

Locust-Bean-Gum-Derived Photocurable Hydrogels: Carob Identity, Galactomannan Structure, Methacrylation, Oxidation, Network Attribution, Injectability, Hydration and Qualification

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Statement of Significance

Locust bean gum can be a native galactomannan thickener, a methacrylated photocurable precursor, an oxidised aldehyde-bearing partner or a physical component of another network. These roles are not interchangeable. Carob seed and endosperm identity, galactose substitution, molar-mass state, hydration history, derivatisation, network owner and released-article state must precede claims of photocure, injectability, printing or cartilage repair.

Keywords: locust bean gum; carob; galactomannan; methacrylation; oxidation; photocrosslinking; injectable hydrogel; cartilage; network attribution; qualification

Abstract

Locust bean gum (LBG) is a carob-seed galactomannan whose hydration and association depend on source, processing, molar mass and galactose distribution. Qu et al. reported directly methacrylated LBG as an injectable UV-crosslinked hydrogel. Cheng et al. used oxidised LBG in a double network whose named radical precursor was methacrylated carboxymethyl chitosan. O'Connell et al., Wirzeberger et al. and Merg et al. define parent-polymer, physical-network and hydrated-rheology controls. This review keeps those evidence classes and their network ownership separate.

1. Scope and boundaries

ER-137 owns material-specific identity and qualification of native, methacrylated and oxidised LBG in photocurable hydrogel systems. It covers botanical and endosperm provenance, recovery, molar-mass and galactomannan state, hydration, derivatisation, photoconversion, partner networks, injectability, washing, swelling, degradation, mechanics and biological boundaries.

ER-06 retains biological-response methodology; ER-10 geometric metrology; ER-15 degradation and mechanical evolution; ER-27 conversion; ER-33 washing and drying; ER-67 network architecture; ER-86 extractables; ER-100 corpus architecture; ER-121 methacrylated silk fibroin; ER-123 chitosan; and ER-128 to ER-136 neighbouring photocurable polysaccharides. [C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19].

General AM characteristics and geometric test artefacts should follow the declared ISO/ASTM standards [S1,S3].

Carob pod flour, seed gum and purified endosperm galactomannan are not synonyms. Parent LBG, LBG-methacrylate and oxidised LBG are distinct materials. Physical synergy with carrageenan is not photoconversion. In an MA-CMCS/OLBG formulation, MA-CMCS owns the named radical network unless direct LBG conversion is demonstrated. Injectability alone does not establish extrusion or vat-printing qualification.

2. Controlled LBG-derived photocurable state chain

State	Minimum identity	Failure if omitted
Incoming LBG	Carob/cultivar and seed-endosperm source, recovery, supplier/lot, purity, protein, ash, moisture, microbial state, galactose architecture, molar mass and storage	LBG name replaces botanical and molecular identity
Hydrated parent or derivative	Water quality, dissolution, temperature, ageing and shear; or reaction/purification, measured methacrylation or aldehyde content, residuals and storage	Physical hydration and derivative identity are conflated
Injectable or printable precursor	LBG role, partners/cells, solids, salts, initiator, viscosity/yield/recovery, optical state, shear history and age	Network owner and delivery state disappear
Released article	Delivery/light process, post-cure, wash, conversion, soluble fraction, residuals, hydrated dimensions, mechanics and biology	As-cured and released states are conflated

Table 1. Minimum state chain for LBG-derived photocurable hydrogels.

This material and article chain is separate from process and production-site qualification under ISO/ASTM 52920:2023 [S2].

3. Primary evidence and controlled interpretation

3.1 Botanical, endosperm and molecular identity precede formulation

LBG is recovered from *Ceratonia siliqua* seed endosperm. Cultivar and harvest, seed dehulling and germ removal, milling, purification, protein and ash burden, moisture, microbial state, mannose-to-galactose architecture and molar-mass distribution affect dissolution and viscosity. O'Connell et al. showed that AF4 and light-scattering method choices are material to LBG molecular characterisation [3]. Supplier grade alone is not molecular identity.

