IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Boswellia Serrata-Loaded Nanostructured Lipid Carriers for Topical Inflammation

Amit D. Pote[1], Dr. Ravi U. Kurhade[2], Dr. Pratapsinh V. Kachave[3], Mr. Rushikesh S. Sarde [4], Mr. Nishinandan M. Shinde[5]

[1]M. Pharm Final Year Student, Department of Pharmacology
[2]Principal, Department of Pharmaceutics
[3]Professor, Department of Pharmacology
[4]Assistant Professor, Department of Pharma Chemistry
[5]Assistant Professor, Department of Pharmaceutics
MDA School of Pharmacy, Kolpa, Latur, Maharashtra
amitreddy242@gmail.com

Abstract: *Boswellia serrata oleo-gum-resin is a traditional medicinal material whose non-volatile fraction contains pentacyclic triterpenes, including 11-keto-beta-boswellic acid (KBA) and 3-O-acetyl-11-keto-beta-boswellic acid (AKBA). Experimental studies support effects on 5-lipoxygenase-dependent leukotriene formation and other inflammatory pathways, but translation into a reproducible topical product remains difficult. The extract is chemically variable, highly lipophilic and poorly dispersible in water; marker concentrations used in mechanistic experiments may not reflect concentrations achieved in tissue. Nanostructured lipid carriers (NLCs) offer a plausible strategy for incorporating lipophilic constituents and increasing contact with the skin, yet high loading or small particle size does not ensure release, viable-skin delivery, safety or clinical efficacy. This review critically integrates inflammation biology, skin-barrier considerations, Boswellia chemistry and pharmacology, conventional delivery limitations, NLC formulation science, Quality by Design (QbD), analytical standardisation, ex-vivo skin disposition and safety. Delgocitinib 2% cream is discussed as a modern topical pan-Janus kinase inhibitor and a useful pharmacological benchmark for chronic hand eczema, while emphasising that a standardised herbal nanogel cannot be considered dose-equivalent or therapeutically equivalent. The strongest development strategy is a stage-gated one: authenticate the botanical material; establish a fingerprint and marker assay; select lipids and surfactants on measured solubility and tolerability; optimise the product using risk-based experimentation; verify independent batches; and demonstrate controlled release, mass-balanced local skin retention, non-cytotoxic activity and acceptable dermal safety. Current evidence supports the scientific rationale for a Boswellia-NLC gel but does not establish clinical effectiveness. Well-controlled formulation-specific studies and ultimately human trials are required.*

Keywords: Boswellia serrata; boswellic acid; AKBA; KBA; lipid nanoparticles; nanostructured lipid carrier; topical delivery; skin inflammation; chronic hand eczema; delgocitinib.

INTRODUCTION

I. REVIEW SCOPE AND LITERATURE APPROACH

This narrative review addresses a focused translational question: what evidence is required to develop a defensible topical Boswellia serrata NLC product for inflammatory skin disease? The review integrates four evidence domains: inflammation and skin-barrier biology; chemistry and pharmacology of Boswellia resin; lipid-nanoparticle formulation science; and contemporary topical therapy represented by delgocitinib. The intention is not to claim that the evidence is equivalent to a formal systematic review or meta-analysis.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Priority is given to primary mechanistic studies, clinical trials, authoritative regulatory product information and international technical guidance. Older foundational publications are retained when they establish widely used concepts such as the 500-Da heuristic, diffusion-cell testing or the distinction between solid lipid nanoparticles and NLCs. The review also considers methodological literature on QbD, analytical validation, ex-vivo skin absorption and reporting of animal research [5,11-25].

Table 1. Evidence framework used in the review

Evidence domain	Inclusion emphasis	Main appraisal question
Inflammation/skin	Mechanistic and barrier studies	Is the pathway relevant to topical inflammatory disease?
Boswellia chemistry	Authenticated resin, defined boswellic acids	Is the tested material chemically characterised?
Pharmacology	Biochemical, cellular, animal and clinical studies	Are concentration and exposure plausible?
Nanocarriers	SLN/NLC formulation and dermal studies	Does the carrier improve release and skin disposition?
Comparator	Delgocitinib trials and product information	What can be benchmarked without claiming equivalence?
Guidance	ICH, OECD, WHO and ARRIVE	Are methods and interpretations aligned with accepted principles?

Because botanical preparations differ in species, source, extraction and marker composition, results are interpreted at the formulation level. Evidence from oral products is not assumed to establish topical activity, and evidence from isolated AKBA is not automatically assigned to the whole extract.

II. INFLAMMATION AS A NETWORK RATHER THAN A SINGLE TARGET

Inflammation begins when pattern-recognition and damage-sensing systems detect infection, injury or loss of homeostasis. Vascular mediators increase blood flow and permeability, while cytokines and chemokines recruit and activate leukocytes. These processes are protective when time-limited, but persistent signalling can drive tissue remodelling, sensory hypersensitivity and barrier dysfunction [1-3,33-35].

A topical formulation may influence several levels of this network. Eicosanoids such as leukotrienes and prostaglandins regulate vascular and leukocyte responses. TNF-alpha, IL-1beta and IL-6 amplify local inflammation. NF-kappaB and MAPK pathways coordinate transcriptional responses, while JAK-STAT signalling transmits signals from numerous cytokine receptors. Resolution is an active process involving mediator switching, removal of inflammatory cells and restoration of tissue function rather than simple disappearance of pro-inflammatory signals.

