

Xanthan-Gum-Enabled Photocurable Bioinks: Microbial Identity, Unsaturated Derivatives, Rheology, Methacrylated Xanthan, Extrusion, Hydration, Network Attribution and Qualification

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Statement of Significance

Xanthan in a photocurable ink is not automatically a photocurable xanthan network. Microbial production, recovery, acetyl/pyruvyl state, molar mass, counterions and moisture define the parent polymer. Native xanthan may control rheology while another macromer cures; unsaturated xanthan may participate covalently.

Keywords: *xanthan gum; methacrylated xanthan; unsaturated xanthan; rheology modifier; GelMA; PEGDMA; extrusion bioprinting; network attribution; qualification*

Abstract

Photocurable xanthan-containing systems include native xanthan rheology modifiers and partner-owned networks in which GelMA, PEGDA/PEGDMA or methacrylated collagen peptide carries the light-triggered cure. Methacrylated xanthan is confirmed as a covalent network participant in one systematically characterised extrusion system, while unsaturated xanthan derivatives remain a separate, source-unconfirmed evidence class. This review keeps polymer identity, rheological function, covalent ownership and article state explicit.

1. Scope and boundaries

ER-134 owns identity and qualification of xanthan-containing photocurable bioinks: microbial source and recovery, acetyl/pyruvyl and molar-mass state, native versus unsaturated xanthan, rheology, extrusion, conversion, network attribution, washing, hydration, 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-122 collagen methacryloyl; and ER-123 to ER-133 neighbouring biopolymer derivatives. [C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,C21].

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

Native, unsaturated and methacrylated xanthan are not interchangeable. Viscosity or suppressed sedimentation does not prove covalent incorporation. A cured partner-XG composite does not prove xanthan photopolymerised; feed ratio is not measured substitution, and print fidelity is not bulk conversion or biological safety.

2. Controlled xanthan-containing photoresin state chain

State	Minimum identity	Failure if omitted
Incoming xanthan	Microbial process/recovery, grade/lot, molar mass, acetyl/pyruvyl state, counterions, salts, purity, ash, moisture and storage	Xanthan name replaces feedstock identity
Native or photoactive XG	Role declaration; for MXG, reagent/feed, reaction/purification, measured substitution, residuals and storage	Thickener and covalent participant are conflated
Ink or precursor	XG role, co-macromers/alginate/cells, solids, pH, salts, temperature, initiator, optical state, shear history and age	Rheology and network ownership disappear
Article	Extrusion/light process, post-cure, wash, conversion, soluble fraction, residuals, hydrated dimensions, mechanics and biology	Deposited, cured, washed and hydrated states are conflated

Table 1. Minimum state chain for xanthan-containing photocurable constructs.

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 Microbial production and substituent state precede formulation

Xanthan is a microbial exopolysaccharide with a beta-1,4-glucan backbone and charged side chains. Producing strain, fermentation, recovery, thermal history, molar mass, acetyl/pyruvyl state, counterions, salts, purity, moisture and storage govern conformation, ionic response, viscosity and yield behaviour. Trade name alone is not feedstock identity.

3.2 Unsaturated xanthan is a derivative class, not proof of photocure

Hamcerencu et al. synthesised unsaturated xanthan derivatives and linked reaction conditions to chemical and macromolecular state [1]. This supports polymerisable functionality, not by itself photoconversion, printability or hydrated performance. Reagent, feed basis, purification and measured substitution must travel with any cure claim.

3.3 Native xanthan can control ink rheology without owning the network

Dubbin et al. used xanthan to thicken PEGDA and limit cell sedimentation in a one-hour benchmark [2]. PEGDA and GelMA droplets were light-cured; xanthan was rheological, not the named photoactive macromer. Sedimentation, extrusion survival and post-cure viability remain separate tests.

3.4 Methacrylated xanthan changes covalent participation in multicomponent inks

Li et al. combined GelMA/alginate/PEGDMA/xanthan gum in a systematically characterised extrusion bioink and separately synthesised methacrylated xanthan gum, which the authors designate M-Gum [3]. Non-modified xanthan modified viscosity but did not contribute to network crosslinking, whereas M-Gum was crosslinked through its methacrylate groups alongside GelMA and PEGDMA; a ninhydrin assay gave an incorporated-methacrylate to gum-repeat-unit molar ratio of 1/3.2, and the substitution raised the compressive modulus of a 10% GelMA, 3% gum hydrogel from 51.25 to 87.63 kPa while slowing collagenase degradation. Printability, mechanics, degradation and cell results belong to the complete formulations and controls.

3.5 GelMA-XG and collagen-peptide-XG composites retain partner ownership

Deidda et al. made 5% GelMA extrudable with xanthan and evaluated print and hiPSC endpoints [4]. Weng et al. combined native xanthan with UV-cured methacrylated collagen peptide and evaluated hMSC responses [5]. Xanthan supplied rheology and physical interactions; the methacrylated partner owns the named radical cure unless xanthan conversion is shown.

4. Rheological, formulation and optical-process control

Parent lot/state, native or methacrylated xanthan, solids, salts, pH, partners, cells and initiator define the precursor. Temperature, age, shear, cartridge, nozzle and flow define extrusion; spectrum, irradiance, exposure, oxygen, depth and geometry define conversion. Monitor the complete formulation through its working life.

No-XG, native-XG, MXG, dark, initiator-light, no-photoactive-partner and complete controls are required. Matched GelMA, PEGDA/PEGDMA, alginate or collagen-peptide controls separate viscosity, physical/ionic association and covalent cure.