3.2 Methacrylated LBG is a directly photocurable derivative

Qu et al. reported LBG-methacrylate hydrogels that were injectable and crosslinked in situ under UV irradiation [1]. The evidence supports a direct LBG-owned radical precursor, controllable degradation and the reported chondrogenic-differentiation and in-vivo cartilage models. Transfer requires parent lot, reaction and purification, measured methacrylation, residual reagents, initiator, spectrum, irradiance, exposure, geometry, wash and hydrated test state.

3.3 Oxidised LBG can support a partner-owned photocrosslinked network

Cheng et al. combined methacrylated carboxymethyl chitosan with oxidised LBG, allicin and decellularised cartilage powder [2]. The paper supports a photocrosslinked composite hydrogel and its stated cartilage models. The source assigns the radical network to MA-CMCS and attributes OLBG's contribution to Schiff-base reaction with MA-CMCS amino groups; aldehyde content, MA-CMCS conversion and OLBG retention nonetheless require separate measurements and matched controls.

3.4 Physical LBG networks remain essential non-photo controls

Wirzberger et al. studied physically crosslinked LBG-kappa-carrageenan hydrogels with controlled dissolution, shear-thinning and self-healing behaviour [4]. Merg et al. prepared native LBG hydrogels at 2%, 3% and 4% w/v and measured pseudoplastic flow and concentration-dependent bioadhesion [5]. These studies define physical and hydration comparators; neither is evidence of LBG photoconversion.

3.5 Injectable, printable and released-article states are distinct

An injectable precursor may flow through a syringe yet fail nozzle recovery, layer fidelity, light penetration or post-wash dimensional retention. Qualification therefore separates syringe delivery, extrusion deposition, in situ cure and any vat-photopolymerisation claim. The released article must be defined after irradiation, washing, swelling and any soluble-fraction loss, not only at the formulation or as-cured state.

4. Hydration, rheology and optical-process control

Parent LBG lot, derivative and substitution or oxidation, solids, salts, partners, cells and initiator define the precursor. Dissolution temperature, water quality, ageing and shear history define hydration. Hardware, nozzle, pressure and speed define delivery. Spectrum, irradiance, exposure, oxygen, depth and geometry define conversion.

Native-LBG, LBG-MA, OLBG, no-LBG, no-partner, dark, initiator-light and complete-formulation controls separate physical thickening, aldehyde-mediated association, partner-macromer conversion and direct LBG photochemistry. Without chemical conversion and mass-balance evidence, mechanics cannot be assigned to one network owner.

5. Washing, hydration, degradation and biological boundaries

Evidence block	What it can show	What it cannot establish alone
Feedstock/derivative identity	Method-specific source, purity, molar mass, galactose architecture, methacrylation, aldehydes and residuals	Photoconversion or released-article performance
Hydration/rheology/delivery	Lot-, concentration-, water-, temperature-, age-, shear-, syringe- or nozzle-specific flow	Covalent network ownership or transferable print settings
Conversion/article state	LBG/partner conversion, soluble fraction, OLBG retention, hydration, dimensions and mechanics	Universal degradation or service life
Biological model	Response of the exact washed formulation in the stated cell, antimicrobial or cartilage model	General safety, clinical efficacy or regulatory approval

Table 2. Evidence blocks that must remain separate for LBG-derived hydrogels.

ISO 10993-12:2021/Amd 1:2025 and ISO 10993-18:2020/Amd 1:2022 anchor sample preparation and chemical characterisation [S4,S5]. ISO 10993-1:2025 frames biological safety within risk management [S6]. Chondrogenic

markers, viability, antimicrobial endpoints or cartilage repair in the reported models do not establish universal biocompatibility, clinical efficacy or regulatory approval.

6. Release matrix

Gate	Minimum evidence	Claim withheld
Parent identity	Carob source/cultivar, recovery, lot, purity, protein/ash/moisture, galactose architecture, molar mass, microbial and storage state	Generic LBG equivalence
Derivative state	Reaction/purification, measured methacrylation or aldehyde content, residuals, molar-mass change, stability and storage	Derivative acronym as chemical identity
Role attribution	Native/LBG-MA/OLBG, no-LBG, no-partner, dark, initiator-light and complete controls plus conversion and mass balance	Unverified physical, secondary or radical ownership
Process	Complete formulation, hydration/rheology/age state, hardware, spectrum, irradiance, exposure, oxygen and geometry	Transferable injection, deposition or cure settings
Article state	As-cured, post-cured, washed, hydrated and dried x/y/z, mass, soluble fraction, residuals and mechanics	Unqualified composition, dimensions or stability
Biological boundary	Exact roles, delivery/light stress, wash/extract, model, dose, endpoint, duration, controls and statistics	Universal biocompatibility or clinical suitability

Table 3. Minimum release architecture for LBG-derived photocurable hydrogels.