These concepts shape experimental interpretation. A decrease in one mediator may indicate pathway modulation, assay interference or cytotoxicity. Viability, timing, matrix controls and orthogonal endpoints are therefore needed. For a botanical extract, multi-target activity may be valuable, but broad activity also increases the need for chemical standardisation and safety controls.

Table 2. Inflammatory network and interpretation

Level	Representative components	Topical-development implication
Initiation	Pattern-recognition receptors, alarmins and microbial products	Model and trigger determine relevance
Amplification	TNF-alpha, IL-1beta, IL-6, chemokines	Measure a panel rather than one biomarker
Lipid mediators	5-LOX/leukotrienes and COX/PGE2 pathways	Mechanistic rationale for boswellic acids
Signal transduction	NF-kappaB, MAPK and JAK-STAT	Different active substances may converge on outcomes

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Resolution	Efferocytosis and pro-resolving mediators	Excessive suppression is not synonymous with repair

III. SKIN BARRIER AND CHRONIC HAND ECZEMA

The epidermis is both a physical barrier and an immune organ. The stratum corneum limits water loss and entry of external chemicals, while keratinocytes produce cytokines, chemokines, antimicrobial peptides and alarmins. Barrier injury caused by detergents, wet work, friction or allergens can increase transepidermal water loss and sustain inflammation. Disease may further alter lipid organisation and protein expression, creating a feedback loop between permeability and immune activation [4,36,37].

Chronic hand eczema is heterogeneous. Irritant, allergic, atopic and mixed mechanisms can produce erythema, scaling, vesiculation, hyperkeratosis and painful fissures. Occupational exposure and repeated washing are common perpetuating factors. Treatment performance depends not only on pharmacology but also on spreadability, residue, compatibility with work and gloves, and tolerance during repeated use [38-40].

The delivery objective should therefore be stated carefully. For a locally acting anti-inflammatory product, high systemic flux is not the principal goal. An ideal profile provides reproducible application, release from the vehicle, partitioning into the stratum corneum and viable epidermal or dermal layers, and limited unnecessary systemic exposure. The conventional 500-Da rule is a heuristic rather than an absolute barrier; molecular size, lipophilicity, hydrogen bonding, vehicle and skin condition interact [5].

Table 3. Topical performance attributes

Topical attribute	Clinical or biological relevance	Measurement
pH and excipient tolerability	Avoids worsening barrier damage	Validated irritation testing
Rheology and spreadability	Influences dose uniformity and adherence	Controlled rheometry and application studies
Release	Determines availability from the vehicle	Diffusion-cell study
Skin retention	Represents local deposition	Layer-specific extraction and assay
Receptor flux	Indicates transdermal passage	Cumulative receptor analysis
Mass balance	Supports validity of disposition results	Donor, skin, receptor and apparatus recovery

IV. BOSWELLIA SERRATA: BOTANICAL AND CHEMICAL FOUNDATION

Boswellia serrata, known as Indian frankincense, Salai or Shallaki, yields an oleo-gum-resin from the bark. The material contains a volatile oil fraction, gum polysaccharides and a resin fraction rich in triterpenoids. The non-volatile boswellic acids are chemically distinct from frankincense essential oil and are the principal constituents used for pharmaceutical standardisation [7-10,41].

The main boswellic-acid family includes beta-boswellic acid, acetyl-beta-boswellic acid, KBA, AKBA and related alpha isomers. Tirucallic acids and other triterpenoids may also contribute to biological effects. Composition varies with species, geographical source, harvesting, resin age, storage and extraction. Consequently, the common name of the plant or a supplier declaration is insufficient for a reproducible medicinal product.

Table 4. Pharmaceutical identity of a Boswellia extract

Quality element	Why it is needed	Example evidence
Accepted botanical name and plant part	Prevents substitution and ambiguity	Qualified authentication and voucher material
Traceable lot and sampling	Allows investigation of variability	Supplier, origin and retained sample

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Pharmacognostic tests	Detects foreign matter and gross deterioration	Macroscopy, moisture, ash and extractives
Chromatographic fingerprint	Describes the broader chemical pattern	HPTLC or HPLC profile
KBA and AKBA assay	Provides quantitative marker control	Validated marker-specific method
Contaminant limits	Protects safety and method validity	Microbial, metals, pesticides, aflatoxins and solvents

A standardised extract is therefore defined by a control strategy rather than a single percentage claim. Fingerprinting and marker assay answer complementary questions: the first detects broader compositional change, while the second supports dose and stability calculations.

V. KBA AND AKBA: PHYSICOCHEMICAL AND PHARMACOKINETIC CONSIDERATIONS

KBA and AKBA are large, predominantly hydrophobic pentacyclic molecules. KBA contains a hydroxyl, ketone and carboxylic-acid function; AKBA is acetylated at the 3-hydroxyl position and is more hydrophobic. Both show very limited aqueous solubility. These features support incorporation into lipid phases but may also produce strong carrier retention and difficult extraction from biological matrices.

Oral pharmacokinetic studies have reported low or variable circulating exposure to several boswellic acids, especially AKBA, relative to concentrations commonly used in mechanistic experiments [8,9,42]. Factors include poor dissolution, food effects, intestinal transport, metabolism and formulation differences. Local topical delivery could reduce dependence on gastrointestinal absorption, but it introduces the independent challenge of crossing the stratum corneum.

