

Gum-Arabic-Derived Crosslinkable Hydrogels: Acacia Identity, Methacrylation, Periodate Oxidation, DIW Network Attribution and Photocure Qualification

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Statement of Significance

Gum arabic can denote an Acacia exudate with lot-dependent polysaccharide-protein structure, a glycidyl-methacrylate derivative, a periodate-oxidised aldehyde partner, a grafted radical hydrogel or a physical rheology modifier in another polymer network. These states are not interchangeable. Direct light-driven conversion and vat-printing evidence must be demonstrated rather than inferred from methacrylate naming, chemical free-radical curing or direct-ink writing.

Keywords: *gum arabic; Acacia senegal; methacrylation; periodate oxidation; PEGDMA; direct ink writing; network attribution; photocure boundary; qualification*

Abstract

Gum arabic (GA) is a structurally heterogeneous Acacia exudate. Kersten et al. quantified variation across twenty Acacia senegal samples. Gerola et al. prepared GMA-modified GA with substitution-dependent swelling and pH response. Ibrahim et al. reported GA/PEGDMA hydrogels formed by chemical free-radical polymerisation. Pandit et al. used periodate-modified GA to crosslink PVA, while Wang et al. reported a gum-Arabic-based three-dimensional printed hydrogel for customizable sensors. This review separates GA identity, derivative state, network ownership, printing mode and the still-unproven photocure/vat-transfer step.

1. Scope and boundaries

ER-138 owns material-specific identity and qualification of native, methacrylated and oxidised gum arabic in crosslinkable and printable hydrogel formulations. As an editorial qualification boundary, Acacia senegal and Acacia seyal material states are not assumed equivalent in the absence of matched identity evidence. It covers botanical species, harvest and commercial quality, molecular and protein-bearing fractions, derivatisation, radical or condensation network ownership, DIW rheology, optical qualification requirements, washing, swelling, release 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; and ER-121 to ER-137 neighbouring protein and polysaccharide photoresin families. [C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,C21,C22,C23,C24,C25].

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

Acacia senegal and Acacia seyal material states are not automatically equivalent. Native GA, methacrylated GA and periodate-oxidised GA are distinct. A GA/PEGDMA hydrogel made by chemical free-radical polymerisation is not proof of photopolymerisation. The accessible record for Wang et al. establishes a gum-Arabic-based three-dimensional printed sensor hydrogel, but does not independently establish its ink rheology, network chemistry or initiation route. Three-dimensional printing performance is not vat-photopolymerisation performance.

2. Controlled gum-arabic-derived crosslinkable state chain

State	Minimum identity	Failure if omitted
Incoming GA	Acacia species/geography/harvest, supplier/lot/grade, sugars/uronic acids, protein, molar-mass distribution, ash, moisture, microbial and storage state	The GA name replaces botanical and molecular identity
Crosslinkable derivative	Native, GMA-modified or periodate-oxidised identity; reaction, purification, measured substitution or aldehydes, residuals and stability	A derivative acronym replaces chemical identity
Formulation/process	GA role, partners/monomers, fillers/surfactants, solids, water/salts, initiator, rheology, age, deposition or optical process	Rheology, network owner and cure mechanism disappear

State	Minimum identity	Failure if omitted
Released article	Conversion or retention, gel/sol fraction, residuals, post-cure/wash, hydrated dimensions, mechanics, release and model	As-made and released states are conflated

Table 1. Minimum state chain for gum-arabic-derived crosslinkable 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, commercial and molecular identity precede derivatisation

GA composition depends on species, geography, harvest, post-harvest cleaning, grade and lot. Kersten et al. analysed twenty *Acacia senegal* samples and found material variation in monosaccharides, protein content, molecular mass and size; molecular mass correlated with emulsion viscosity [1]. A supplier name therefore does not replace species, lot, protein-bearing fraction, ash, moisture, microbial and molecular-distribution data.

3.2 Methacrylation creates a crosslinkable derivative, not automatic photocure evidence

Gerola et al. prepared modified gum arabic (M-GA_x) with different degrees of substitution using different percentages of glycidyl methacrylate, and reported degree-of-substitution- and pH-dependent swelling in simulated gastric and intestinal fluids together with non-toxicity against Caco-2 cells, with curcumin as the model payload [2]. This supports a GA-owned unsaturated derivative and chemically formed hydrogel matrices. Transfer to a photoresin requires photoinitiator identity, spectrum, irradiance, conversion, oxygen, thickness and released-article measurements.

