

## Egg and Albumin- Inspired Organic Bioplastics as Eco-Friendly Materials for Bone Healing Applications

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### **ABSTRACT:**

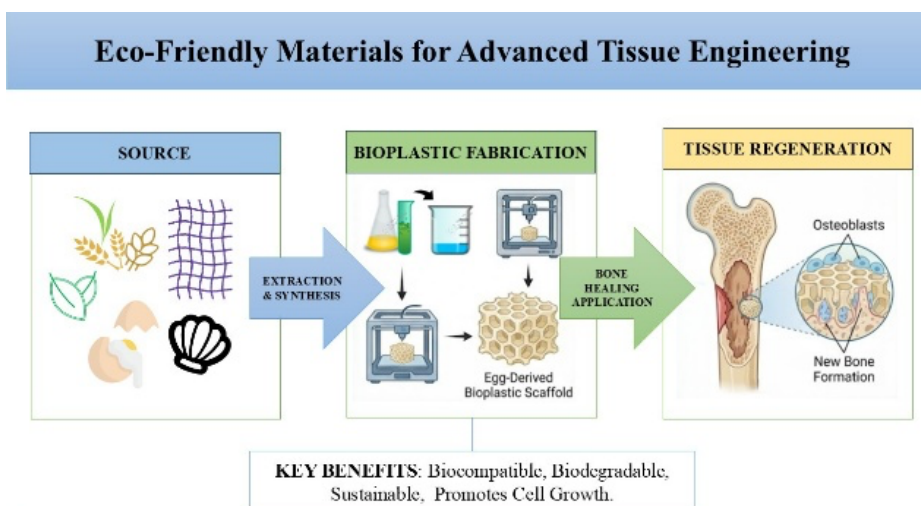
Due to increasing demand for biocompatible and safe materials, protein-based bioplastics have been increasingly explored as alternatives to common plastics derived from non-renewable fossil resources. Egg albumin appears to be a promising organic polymer material for bioplastics because of its biodegradability, lower immunogenicity, film forming properties and bioactivity. Meanwhile, eggshell waste has been used as a green source of calcium salt for hydroxyapatite synthesis to produce mineralized organic-inorganic composites resembling the structure and function of natural bone. Since 2020, much progress has been made in developing albumin-based hydrogels, electrospun scaffolds and 3D-printed composites for bone regeneration purposes. In vitro studies have shown accelerated osteoblast growth, differentiation of mesenchymal stem cells and mineralization of cultures on matrices based on albumins. In vivo studies have recorded improved healing of defects and increased bone mineral density with the presence of albumins in combination with other bioactive ceramics such as hydroxyapatite (HAp) and  $\beta$ -tricalcium phosphate. This review discusses recent developments in the processing, architecture, physicochemical properties, biocompatibility and translation of egg albumin bioplastics, and highlights their potential in sustainability and the circular bioeconomy and the mechanistic role of albumin in modulating both osteogenesis and the inflammatory response. Current and future limitations are also discussed to guide successful future research towards the clinical translation of these green biomaterials.

**KEYWORDS:** Bioplastics; Albumin-based hydrogels; Hydroxapatite; Green Biomaterials

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### **GRAPHICAL ABSTRACT**



## HIGHLIGHTS

- Albumin bioplastics are sustainable, biodegradable, and biocompatible.
- Eggshell-derived hydroxyapatite enhances bone-mimicking composites.
- Promotes osteoblast growth and faster bone regeneration.
- Challenges remain in strength, scaling, and clinical use.