7. Failure-mode interpretation

- The nominally same LBG hydrates or flows differently: verify cultivar/source, endosperm recovery, purity, molar-mass distribution, galactose architecture, moisture, water quality, dissolution, temperature, ageing and shear history.
- LBG-MA cures but remains weak after swelling: quantify substitution, initiator and dose, conversion, soluble fraction, network density and hydrated mechanics before increasing exposure.
- An MA-CMCS/OLBG composite cures: use no-OLBG, no-MA-CMCS, dark and complete controls and measure each relevant conversion or retention marker before assigning double-network ownership.
- A precursor is injectable but does not print: test yield stress, recovery, ageing, nozzle and speed separately from syringe force and post-cure article stability.
- A physical LBG-carrageenan gel appears stable: distinguish physical association and controlled dissolution from any covalent or photochemical claim.
- A cartilage or cell result is favourable: retain exact derivative, formulation, wash, model, dose, endpoint, duration, controls and statistics; withhold general safety or clinical claims.

8. Minimum workflow and research priorities

- Freeze species/cultivar and seed/endosperm recovery where available, supplier and lot, purity, protein, ash, moisture, microbial state, mannose-galactose architecture, molar-mass distribution, storage and hydration history.
- For LBG-MA or OLBG, report reaction, purification, measured methacrylation or aldehyde content, residual reagents, molar-mass change, storage and batch stability.
- Map LBG role, partner polymers, salts, cells, initiator, solids, water quality, temperature, viscosity, yield stress, recovery, ageing, optical attenuation and conversion over the working interval.
- Record delivery mode, hardware, nozzle, pressure or flow, speed, layer, geometry, spectrum, irradiance, exposure, oxygen, post-cure and wash.
- Measure direct LBG and partner conversion where applicable, insoluble and soluble fractions, OLBG retention, residual initiator and derivatisation reagents, and x/y/z dimensions through released-article states.
- Use native-LBG, LBG-MA, OLBG, no-LBG, no-partner, dark, initiator-light and complete controls to assign hydration, physical association, secondary chemistry and radical cure.
- Test swelling, dissolution, mass loss and mechanical retention in defined media over time; distinguish LBG release, partner degradation, physical-network relaxation and covalent-network cleavage.
- Separate injection, extrusion and irradiation injury, extract cytotoxicity, proliferation and tissue models from biological safety, therapeutic efficacy and regulatory conclusions.

9. Conclusions

LBG-derived photocurable materials are controlled botanical-feedstock, molecular, hydration, derivative, formulation, network-attribution, optical-process, washing and released-article states.

Primary evidence supports directly photocrosslinkable LBG-MA, OLBG in a partner-owned photocrosslinked composite, and native LBG physical hydrogels. Those evidence classes are not interchangeable.

Release requires traceability through source, lot, molar mass, galactose architecture, hydration, derivative, measured functionality, formulation role, process, conversion, washing, soluble fraction, residuals, dimensions, mechanics and model.

Limitations

This paper is a qualitative engineering review, not a systematic meta-analysis. The cited studies use different LBG identities, derivatives, partners, physical or covalent networks, processes, article states and biological models. Numerical values are study-specific evidence, not universal design values.

Author contributions

Juan Segurola: conceptualisation, evidence synthesis, boundary definition, engineering interpretation, manuscript preparation and final author verification.

Competing interests

The author is founder and CEO of 3Dresyns by Resyner Technologies S.L. No comparative product recommendation is made.

Data availability

No new experimental dataset was generated. Scientific statements derive from the cited primary literature and official standards. The review package includes QA and source-boundary controls.

Company information

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