3.3 PEGDMA and periodate-PVA systems require explicit network ownership

Ibrahim et al. combined GA and PEGDMA through chemical free-radical polymerisation; composition controlled product yield, gel content, gel time and mechanics, while swelling and quercetin release depended on composition and pH, and degradation was medium-dependent, significant in acidic medium and insignificant in basic medium [3]. Pandit et al. oxidised GA with periodate and used aldehyde-bearing GA to crosslink PVA for folic-acid delivery and photoprotection [4]. Neither system establishes light-driven GA conversion. PEGDMA radical ownership and oxidised-GA/PVA condensation must remain distinct from any future GA-methacrylate photocure.

3.4 A gum-Arabic-based 3D-printed sensor hydrogel does not establish a GA-owned photocure

Wang et al. reported a gum-Arabic-based three-dimensional printed hydrogel for customizable sensors [5]. The Crossref deposit carries no abstract, so the ink rheology, network chemistry and initiation route are not reproduced here. The work supports formulation-specific three-dimensional printing and sensing; nothing in the accessible record evidences a gum-Arabic-owned photocure. The material therefore cannot validate DLP, SLA or TPP without a separate resin and exposure study.

3.5 A defensible photocure candidate must close the missing optical evidence

A GA-methacrylate candidate may be photochemically plausible, but qualification begins only after direct double-bond conversion, working-curve, depth, lateral-cure, soluble-fraction and dose-resolved measurements. Controls must include native GA, GA-methacrylate without light, initiator-light, no-GA macromer and complete formulation. Until then, and noting that the accessible records used here do not supply a verified photoinitiator, exposure spectrum or irradiance, claims are limited to crosslinkable chemistry and formulation design, not vat printability.

4. Hydration, rheology, network and optical-process control

Species and lot, protein-bearing fraction, molar-mass distribution, substitution or aldehyde content, water, salts, partners and initiator define the precursor. Dissolution, temperature, ageing and shear define hydration. DIW hardware defines deposition; spectrum, irradiance, exposure, oxygen, layer and geometry define photocure.

Native-GA, GA-MA, oxidised-GA, no-GA, no-partner, dark, initiator-light and complete-formulation controls are required to separate emulsification or thickening, condensation, partner-monomer polymerisation and direct GA photochemistry. Mechanics or print fidelity alone cannot assign network ownership.

5. Washing, swelling, release and biological boundaries

Evidence block	What it can show	What it cannot establish alone
Feedstock/derivative identity	Method-specific species, lot, composition, molar mass, methacrylation, aldehydes and residuals	Photoconversion or released-article performance
Hydration/rheology/DIW	Formulation-, water-, temperature-, age-, shear-, nozzle- and speed-specific deposition	Covalent ownership or vat-transferable settings

Evidence block	What it can show	What it cannot establish alone
Network/article state	GA/partner conversion or retention, gel/sol fraction, wash, hydration, dimensions and mechanics	Universal degradation or service life
Application model	Release, sensing or cell response of the exact formulation and article state	General safety, clinical efficacy or regulatory approval

Table 2. Evidence blocks that must remain separate for gum-arabic-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]. Caco-2 non-toxicity, release, sensor performance or any single extract result does not establish universal biocompatibility, clinical efficacy or regulatory approval.

6. Release matrix

Gate	Minimum evidence	Claim withheld
Parent identity	Acacia species/source, lot/grade, composition, protein, molar mass, ash/moisture, microbial and storage state	Generic gum-arabic equivalence
Derivative state	Reaction/purification, measured methacrylation or aldehydes, residuals, molar-mass change, stability and storage	Derivative name as complete identity
Network attribution	Native/GA-MA/oxidised-GA, no-GA, no-partner, dark, initiator-light and complete controls plus conversion/mass balance	Unverified physical, condensation, redox or photo ownership
Process	Complete formulation and age, DIW hardware or light spectrum/irradiance/exposure/oxygen/layer/geometry	Transferable deposition or cure settings
Article state	As-made, washed, hydrated and dried x/y/z, mass, gel/sol fraction, residuals and mechanics	Unqualified composition, dimensions or stability
Application boundary	Exact delivery/process stress, wash/extract, model, dose, endpoint, duration, controls and statistics	Universal biocompatibility or clinical suitability

Table 3. Minimum release architecture for gum-arabic-derived crosslinkable hydrogels.