Table 5. Marker properties and development consequences

Property	Potential benefit	Potential limitation
High lipophilicity	Good affinity for lipid carriers and skin lipids	Poor aqueous dispersion and possible carrier sequestration
Large molecular framework	May support membrane or enzyme interactions	Uncertain passive penetration into viable skin
Acidic functional group	Allows pH-dependent ionisation	Assay recovery and partitioning may vary with pH
Low oral exposure	Supports exploration of local delivery	In-vitro potency may exceed achievable tissue level
Marker measurability	Enables standardisation and mass balance	Two markers do not represent the whole extract

For topical products, bioavailability should be expressed in relation to release and skin compartments rather than assumed from oral pharmacokinetics. The critical question is whether intact markers are recovered in relevant tissue layers at concentrations associated with activity, while the formulation remains safe and chemically stable.

VI. ANTI-INFLAMMATORY MECHANISMS OF BOSWELLIA CONSTITUENTS

The best-known mechanism is modulation of 5-lipoxygenase-dependent leukotriene biosynthesis. Early studies described boswellic acids as non-redox 5-lipoxygenase inhibitors, with AKBA showing substantial activity in selected systems [6]. Later work indicated that interaction with the enzyme can be allosteric and dependent on compound structure, concentration and experimental context. The findings provide a mechanistic basis but do not establish topical efficacy.

Other reported targets include prostaglandin E2-related pathways, proteases and signalling associated with NF-kappaB and MAPKs [7,10]. Whole-extract effects may arise from several constituents and cannot be assigned solely to KBA or AKBA. Conversely, activity of an isolated compound should not be automatically attributed to an extract with low or unreported marker content.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

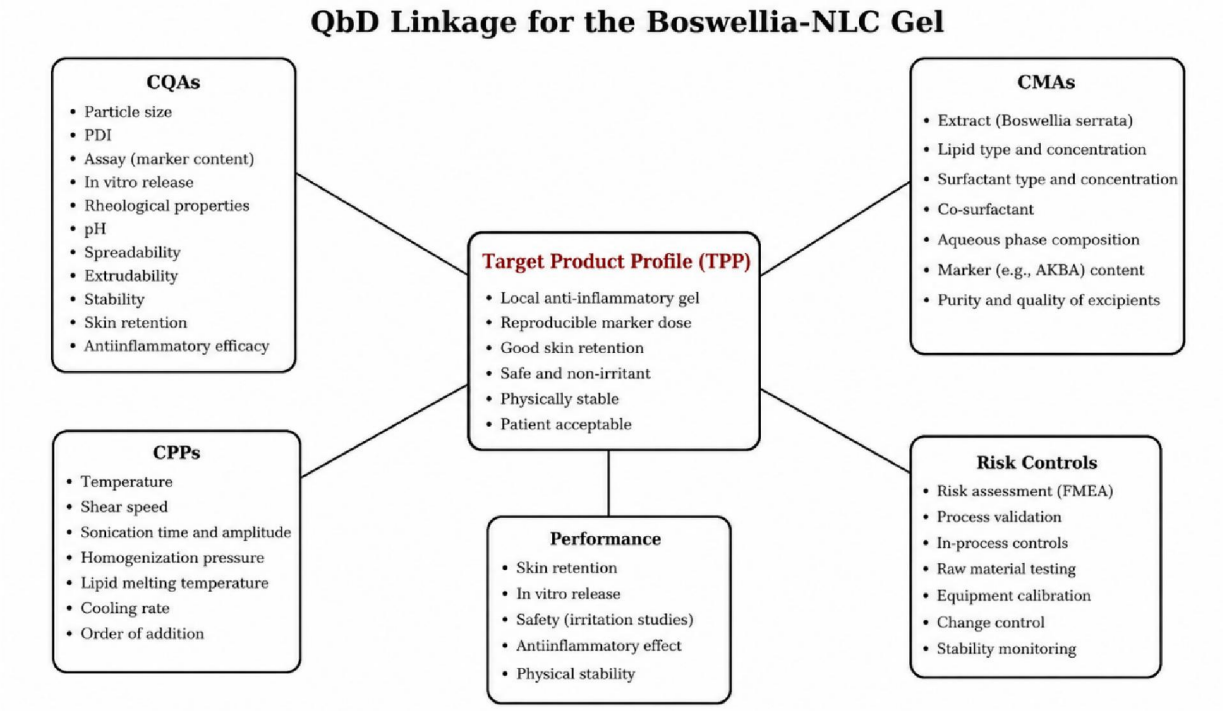

Figure 1. Mechanistic pathways must be interpreted together with release, tissue exposure and safety.

Table 6. Hierarchy of mechanistic claims

Claim level	Evidence needed	What it does not establish
Enzyme inhibition	Defined compound, concentration and assay controls	Activity of an uncharacterised extract
Cellular anti-inflammatory effect	Viability-corrected mediator response	Clinical benefit or adequate skin exposure
Whole-extract activity	Fingerprint, marker content and matrix controls	Contribution of one constituent
Topical formulation activity	Release, skin retention and biological response	Therapeutic equivalence to an approved drug

VII. PRECLINICAL EVIDENCE AND ITS INTERPRETATION

Boswellia extracts and boswellic acids have been evaluated in biochemical assays, cultured cells and animal models of inflammation. The overall literature supports biological plausibility, but study materials and doses are heterogeneous. Some studies use isolated AKBA, others use enriched extracts and others use incompletely characterised commercial products. This diversity limits quantitative comparison.

Preclinical models are useful for identifying pathway engagement and comparing formulations under controlled conditions. They cannot replicate the full heterogeneity of chronic hand eczema. A robust topical programme should use a concentration ladder, viability assessment, blank-carrier control and a marker-matched plain formulation. Animal testing should follow a non-animal-first sequence and use randomisation, blinding and predefined exclusions [24,25].