## 1. Introduction:

Repair of bone defects resulting from bone trauma, tumor removal, fracture non-union or degenerative diseases of bone is a common clinical conundrum affecting millions of people globally each year. The clinical gold standard reconstructive technique using autografts has limitations such as donor site morbidity, limited availability and long recovery time, and so there has been meaningful research and development into synthetic and biomimetic substitutes (Zhang et al., 2021; Bose et al., 2022). Consequently BTE became an interdisciplinary field combining materials science, biology and engineering which seeks to design scaffolds able to induce osteogenesis, angiogenesis and to integrate functionally with the host (Oryan, Alidadi & Moshiri, 2020). Increasing emphasis has also been placed on the sustainability of biomaterials. For example, polymers that are commonly derived from petroleum, such as poly(methyl methacrylate) and some synthetic polyesters, can present sustainability issues related to their non-renewability and the degradation products they produce (Ramesh et al., 2022). Bio-based polymers are being investigated in this area as environmentally friendly materials with a lower carbon footprint and improved biocompatibility (Nair & Laurencin, 2020; Kaczmarek et al., 2023). Protein-based bioplastics, derived from renewable biomass, are a promising avenue in bioplastics with this aim. Albumin has been shown to be a versatile scaffold-forming material due to its biocompatibility, biodegradability and tunable denaturation and crosslinking capacity to form stable matrices. Egg white and serum contain large amounts of this globular

protein (Kuten Pella et al., 2022). Egg white-derived albumin (ovalbumin, OVA) has been presented as a low-cost and easily available protein derived from agricultural waste and suitable for circular bioeconomy (Zhang, Pham & Tran, 2024). Albumin has domains responsible for cellular interaction and growth, and its breakdown products are non-toxic amino acids that can be reused for metabolism (Meng et al., 2023).

Besides the extraction of proteins, eggshell waste (calcium carbonate) has also been extensively studied as a biogenic precursor of hydroxyapatite, which is the major inorganic constituent of bone (Abdulhusein et al., 2025). Hydroxyapatite obtained from eggshells has been found to have similar crystallinity, bioactivity, as well as environmental and economic benefits compared to synthetic hydroxyapatite (Siddiqui et al., 2021). An organic-inorganic composite using albumin and HA obtained from eggshell has been reported to match the natural composition of bone extracellular matrix, which is made of collagen fibrils mineralized with nanoparticle crystals (Bose et al., 2022). From a biological perspective, scaffolds must also be able to actively modify the cellular microenvironment. Between 2020 and 2025, in vitro studies assessed the effect of albumin on osteoblast adhesion and proliferation on protein-free matrices and showed a positive effect (Junka et al., 2022). Additionally, MSCs cultured on composites reinforced with albumin were found to upregulate osteogenic markers such as RUNX2, ALP and osteocalcin (Meng et al., 2023). The incorporation of nano-hydroxyapatite eases mineralization and alkaline phosphatase activity, suggesting synergy between the organic protein and inorganic mineral phases (Siddiqui et al., 2021).

Likewise, animal defect models have also shown promising results in vivo when albumin-based matrices are mineralized with HA, showing an increased volume fraction and a faster rate of new bone formation (Abdulhusein et al., 2025). Furthermore, protein-based scaffolds may modulate macrophage polarization towards the M2 phenotype, and pro-healing M2 macrophages have been shown to be pro-osteogenic and to limit the long-term inflammation (Kaczmarek et

al., 2023), which is increasingly considered to support the successful bone healing. Many knowledge gaps remain however, particularly the mechanical properties of pure albumin scaffolds which may be insufficient for load-bearing applications. Crosslinking strategies have led to improved stability but may raise concerns regarding cytotoxicity and long-term degradation kinetics (Ramesh et al., 2022). Most of the studies have been conducted in vitro, with very few large animal studies or standardized clinical trials. Scaling up production and reproducibility of fabrication processes of albumin-based bioplastics should be systematically investigated.

Hence, the current review seeks to update the advances in the development of egg albumin-based organic bioplastics for bone tissue engineering applications between 2020 and 2026. Sustainable raw material sourcing, Fabrication methodologies, Physicochemical and mechanical performance, In vitro and in vivo biological outcomes, Translational potential and clinical relevance and Environmental advantages within circular bioeconomy frameworks. With the use of a materials science perspective, as well as clinical and biological considerations, this review seeks to elucidate the potential role of albumin-based bioplastics in future bone regeneration strategies.