7. Failure-mode interpretation

- The nominally same GA gives different viscosity or cure behaviour: verify species, geography, harvest, grade, lot, protein, monosaccharides, molar-mass distribution, moisture, water quality and hydration history.
- Methacrylated GA forms a gel but cure ownership is uncertain: report reaction and purification, measured substitution, initiator or redox system, conversion, gel/sol fraction and matched native-GA controls.
- A partner-monomer formulation cures: use no-GA and no-partner controls plus conversion and mass balance before claiming a GA-owned covalent network.
- A deposited ink retains shape: preserve nozzle, speed, pressure, temperature, recovery and ageing evidence; do not translate extrusion fidelity into a vat-printing claim.
- An oxidised-GA/PVA gel is stable: quantify aldehydes, PVA identity, condensation, residual periodate and soluble fractions; photoprotection is an endpoint, not a photopolymerisation mechanism.
- A release, sensing or cell result is favourable: retain exact formulation, washing, model, dose, endpoint, duration, controls and statistics; withhold general safety and clinical claims.

8. Minimum workflow and research priorities

- Freeze species, geography and harvest where available, supplier and lot, commercial grade, protein, sugar and uronic-acid composition, molar-mass distribution, ash, moisture, microbial and storage state.
- For GA-MA or oxidised GA, report reagent feed, pH, temperature, reaction time, purification, measured substitution or aldehyde content, molar-mass change, residuals, storage and batch stability.
- Map GA role, partner monomers or polymers, fillers, surfactants, salts, payload or cells, initiator, solids, water, viscosity, yield, recovery, ageing, optical attenuation and conversion over the working interval.
- Record delivery mode, hardware, nozzle, pressure or flow, speed, layer and geometry; for light cure record spectrum, irradiance, exposure, oxygen, post-cure and wash.
- Measure GA and partner conversion or retention, gel and soluble fractions, residual initiator, periodate and derivatisation reagents, and x/y/z dimensions through as-cured, washed, hydrated and dried states.
- Use native-GA, GA-MA, oxidised-GA, no-GA, no-partner, dark, initiator-light and complete controls to assign physical rheology, condensation, redox polymerisation and optical conversion.
- Test swelling, dissolution, release, mass loss and mechanical retention in defined media over time; distinguish GA loss, partner-network degradation, physical relaxation and covalent cleavage.
- Separate DIW and irradiation stress, extract cytotoxicity, release and sensing tests from biological safety, therapeutic efficacy and regulatory conclusions.

9. Conclusions

GA-derived crosslinkable materials are controlled botanical-feedstock, molecular, derivative, formulation, network-attribution, deposition, optical-process, washing and released-article states.

Primary evidence supports lot-dependent GA structure, chemical GA/PEGDMA radical gels and oxidised-GA/PVA networks. Publisher records additionally establish modified-GA matrices and a gum-Arabic-based three-dimensional printed sensor-hydrogel paper, without importing unread linkage, rheology, network or initiation details. It does not yet establish a qualified GA-owned vat photorexin.

Release requires traceability through species and lot, molecular composition, hydration, derivative 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 GA identities, derivatives, partners, curing mechanisms, processes, article states and application models. Numerical values are study-specific evidence, not universal design values.

Author contributions

Juan Seguro: 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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References - independent scientific evidence