Table 7. Preclinical evidence hierarchy

Model	Strength	Common limitation	Best use
Cell-free enzyme assay	Direct mechanistic information	No barrier, metabolism or cytotoxicity context	Target plausibility and screening

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Activated macrophages	Cytokine and nitric-oxide responses	Limited epidermal relevance	Concentration-response and carrier controls
Keratinocytes	Relevance to epidermal signalling	Simplified immune environment	Barrier-cell and cytokine endpoints
Reconstructed epidermis	Human-relevant irritation framework	Limited systemic and immune components	Safety gate before animal use
Topical animal model	Integrated tissue response	Species and model differences	Comparative formulation performance

The most important interpretive safeguard is exposure plausibility. A mediator response at a nominal concentration is meaningful only when the active material is released from the formulation, recovered from the assay matrix and present at non-cytotoxic levels.

VIII. CLINICAL EVIDENCE FOR BOSWELLIA PREPARATIONS

Clinical studies have explored Boswellia preparations in osteoarthritis, asthma, inflammatory bowel disease and other conditions [43-46]. Some trials report symptomatic improvement and acceptable short-term tolerability. However, the literature is not directly transferable to a topical dermatological product because routes, formulations, extract specifications, comparators and endpoints differ.

Osteoarthritis trials illustrate both promise and uncertainty. Randomised studies of standardised extracts have reported improvements in pain or function, but products may differ in enrichment, bioavailability technology and co-ingredients [43,44]. Trials in asthma and colitis provide additional evidence that Boswellia preparations can influence inflammatory disease, yet they are small and often predate current expectations for botanical characterisation [45,46].

Table 8. Translational meaning of clinical Boswellia evidence

Evidence observation	Relevance to topical development	Limitation
Clinical responses reported in oral studies	Supports human biological plausibility	Does not establish skin delivery or local efficacy
Generally acceptable short-term tolerability	Supports continued investigation	Systemic and topical safety profiles differ
Different standardised extracts show activity	Highlights importance of product definition	Prevents pooling of all Boswellia products
Marker-enriched or enhanced-bioavailability products exist	Shows formulation can influence exposure	Cannot predict NLC-gel performance
Few direct topical trials	Identifies opportunity for research	Leaves a major evidence gap

Accordingly, oral clinical evidence should be used to justify further research, not to support a claim that a topical NLC gel treats chronic hand eczema. A dedicated clinical programme would require a defined product, validated dose, local safety data and disease-specific outcomes.

IX. WHY CONVENTIONAL BOSWELLIA DELIVERY IS DIFFICULT

A conventional gel containing a lipophilic extract may show poor content uniformity, precipitation, slow dissolution or inconsistent release. Co-solvents and penetration enhancers can improve apparent solubility but may irritate compromised skin. The extract itself can interfere with colorimetric assays and may adsorb to filters, membranes or laboratory plastics. These practical issues can create false conclusions about activity or recovery.

High lipophilicity creates a dual problem. It favours partitioning into lipids but can reduce the thermodynamic activity that drives release from a lipid-rich vehicle. A formulation with very high entrapment may therefore deliver less marker to skin than a simpler gel. The solid-to-liquid lipid ratio, surfactant system and polymer matrix must be balanced rather than optimised for one response.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Table 9. Conventional delivery limitations and controls

Problem	Possible formulation response	Required control
Poor water dispersion	Lipid carrier or co-solvent	Distinguish true solubility from colloidal dispersion
Batch variability	Fingerprint and marker normalisation	Use a qualified lot and retained sample
Precipitation after dilution	Select compatible lipids/surfactants	Stress and dilution studies
Assay interference	Matrix-specific sample preparation	Placebo, blank carrier and spike recovery
Irritation risk	Minimise surfactant/penetration enhancer burden	Blank formulation and dermal-safety testing
Excessive carrier retention	Increase matrix imperfection or revise ratio	Release plus skin-disposition study

The value of a nanocarrier is therefore comparative. It must outperform a well-designed, marker-matched conventional formulation under the same dose and analytical conditions.

X. FROM SOLID LIPID NANOPARTICLES TO NANOSTRUCTURED LIPID CARRIERS

Solid lipid nanoparticles (SLNs) were developed as colloidal carriers composed mainly of lipids that remain solid at body temperature. They offer physical protection, occlusion and compatibility with lipophilic actives, but highly ordered lipid crystals may expel incorporated molecules during storage. NLCs incorporate a liquid lipid into the solid matrix, producing structural imperfections that can increase loading and reduce expulsion [11-13,47,48].

NLCs are commonly categorised as imperfect, amorphous or multiple-type matrices depending on lipid organisation. These categories are conceptual; actual structure depends on lipid chemistry, ratios, cooling history and storage. Differential scanning calorimetry and X-ray diffraction can provide supportive evidence, but marker assay, release and stability remain the decisive performance measurements.

Table 10. SLN and NLC comparison

Feature	SLN	NLC	Interpretation
Lipid matrix	Predominantly solid lipid	Solid plus liquid lipid	NLC creates intentional lattice disorder
Loading capacity	Can be limited by crystallinity	Often higher for lipophilic actives	Must be confirmed for each marker
Drug expulsion	Possible during polymorphic transition	Potentially reduced	Long-term stability still required
Release control	Dependent on matrix and location	Tunable by lipid ratio	High entrapment can still slow release
Topical benefit	Occlusion and contact	Similar plus flexible matrix design	Safety and skin deposition determine value

For a Boswellia extract, the multi-component nature adds complexity because different triterpenes may partition differently. Product characterisation should therefore measure both KBA and AKBA and retain the extract fingerprint where feasible.

