food is not automatically demonstrated to be suitable in every topical cosmetic use or concentration.[2-4,22]

Lip products merit attention because repeated application and incidental oral exposure are reasonably foreseeable. Ingredient suitability, flavour or fragrance sensitization, visible contamination, packaging cleanliness and the potential presence of unwanted elements should be considered. Published surveys of lip cosmetics have investigated elemental profiles and consumer exposure, illustrating the value of raw-material and finished-product quality control; these findings do not establish that beetroot balm itself contains contaminants, but they do support the need for appropriate specifications and testing.[22]

For an Indian product, development and commercialization should be checked against the Cosmetics Rules, 2020 and other applicable requirements in force at the time of manufacture

and sale, including labeling, manufacturing, ingredient quality and claims. The review does not constitute legal advice, and exact obligations depend on the product category, supply chain and intended claims. Regulatory conditions in another market may differ. As an example, U.S. FDA rules require cosmetic color additives to be permitted for the intended use; this illustrates why an ingredient's status as a natural pigment or food colorant cannot by itself be used to infer that it is accepted for every lip cosmetic application in every jurisdiction.[24]

7. ADVANTAGES AND POTENTIAL APPLICATIONS

A beetroot-enriched lip balm has a plausible role as a tinted botanical cosmetic in which a plant-derived extract contributes to product colour while the lipid base provides lubrication and a protective film. Its advantages may include visual differentiation, the opportunity to investigate natural pigment formats and the ability to compare different extract-processing approaches. These are development opportunities rather than demonstrated market advantages, and each depends on a stable, reproducible extract and a finished formula with acceptable use properties.[7,9,10,20-22]

The technology could be adapted to sticks, pots or other formats, but package geometry and contact with air and light may alter product performance. A higher pigment load may be suitable when intense tint is the goal, while a lower load or a more concentrated standardized extract could be preferable when a subtle tint and low ingredient loading are prioritized. Any adaptation should compare colour uniformity, payoff, transfer, odour, texture and storage behaviour using the same measurement procedures.[2-4,21]

Potential antioxidant-related positioning requires caution. A formulation may contain betalains and phenolics, but the evidence available from chemical assays and food studies does not demonstrate that the finished balm prevents damage or treats a lip disorder. Studies that wish to test such hypotheses need a validated assay on the finished product, justified exposure conditions and, for claims implying a benefit to people, appropriately designed clinical or user studies. Cosmetic appearance and therapeutic efficacy should remain clearly separated in the scientific narrative.[6,14-17]

FUTURE PERSPECTIVES

The first priority is standardization of the beetroot raw material and extract. Future studies should report botanical identity, plant part, source and processing history, extraction solvent, solvent-to-solid ratio, yield, dry matter, storage conditions and at least one relevant pigment

measure. Chromatographic characterization would be particularly useful where a study makes claims about betanin or another defined constituent. Standardized inputs are necessary before differences in finished-product performance can be attributed confidently to formulation variables.[9-13,19,20]

The second priority is rational comparison of extract formats. Studies could compare a characterized liquid extract with a dried or encapsulated form, while accounting for carrier content, actual pigment loading, sensory effects and processing conditions. A staged design could first screen compatibility and colour release, then optimize the wax–oil base, and finally test the best candidates for stability. Such a sequence is more informative than changing multiple components at once without a design strategy.[3,19,20]

Third, investigators should improve measurement quality and reporting. A useful study would define test methods before evaluating batches, include independent replicate batches, specify exact units and sample conditioning, and report variability rather than only qualitative observations. Colour measurement and pigment assay should be paired when feasible; physical properties should be measured at controlled temperatures; and sensory testing should be documented separately from instrument-based results. Proposed acceptance criteria should be justified by product function, benchmark data or applicable standards rather than copied from unrelated formulas.[3,23]

Fourth, stability and packaging should be treated as part of formulation design, not as a final afterthought. A study could compare selected package materials and light-protection options, evaluate temperature exposure and storage duration, and track both physical attributes and pigment-related markers. The protocol should reflect likely handling and use conditions and should distinguish preliminary accelerated observations from real-time shelf-life evidence. Microbiological risk assessment and finished-product safety testing must be proportionate to the formulation and intended use.[20,21]

Finally, the research field would benefit from a clear separation of cosmetic and therapeutic objectives. If the intended purpose is tint and emolliency, the study should prioritize colour consistency, comfort, glide, payoff, stability and consumer acceptability. If antioxidant-related claims are proposed, the evidence chain needs to progress from extract characterization to finished-product testing and, where required, appropriate human evidence. The most useful future studies will be those that produce reproducible, transparent results and openly report negative findings such as poor spreadability or colour loss.[6,14]

CONCLUSION

Beetroot extract is a scientifically plausible source of plant-derived colour for herbal lip balm because red beetroot contains betalain pigments, including betacyanins such as betanin. However, the practical value of the ingredient depends on its composition, concentration, pigment retention and behaviour in the finished formulation. Evidence from food and extract research helps explain the chemistry of betalains, but those findings do not independently establish benefits or performance for a topical lip product.

Successful development requires coordinated selection of waxes, oils, butters and extract format, followed by controlled manufacture and structured optimization. Colour intensity should be considered together with spreadability, payoff, hardness, softening behaviour, homogeneity, odour, packaging compatibility and stability. Measurements must be methodologically appropriate: in particular, pH should not be assigned to a conventional anhydrous balm without describing the aqueous dispersion or measurement procedure. Published direct evidence shows promise for colour development but also highlights limitations such as low spreadability; it does not identify a universally optimal extract concentration.

Further research should use standardized beetroot extracts, quantitative pigment markers, replicated formulation batches, suitable experimental designs and stability protocols adapted to the final matrix and package. Microbiological risk, raw-material quality, sensitization potential, labeling and jurisdiction-specific cosmetic requirements should be considered before any commercial or human-use claims are made. The strongest future contributions will be reproducible studies that clearly distinguish measured product properties from proposed mechanisms and that report both successful and unsuccessful formulation outcomes.

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