- [1] Kersten, F., Martin, D., van der Schaaf, U. S. and Wefers, D. Gum Arabic - Same but different: Comparative analysis of structural characteristics and emulsifying properties of 20 Acacia senegal samples of various qualities. *Food Hydrocolloids* 165 (2025) 111231. DOI: 10.1016/j.foodhyd.2025.111231. <https://doi.org/10.1016/j.foodhyd.2025.111231>
- [2] Gerola, A. P., Silva, D. C., Matsushita, A. F. Y., Borges, O., Rubira, A. F., Muniz, E. C. and Valente, A. J. M. The effect of methacrylation on the behavior of Gum Arabic as pH-responsive matrix for colon-specific drug delivery. *European Polymer Journal* 78 (2016) 326-339. DOI: 10.1016/j.eurpolymj.2016.03.041. <https://doi.org/10.1016/j.eurpolymj.2016.03.041>
- [3] Ibrahim, S. M., Yin, T. Y. and Misran, M. Arabic Gum Grafted PEGDMA Hydrogels: Synthesis, Physico-Chemical Characterization and In-vitro Release of Hydrophobic Drug. *Macromolecular Research* 28(Suppl 1) (2020) 1220-1231. DOI: 10.1007/s13233-020-8166-1. <https://doi.org/10.1007/s13233-020-8166-1>
- [4] Pandit, A. H., Mazumdar, N., Imtiyaz, K., Rizvi, M. M. A. and Ahmad, S. Periodate-Modified Gum Arabic Cross-linked PVA Hydrogels: A Promising Approach toward Photoprotection and Sustained Delivery of Folic Acid. *ACS Omega* 4(14) (2019) 16026-16036. DOI: 10.1021/acsomega.9b02137. <https://doi.org/10.1021/acsomega.9b02137>
- [5] Wang, T., Yu, Z., Si, J., Liu, L., Ren, X. and Gao, G. Gum Arabic-based three-dimensional printed hydrogel for customizable sensors. *International Journal of Biological Macromolecules* 254(Pt 3) (2024) 128072. DOI: 10.1016/j.ijbiomac.2023.128072. <https://doi.org/10.1016/j.ijbiomac.2023.128072>

Standards and measurement references

- [S1] ISO/ASTM 52927:2024. Additive manufacturing - General principles - Main characteristics and corresponding test methods. Edition 1. <https://www.iso.org/standard/81802.html>
- [S2] ISO/ASTM 52920:2023. Additive manufacturing - Qualification principles - Requirements for industrial additive manufacturing processes and production sites. Edition 1. <https://www.iso.org/standard/76911.html>
- [S3] ISO/ASTM 52902:2023. Additive manufacturing - Test artefacts - Geometric capability assessment of additive manufacturing systems. Edition 2. <https://www.iso.org/standard/79683.html>
- [S4] ISO 10993-12:2021 with Amendment 1:2025. Biological evaluation of medical devices - Part 12: Sample preparation and reference materials. Edition 5. <https://www.iso.org/standard/88205.html>
- [S5] ISO 10993-18:2020 with Amendment 1:2022. Biological evaluation of medical devices - Part 18: Chemical characterization of medical device materials within a risk management process. Edition 2. <https://www.iso.org/standard/64750.html>
- [S6] ISO 10993-1:2025. Biological evaluation of medical devices - Part 1: Requirements and general principles for the evaluation of biological safety within a risk management process. Edition 6. <https://www.iso.org/standard/10993-1>