## 2. Organic Raw Materials Used in Bioplastic Production:

The potential of recent rapid development of biodegradable bioplastics for biomedical applications reflects the need to reduce environmental issues as well as the demand for bio-based substitutes for petroleum-based commodity polymers. Organic raw materials for bioplastics include renewable biobased feedstocks, such as plant polysaccharides, animal proteins, biopolymers produced by microorganisms, and agriculture-based waste (Kaczmarek et al., 2023; Ramesh et al., 2022). The criteria used to select materials for bone tissue engineering are environmental and biological.

### 2.1. Plant-Derived Polysaccharides

Familiar polysaccharides used in bioplastic production are starch, cellulose, alginate and chitosan. Starch bioplastics are low cost and biodegradable, though they need to be reinforced to improve their biomedical mechanical properties and moisture sensitivity (Nair & Laurencin, 2020). To improve tensile strength and other mechanical properties, composite scaffolds containing cellulose nanofibers have been used (Bose et al., 2022). Chitosan is derived from crustacean exoskeletons and has intrinsic antibacterial properties. Because of its close resemblance to the glycosaminoglycans found in the bone ECM, it is attractive for bone regeneration (Siddiqui et al., 2021). However, polysaccharide-based systems often cannot achieve sufficient levels of osteoinduction alone, requiring bioactivity to be improved using protein or mineral reinforcement.

### 2.2. Animal-Derived Protein

Proteins such as collagen, gelatin, silk fibroin and albumin have demonstrated superior cell interaction relative to polysaccharides. Collagen has been studied most extensively as it is a major component of the native bone matrix; however its cost and the ethical issues and variability associated with animal derived collagen have led to investigations into other protein sources (Oryan, Alidadi & Moshiri, 2020). Albumin offers several advantages such as Abundant and inexpensive, Low immunogenicity, Good film-forming capability, Controlled degradability and Functional groups suitable for crosslinking. Albumin derived from egg white is highly attractive, being derived from agricultural by-products, and thus supporting the principles of circular bioeconomy (Zhang, Pham & Tran, 2024).

### 2.3. Eggshell-Derived Mineral

Due to its calcium carbonate ( $\text{CaCO}_3$ ) nature, eggshell is a potential green source of materials for the preparation of hydroxyapatite. By calcination followed by the wet chemical precipitation, eggshell-derived  $\text{CaCO}_3$  can be converted to nano-hydroxyapatite (nHA) having a similar structure to biological apatite (Abdulhussein et al., 2025). This reduces agricultural waste and reduces the cost of HA production compared to production via synthetic methods. Eggshell-derived HA shows: high osteoconductive, favorable Ca/P ratio and Higher surface roughness improves cell attachment.

## 3. Albumin-Derived Biomaterials

Due to its adaptable and flexible structure, as well as its biocompatibility, albumin has practical applications in tissue engineering. While albumin has commonly been used for drug release, between 2020 and 2026 this has been expanded for use in scaffolds for hard tissue regeneration (Kuten Pella et al., 2022).

### 3.1. Structural and molecular Characteristics

Albumin is globular in nature, consisting of  $\alpha$ -helical regions crosslinked by disulfide bonds. Upon heat or chemical denaturation, the albumin molecule undergoes a conformational change exposing the hydrophobic regions, which then cause intermolecular crosslinking and network formation (Meng et al. 2023). This property enables the formation of films, hydrogels and porous scaffolds without the need for complex synthetic polymers.

### 3.2. Types of Albumin-Based Biomaterials

Albumin hydrogels show high water content to solve the nutrient diffusion and cell migration, whereas Mineralized albumin hydrogels contain nano-HA, which has been shown to optimize osteogenic differentiation in mesenchymal stem cells (Meng et al., 2023). Albumin-integrated electrospinning with biodegradable polymers yields nanofibrous matrices with an analogous thread-like framework (Junka et al., 2022). This results in improved surface area and promotes cell adhesion. The various organic raw

materials used in albumin based bioplastics are tabulated in Table 1.