XI. NLC COMPOSITION AND MANUFACTURING METHODS

A typical NLC contains a solid lipid, liquid lipid, surfactant and aqueous phase. Topical conversion adds a gelling polymer, pH adjustment and possibly a preservative. Common production methods include hot or cold homogenisation, ultrasonication, microemulsion dilution, solvent-emulsification and high-pressure homogenisation. Method selection should reflect extract stability, laboratory capability, scale-up potential and residual-solvent risk.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Hot emulsification with high-shear homogenisation and ultrasonication is accessible for academic development. The lipid and aqueous phases are heated, combined, homogenised, size-reduced and cooled. Critical process variables include phase temperature, order and rate of addition, actual shear or energy input and cooling profile. Reporting only rpm or sonication time without geometry, volume and temperature limits reproducibility.

Table 11. Material and process variables

Variable	Expected influence	Control strategy
Solid:liquid lipid ratio	Loading, crystallinity, release and stability	Screen and include in DoE
Surfactant type/concentration	Size, PDI, interfacial release and irritation	Use dermally acceptable minimum
Total lipid concentration	Viscosity, loading and size-reduction demand	Set from pilot processability
Phase temperature	Melting, degradation and emulsification	Record actual product temperature
Homogenisation/sonication	Droplet breakup and heating	Characterise equipment and energy input
Cooling history	Crystallisation and polymorphism	Standardise rate and endpoint

Scale-up may change shear distribution, heat transfer and cooling. A laboratory optimum should therefore be treated as provisional until verified across independent batches and challenged by relevant process variation.

XII. TOPICAL NLC PERFORMANCE: RELEASE, SKIN RETENTION AND SAFETY

Topical NLC evaluation should distinguish formulation quality from biological performance. Particle size and PDI describe the dispersion, but they do not show that an active substance leaves the carrier or reaches viable skin. In-vitro release and ex-vivo disposition provide complementary information. Release testing asks whether the formulation makes markers available; skin studies ask where the released material is deposited.

A complete diffusion-cell experiment accounts for the applied dose in donor residue, washes, stratum corneum, viable skin, receptor fluid and apparatus rinses. High receptor concentration may indicate transdermal passage rather than local retention. Conversely, high donor recovery with low skin and receptor recovery may indicate poor release. The preferred pattern for a locally acting product is formulation-dependent and should be defined prospectively [15,23].

Table 12. Interpretation of topical NLC results

Finding	Possible explanation	Additional evidence needed
High entrapment, low release	Strong marker-lipid affinity	Lipid-ratio change and discriminatory release
High stratum-corneum retention	Superficial partitioning or occlusion	Separate viable epidermis/dermis analysis
High receptor flux	Barrier damage or effective transdermal delivery	Integrity and irritation data
Low total recovery	Adsorption, degradation or extraction failure	Spike recovery and device rinses
Strong cell effect, poor skin retention	Assay exposure not reproduced topically	Reformulate or lower claim level
Good skin retention, irritation	Excess surfactant or penetration enhancement	Blank-carrier safety and reformulation

Safety is not inferred from the natural origin of the extract or nanoscale size. Excipient purity, surfactant concentration, microbial quality and repeated-use tolerability require direct assessment.

DOI: 10.48175/IJARSCT-37818

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

XIII. QUALITY BY DESIGN FOR A BOTANICAL NLC GEL

QbD provides a structured method for converting the intended product into measurable attributes and controlled variables [16-20]. For a Boswellia NLC gel, the quality target product profile includes a homogeneous cutaneous dosage form, defined marker content per gram, acceptable application properties, reproducible release, local skin deposition, dermal safety and stability. Critical quality attributes include marker assay and uniformity, size distribution, PDI, pH, rheology, microbial quality and performance tests.

Botanical products require explicit critical material attributes: extract identity, fingerprint, marker content, moisture and residual solvent; lipid grade and polymorphic behaviour; surfactant identity and concentration; polymer grade and water quality. Process parameters include phase temperature, mixing, sonication, cooling and gel incorporation. Risk assessment prioritises variables for experimentation, while a response-surface design quantifies interactions.

Table 13. QbD workflow and safeguards

QbD step	Boswellia-NLC application	Common error to avoid
Define QTPP	Local gel with controlled marker dose and retention	Using generic nanoparticle targets without product context
Identify CQAs	Assay, size, PDI, release, rheology and safety	Treating every measured variable as critical
Assess risk	Link CMAs/CPPs to CQAs	Scoring without scientific justification
Design experiments	Study influential factors and interactions	Choosing ranges from unrelated publications
Optimise and verify	Balance responses in independent batches	Accepting software-predicted optimum without verification
Control lifecycle	Monitor materials, process and stability	Assuming QbD ends after DoE

The purpose of QbD is not to guarantee a favourable result. It makes assumptions, decisions, uncertainty and failure responses visible.

XIV. ANALYTICAL STANDARDISATION, STABILITY AND REGULATORY-QUALITY CONSIDERATIONS

A defensible analytical procedure should be fit for each matrix in which KBA and AKBA are measured. Extract, dispersion, gel, release medium, skin homogenate and receptor fluid can differ substantially in recovery and interference. Validation therefore needs specificity, range, accuracy, precision, robustness and solution stability appropriate to the intended decision [19,20].