5. Hydration, dissolution, degradation and biological boundaries

Evidence block	What it can show	What it cannot establish alone
Parent/derivative identity	Method-specific substituent, molar-mass, ionic, substitution and solution state	Photoconversion or article performance
Rheology/printing	Formulation-, temperature-, shear-, nozzle- and geometry-specific sedimentation and deposition	Covalent network ownership or transferable settings
Conversion/article state	Partner- and MXG-specific conversion, soluble fraction, hydration, dimensions and mechanics	Universal degradation or service life
Biological model	Response of the exact ink, print, extract or cell-loaded construct in the stated model	General safety, clinical efficacy or regulatory approval

Table 2. Evidence blocks that must remain separate for xanthan-containing photoresins.

ISO 10993-12:2021/Amd 1:2025 and ISO 10993-18:2020/Amd 1:2022 anchor preparation and chemical characterisation [S4,S5]; ISO 10993-1:2025 frames biological safety [S6]. Cell viability or differentiation does not establish universal biocompatibility, therapeutic efficacy or approval.

6. Release matrix

Gate	Minimum evidence	Claim withheld
Parent identity	Microbial process/recovery, lot, molar mass, acetyl/pyruvyl state, counterions, salts, purity, moisture and storage	Generic xanthan equivalence
Derivatisation	Reaction/purification, measured substitution, residuals, stability and molecular-state record	Feed or MXG acronym as derivative identity
Role attribution	No-XG, native-XG, MXG, no-partner, dark, initiator-light and complete controls plus conversion	Unverified rheological or covalent ownership
Process	Complete formulation, rheology/age, extrusion hardware, spectrum, irradiance, exposure and geometry	Transferable deposition or cure settings
Article state	Green, post-cured, washed, hydrated and dried x/y/z, mass, soluble fraction, residuals, mechanics and conditioning	Unqualified dimensions, mechanics or stability
Biological boundary	Exact polymer roles, formulation, print/light stress, wash/extract, model, dose, endpoint, duration and statistics	Universal biocompatibility or clinical suitability

Table 3. Minimum release architecture for xanthan-containing photocurable constructs.

7. Failure-mode interpretation

- The nominally same XG ink has different pressure or shape retention: verify producing process, lot, molar mass, acetyl/pyruvyl state, counterions, salts, moisture, concentration, temperature, shear history and cartridge age before changing exposure.
- Cells settle less after XG addition: report the sedimentation metric and time independently from extrusion damage and post-cure viability; viscosity control is not a safety conclusion.
- A native-XG composite cures strongly: quantify conversion of the named photoactive partner and use no-partner/no-XG controls before assigning covalent participation to xanthan.
- Methacrylated XG changes mechanics or degradation: measure incorporated substitution, conversion, soluble fraction and hydrated mass; reagent feed and network incorporation are different quantities.
- A GelMA-XG result transfers poorly to PEGDMA-XG or COPMA-XG: rebuild formulation rheology and optical dose. Partner chemistry, ionic components, temperature and network topology differ.
- A cell-laden construct proliferates or differentiates: retain exact polymer roles, cell source, printing stress, light dose, wash, medium, duration and endpoint; withhold clinical claims.

8. Minimum workflow and research priorities

- Freeze producing strain/process, fermentation and recovery, commercial grade and lot, molar-mass distribution, acetyl/pyruvyl state, counterions, salts, purity, ash, moisture and storage.
- For unsaturated XG, report reagent and feed basis, reaction, purification and drying, measured substitution method/result, residual reagents, molecular-state change and storage.
- Map native/MXG, co-macromers, alginate, cells, initiator and salts, plus pH, temperature, viscosity, yield stress, recovery, sedimentation, optical attenuation and conversion over ink age.
- Record printer, nozzle, pressure or flow, speed, layer, temperature and geometry, plus spectrum, irradiance, exposure, oxygen, post-cure and wash.
- Measure partner- and MXG-specific conversion, insoluble and soluble fractions, residual initiator and derivatisation reagents, and x/y/z dimensions in green, washed, hydrated and dried states.
- Use no-XG, native-XG, MXG, dark, initiator-light, no-partner and complete controls to assign rheology, sedimentation, deposition, covalent cure and mechanics.
- Test swelling, dissolution, mass loss and mechanical retention in defined ionic media over time; distinguish native-XG release, network cleavage and partner degradation.
- Separate cell sedimentation, extrusion injury, curing injury, extract cytotoxicity, proliferation, differentiation and tissue models from safety, efficacy and regulatory conclusions.

9. Conclusions

Xanthan-containing photocurable materials are controlled microbial-feedstock, substituent, derivative, rheological-role, formulation, optical-process, washing and article states.

Primary evidence supports unsaturated xanthan derivatives and native XG as a sedimentation or printability modifier; methacrylated XG is a confirmed covalent participant in the characterised extrusion system of Li et al., while GelMA-, PEGDMA- or COPMA-owned composite networks are independently supported. Those roles are not interchangeable.

Release requires traceability through source, acetyl/pyruvyl and molar-mass state, derivative, substitution, formulation role, rheology, process, conversion, washing, soluble fraction, residuals, hydration, dimensions, mechanics and biological model.

Limitations

This qualitative engineering review is not a systematic meta-analysis. The studies use different xanthan identities, derivatives, partners, formulations, print conditions, article states and models. Values are study-specific.

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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