Related Engineering Review boundaries

- [C1] Segurola, J. Biological Response in Photopolymer Additive Manufacturing: A Review of Formulation Chemistry, Workflow Variables and Qualification Constraints in Dental and Biomedical Applications. ER-06. Zenodo (2026).
- [C2] Segurola, J. Metrology of Vat Photopolymerisation: Resolution, Trueness, Precision and Geometric Fidelity Across Scales. ER-10. Zenodo (2026).
- [C3] Segurola, J. Transport, Degradation and Mechanical Evolution in Vat-Printed Tissue-Engineering Scaffolds: Coupled Design and Qualification. ER-15. Zenodo (2026).
- [C4] Segurola, J. Conversion Metrology and Spatial Cure Heterogeneity in Vat Photopolymerisation: From Exposure to Network State. ER-27. Zenodo (2026).
- [C5] Segurola, J. Washing- and Drying-Induced Extraction, Property Change and Dimensional Response in Vat-Printed Photopolymers. ER-33. Zenodo (2026).
- [C6] Segurola, J. Hierarchical and Double-Network Hydrogels in Vat Photopolymerisation: Microgel Reinforcement, Interpenetration and Energy Dissipation. ER-67. Zenodo (2026).
- [C7] Segurola, J. Analytical Extractables and Leachables from Vat-Printed Photopolymers: Specimen State, Extraction Design, Analytical Coverage and Cross-Study Comparability. ER-86. Zenodo (2026).
- [C8] Segurola, J. From Individual Reviews to a Qualification Corpus: Evidence Architecture Across Engineering Reviews ER-01 to ER-99. ER-100. Zenodo (2026).
- [C9] Segurola, J. Methacrylated Silk-Fibroin Photoresins: Protein Source, GMA Functionalisation, Aqueous DLP, Hydration, Mechanics, Biological State and Qualification. ER-121. Zenodo (2026).
- [C10] Segurola, J. Collagen Methacryloyl Photoresins: Collagen Source, Methacrylation, Triple-Helix State, Low-Temperature DLP, Hydration, Enzymatic Degradation and Qualification. ER-122. Zenodo (2026).
- [C11] Segurola, J. Chitosan-Derived Photocurable Hydrogels: Molecular Weight, Degree of Deacetylation, Methacrylation, Acid-Neutral State, Hybrid PEG Networks, SLA/4D Printing and Qualification. ER-123. Zenodo (2026).
- [C12] Segurola, J. Hyaluronic-Acid Methacrylate/Methacryloyl Photoresins: Source, Molecular Weight, Substitution, DLP Hybrid Networks, Hydration, Hyaluronidase Degradation and Qualification. ER-124. Zenodo (2026).
- [C13] Segurola, J. Alginate-Methacrylate Photoresins: Source, M/G Composition, Methacrylation Route, Covalent-Ionic Dual Networks, Hydration, Degradation and Qualification. ER-125. Zenodo (2026).
- [C14] Segurola, J. Dextran-Methacrylate Photoresins: Molecular Weight, Degree of Substitution, Solvent State, DLP Hybrid Networks, Washing, Degradation and Qualification. ER-126. Zenodo (2026).
- [C15] Segurola, J. Methacrylated-Starch Photoresins: Botanical Source, Amylose/Amylopectin Composition, Gelatinisation, Substitution, Aqueous DLP, Hybrid Bioinks and Qualification. ER-127. Zenodo (2026).
- [C16] Segurola, J. Photocurable Cellulose-Derived Photoresins: Cellulose and CMC Identity, Carboxymethyl and Methacrylate Substitution, Nanocrystal Functionalisation, Aqueous DLP/TPP, Hydration and Qualification. ER-128. Zenodo (2026).

- [C17] Segurolo, J. Photocurable Pectin-Derived Hydrogels: Botanical Identity, Esterification, Methacrylation and Norbornene Routes, Ionic-Photo Dual Networks, Hydration, Degradation and Qualification. ER-129. Zenodo (2026).
- [C18] Segurolo, J. Methacrylated Kappa-Carrageenan Photoresins: Algal Source, Sulfation, Methacrylation, Thermo-Ionic-Photo Networks, Extrusion and DLP, Hydration and Qualification. ER-130. Zenodo (2026).
- [C19] Segurolo, J. Methacrylated Gellan-Gum Photoresins: Microbial Identity, Acyl State, Methacrylation, Thermo-Ionic-Photo Networks, Extrusion, Hydration and Qualification. ER-131. Zenodo (2026).
- [C20] Segurolo, J. Photocurable Pullulan-Derived Photoresins: Microbial Identity, Methacrylate and Norbornene Routes, Inkjet, SLA-TPP, DLP, Hydration and Qualification. ER-132. Zenodo (2026).
- [C21] Segurolo, J. Methacrylated Konjac-Glucomannan Photoresins: Botanical Identity, Acetylation, Oxidation, Substitution, Extrusion, Microspheres, Wound Composites, Hydration and Qualification. ER-133. Zenodo (2026).
- [C22] Segurolo, J. Xanthan-Gum-Enabled Photocurable Bioinks: Microbial Identity, Unsaturated Derivatives, Rheology, Methacrylated Xanthan, Extrusion, Hydration, Network Attribution and Qualification. ER-134. Zenodo (2026).
- [C23] Segurolo, J. Photocurable Guar-Gum-Derived Hydrogels: Botanical Identity, Hydroxypropylation, Methacrylation, Dual Networks, Extrusion, Hydration and Qualification. ER-135. Zenodo (2026).
- [C24] Segurolo, J. Agarose and Methacrylated Agarose in Photocurable Biofabrication: Algal Identity, Gelation Hysteresis, Derivatisation, Microgel Photoannealing, Support Baths, Network Attribution and Qualification. ER-136. Zenodo (2026).
- [C25] Segurolo, J. Locust-Bean-Gum-Derived Photocurable Hydrogels: Carob Identity, Galactomannan Structure, Methacrylation, Oxidation, Network Attribution, Injectability, Hydration and Qualification. ER-137. Zenodo (2026).