Stability of a herbal nanogel is multidimensional. Physical changes include aggregation, lipid polymorphic transition, phase separation, pH drift and viscosity change. Chemical changes include oxidation or loss of markers. Microbiological changes are particularly important for aqueous gels. A release profile can change even when assay and appearance remain acceptable, so performance testing should be included at justified time points [21].

Table 14. Stability and analytical risks

Quality risk	Monitoring test	Interpretive caution
Marker degradation	Stability-indicating chromatography	Loss may be matrix- or extraction-related
Aggregation	DLS/PDI, microscopy and appearance	Dilution can mask instability
Lipid transition	DSC/PXRD with controls	Thermal changes do not always mean failure
Rheology drift	Defined shear programme	Single-point viscosity is insufficient
Microbial growth	Pharmacopoeial limits and preservative efficacy	Natural origin does not ensure antimicrobial protection
Packaging interaction	Assay, mass change and extractables/leachables risk	Short storage cannot establish compatibility

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Regulatory development would also require manufacturing controls, container-closure qualification, safety justification for excipients and a clinical programme. An academic preclinical study can establish a sound foundation but cannot assign an approved shelf life or therapeutic indication.

XV. DELGOCITINIB AS A CONTEMPORARY TOPICAL COMPARATOR

Delgocitinib is a synthetic pan-Janus kinase inhibitor that reduces signalling through multiple cytokine receptors. Topical delgocitinib has been evaluated in chronic hand eczema and is marketed as ANZUPGO 2% cream in relevant jurisdictions [26-31]. It represents a contemporary, mechanism-defined product for a condition in which barrier dysfunction and immune signalling interact.

Its value in a Boswellia formulation study is limited but important. Delgocitinib can demonstrate that a biological model responds to a potent topical anti-inflammatory agent and can provide an external benchmark for selected endpoints. It cannot serve as a marker-matched control because the active substance, concentration, vehicle, molecular target and clinical evidence base are different.

Table 15. Appropriate and inappropriate comparison

Feature	Boswellia-NLC gel	Delgocitinib 2% cream
Active material	Multi-component standardised botanical extract	Single defined synthetic molecule
Identity control	Fingerprint plus KBA/AKBA assay	Drug-substance identity and potency
Mechanistic basis	Multi-target eicosanoid and signalling effects	Pan-JAK inhibition
Development status	Investigational preclinical formulation	Approved/authorised commercial product in relevant markets
Main comparison use	Tests nanocarrier advantage over plain extract	Pharmacological assay benchmark
Unsupported claim	Therapeutic equivalence or non-inferiority	Dose matching to an extract

The comparison should be described as contextual or benchmark-based. Human clinical efficacy of delgocitinib does not validate the animal model or establish that a Boswellia product will achieve the same outcome.

XVI. EVIDENCE GAPS, FUTURE DIRECTIONS AND CONCLUSION

16.1 Evidence gaps

Direct studies of chemically standardised Boswellia serrata NLC gels for inflammatory skin disease are limited.

Many Boswellia studies incompletely report species, extraction method, fingerprint or marker content.

Oral clinical evidence cannot determine topical skin exposure or local efficacy.

NLC publications often emphasise particle size and entrapment while under-reporting mass balance, blank-carrier safety and independent batch verification.

Clinical comparison with delgocitinib would require a separate, adequately powered and ethically approved programme.

16.2 Future research priorities

Develop reference-quality botanical lots with retained samples and transparent fingerprints.

Use matrix-specific validated assays for both KBA and AKBA.

Link QbD optimisation to local skin disposition rather than size alone.

Include plain-extract and blank-carrier controls at equivalent marker dose.

Report neutral or negative outcomes and full mass balance.

Advance to human studies only after repeated-use safety and reproducible product performance are demonstrated.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Translational Roadmap

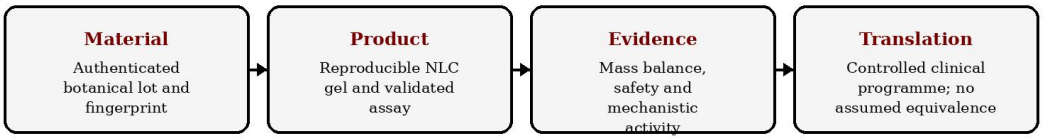

Figure 2. Translational roadmap from authenticated material to clinical development.

16.3 Conclusion

The scientific case for a Boswellia serrata NLC topical gel is plausible but unproven. Boswellic acids provide mechanistic rationale, and NLCs offer a flexible platform for lipophilic constituents. The decisive evidence will come from formulation-specific quality, release, viable-skin retention, safety and biological data. Delgocitinib helps define a modern pharmacological context, but it should not be used to imply dose or therapeutic equivalence. A stage-gated, QbD-informed and analytically rigorous programme offers the most reliable route to a credible product.

REFERENCES

1. Abdel-Tawab M, Werz O, Schubert-Zsilavecz M. Boswellia serrata: an overall assessment of in vitro, preclinical, pharmacokinetic and clinical data. Clin Pharmacokinet. 2011;50:349-369.
2. Ammon HPT. Boswellic acids and their role in chronic inflammatory diseases. Adv Exp Med Biol. 2016;928:291-327.
3. Arthur JSC, Ley SC. Mitogen-activated protein kinases in innate immunity. Nat Rev Immunol. 2013;13:679-692.
4. Benson HAE. Transdermal drug delivery: penetration enhancement techniques. Curr Drug Deliv. 2005;2:23-33.
5. Bissonnette R, et al. Efficacy and safety of delgocitinib cream in adults with moderate to severe chronic hand eczema: DELTA 1 and DELTA 2. Lancet. 2024.
6. Bos JD, Meinardi MMHM. The 500 Dalton rule for the skin penetration of chemical compounds and drugs. Exp Dermatol. 2000;9:165-169.
7. Bouwstra JA, Ponec M. The skin barrier in healthy and diseased state. Biochim Biophys Acta. 2006;1758:2080-2095.
8. Buckley CD, Gilroy DW, Serhan CN. Proresolving lipid mediators and mechanisms in the resolution of acute inflammation. Immunity. 2014;40:315-327.
9. Chakote VR, Dhembre GN, Rajguru JR, Joshi DA. In-Situ Gel for Nasal Drug Delivery. *International Journal of Development Research*. 2018;8(2):18763–18769
10. Coenraads PJ. Hand eczema. N Engl J Med. 2012;367:1829-1837.
11. Dhamale GR, Shinde PB, Rajguru JR. A Review: Gastroretentive Drug Delivery Systems. *International Journal of Pharmaceutical Sciences*. pp.1825–1840. doi:10.5281/zenodo.12818744.
12. Diepgen TL, Andersen KE, Chosidow O, et al. Guidelines for diagnosis, prevention and treatment of hand eczema. J Dtsch Dermatol Ges. 2015;13:e1-e22.
13. Doke R, Rajguru J, Vinchurkar K. Personalized Medicine Through AI-Driven Imaging. In: *Springer Nature*. doi:10.1007/978-3-032-02963-8_7.
14. Elias PM. Skin barrier function. Curr Allergy Asthma Rep. 2008;8:299-305.
15. European Medicines Agency. Anzupgo: European Public Assessment Report. Amsterdam: EMA; 2024.
16. Franz TJ. Percutaneous absorption: on the relevance of in vitro data. J Invest Dermatol. 1975;64:190-195.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

17. Gawai NM, Jadhav RR, Modak A, Sawarkar HS, Rajguru JR. Advancements in Nanogel Technology for Drug Delivery: Current Innovations and Future Perspectives. *African Journal of Biomedical Research*. 2024;27(3S):3200–3212. doi:10.53555/AJBR.v27i3S.2905.
18. Gawari PB, Rajguru JR. Confronting the Nipah Virus: Critical Insights and Practical Recommendations. *International Journal of Creative Research Thoughts (IJCRT)*. 2026;14(2). ISSN: 2320-2882.
19. Gupta I, Gupta V, Parihar A, et al. Effects of Boswellia serrata gum resin in patients with bronchial asthma. Eur J Med Res. 1998;3:511-514.
20. Gupta I, Parihar A, Malhotra P, et al. Effects of gum resin of Boswellia serrata in patients with chronic colitis. Planta Med. 2001;67:391-395.
21. Husch J, Gerbeth K, Fricker G, et al. Effect of phospholipid formulation on oral bioavailability of boswellic acids. Eur J Pharm Sci. 2013;50:403-410.
22. Ingole RD, Gawai NM, Rajguru JR. Nanoformulation of Vitamin D Derivatives and Metabolites. *African Journal of Biomedical Research*. 2024;27(4S). doi:10.53555/AJBR.v27i4S.4897.
23. International Council for Harmonisation. ICH Q10: Pharmaceutical Quality System. Geneva: ICH; 2008.
24. International Council for Harmonisation. ICH Q14: Analytical Procedure Development. Geneva: ICH; 2023.
25. International Council for Harmonisation. ICH Q1A(R2): Stability Testing of New Drug Substances and Products. Geneva: ICH; 2003.
26. International Council for Harmonisation. ICH Q2(R2): Validation of Analytical Procedures. Geneva: ICH; 2023.
27. International Council for Harmonisation. ICH Q8(R2): Pharmaceutical Development. Geneva: ICH; 2009.
28. International Council for Harmonisation. ICH Q9(R1): Quality Risk Management. Geneva: ICH; 2023.
29. J Rajguru R. Development and Validation of RP-HPLC and UV Spectrophotometric Absorptivity Method for Simultaneous Estimation of Cyclobenzaprine Hydrochloride and Aceclofenac in Pharmaceutical Dosage Form. *International Journal of Science & Engineering Development Research*. 2020;5(4):320–329.
30. Jeevan Rajguru R. Magnetic and pH Sensitive Nanoparticles for Cancer Drug Delivery. *Asian Journal of Pharmaceutical Research and Development*. 2019;7(4).
31. JR. Rajguru Development and Evaluation of Nasal Mucoadhesive In-Situ Gel Formulations of Carbamazepine Using In-Vitro, Ex-Vivo and In-Vivo Methods. *International Research Journal of Pharmacy and Medical Sciences*. 2018;1(6).
32. Kimmatkar N, Thawani V, Hingorani L, Khiyani R. Efficacy and tolerability of Boswellia serrata extract in osteoarthritis of knee. Phytomedicine. 2003;10:3-7.
33. Kruger P, Daneshfar R, Eckert GP, et al. Metabolism of boswellic acids in vitro and in vivo. Drug Metab Dispos. 2008;36:1135-1142.
34. Liu T, Zhang L, Joo D, Sun SC. NF-kappaB signaling in inflammation. Signal Transduct Target Ther. 2017;2:17023.
35. Medzhitov R. Origin and physiological roles of inflammation. Nature. 2008;454:428-435.
36. Mehnert W, Mader K. Solid lipid nanoparticles: production, characterization and applications. Adv Drug Deliv Rev. 2001;47:165-196.
37. Muller RH, Mader K, Gohla S. Solid lipid nanoparticles for controlled drug delivery: a review. Eur J Pharm Biopharm. 2000;50:161-177.
38. Muller RH, Radtke M, Wissing SA. Solid lipid nanoparticles and nanostructured lipid carriers in cosmetic and dermatological preparations. Adv Drug Deliv Rev. 2002;54 Suppl 1:S131-S155.
39. Nathan C, Ding A. Nonresolving inflammation. Cell. 2010;140:871-882.
40. Nathan C. Points of control in inflammation. Nature. 2002;420:846-852.
41. Organisation for Economic Co-operation and Development. Test No. 428: Skin Absorption: In Vitro Method. Paris: OECD; 2004.

42. Organisation for Economic Co-operation and Development. Test No. 439: In Vitro Skin Irritation: Reconstructed Human Epidermis Test Method. Paris: OECD; 2021.
43. O'Shea JJ, Schwartz DM, Villarino AV, et al. The JAK-STAT pathway: impact on human disease and therapeutic intervention. Annu Rev Med. 2015;66:311-328.
44. Pardeike J, Hommoss A, Muller RH. Lipid nanoparticles (SLN, NLC) in cosmetic and pharmaceutical dermal products. Int J Pharm. 2009;366:170-184.
45. Percie du Sert N, Hurst V, Ahluwalia A, et al. The ARRIVE guidelines 2.0. PLoS Biol. 2020;18:e3000410.
46. Poeckel D, Werz O. Boswellic acids: biological actions and molecular targets. Curr Med Chem. 2006;13:3359-3369.
47. Proksch E, Brandner JM, Jensen JM. The skin: an indispensable barrier. Exp Dermatol. 2008;17:1063-1072.
48. Rajguru JR, Navghare AB, Shinde SP, Pawar PP, Lokhande PB. An Overview of Implantable Drug Delivery Systems. *International Journal of Creative Research Thoughts (IJCRT)*. 2024;12(1)–F958.
49. Rajguru JR. Cancer Chemotherapy with Peptides and Peptidomimetics Drug and Peptide-Based Vaccines. *International Research Journal of Pharmacy and Medical Sciences*. 2019;2(2).
50. Safayhi H, Mack T, Sabieraj J, et al. Boswellic acids: novel, specific, nonredox inhibitors of 5-lipoxygenase. J Pharmacol Exp Ther. 1992;261:1143-1146.
51. Schindler C, Levy DE, Decker T. JAK-STAT signaling: from interferons to cytokines. J Biol Chem. 2007;282:20059-20063.
52. Sengupta K, Alluri KV, Satish AR, et al. A double blind, randomized, placebo controlled study of Boswellia serrata extract in osteoarthritis of knee. Arthritis Res Ther. 2008;10:R85.
53. Serhan CN. Pro-resolving lipid mediators are leads for resolution physiology. Nature. 2014;510:92-101.
54. Siddiqui MZ. Boswellia serrata, a potential anti-inflammatory agent: an overview. Indian J Pharm Sci. 2011;73:255-261.
55. Sitaphale GR, Tathe PR, Laddha PR, Charhate KB, Rajguru JR. Phytochemical Screening, Isolation, and Characterization of Extract from Various Parts of *Phoenix sylvestris*. *African Journal of Biomedical Research*. 2024;27(3S):3368–3374. doi:10.53555/AJBR.v27i3S.2938.
56. Tathe PR, Laddha PR, Sitaphale GR, Charhate KB, Pimple UA, Jadhao YD, Alhat RM, Rajguru JR. Studies in Preparation and Evaluation of Nanoparticles for Controlled Drug Delivery of Peptide-Based Drugs. *African Journal of Biomedical Research*. 2024;27(3S):3179–3190. doi:10.53555/AJBR.v27i3S.2894.
57. Thyssen JP, Johansen JD, Linneberg A, Menne T. The epidemiology of hand eczema in the general population. Contact Dermatitis. 2010;62:75-87.
58. US Food and Drug Administration. ANZUPGO (delgocitinib) cream, 2%: Prescribing Information. Silver Spring, MD: FDA; 2025.
59. Wayal SR, Barke SA, Darekar SM, Jalindar AS, Gawai NM, Wankhede HR, Bathe RS, Rajguru JR. Development of Currant-Loaded Nanoparticles and Phytosomes for Enhanced Antioxidant Delivery. *International Journal of Environmental Sciences*. 2025;11(22S):4067–4071. doi:10.64252/p2tecx31.
60. Wayal SR, Darekar SM, Jalindar AS, Motr PR, Gawai NM, Bodake PL, Barke SA, Dongare AB, Rajguru JR. Development of a Validated HPTLC Method for the Simultaneous Estimation of Curcumin and Berberine in Dashamoola Kvatha. *International Journal of Environmental Sciences*. doi:10.64252/kq9rtn45.
61. Wayal SR, Rajguru JR, Bhise MR. A Systematic Review on the Effective Teaching Strategies and Methods for Cancer Patient Education. *Journal of Cancer Education*. 2025. doi:10.1007/s13187-025-02759-z.
62. Wissing SA, Kayser O, Muller RH. Solid lipid nanoparticles for parenteral drug delivery. Adv Drug Deliv Rev. 2004;56:1257-1272.
63. World Health Organization. Quality Control Methods for Herbal Materials. Geneva: WHO; 2011.
64. Worm M, et al. Efficacy and safety of topical delgocitinib in chronic hand eczema: a randomised dose-ranging trial. Br J Dermatol. 2022.