**Table 1. Organic Raw Material Used in Albumin-based Bioplastic for Bone Healing Application**

Raw Materials	Sources	Function in Scaffold	Main Advantages	Disadvantages
Egg white albumin	Fowl eggs	Polymeric matrix	Biodegradable, Biocompatible, Abundant	Mechanical strength is less intrinsic
Eggshell-derived hydroxyapatite (HAp)	Agricultural waste	Osteoconductive mineral phase	Cost-effective, Bioactive, Sustainable	Controlled synthesis is needed
Cellulose nanofiber	Plant biomass	Mechanical reinforcement	Tensile strength is high	Surface modification is required
Chitosan	Exoskeletons	Structural reinforcement	Mimetic-ECM, Antibacterial	Sensitive to pH
Gelatine	Collagen hydrolysis	Supports cell adhesion	Bioactive and Biodegradable	Rapid degradation

#### 4. Preparation and Formation of Albumin-Derived Organic Bioplastic

The albumin-based organic biomaterial for bone healing needs precise control over protein denaturation, crosslinking kinetics, pore architecture and mineral integration. it may consist of processing strategies. It may directly influence scaffold mechanical integrity, degradation rate, surface chemistry and cellular response. The Different methods for the preparation of Albumin-Derived Organic Bioplastic were shown in Figure 1.

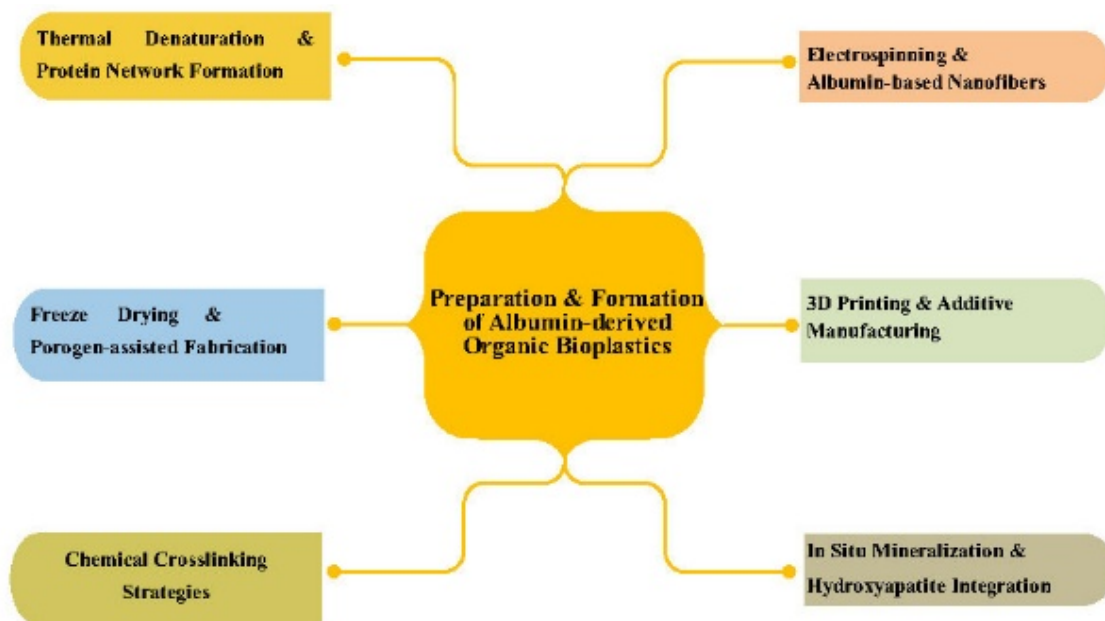


Figure 1: Types of Preparation methods in Albumin-Derived Organic Bioplastic

The conformational transition of albumin undergoes heating above 60-70 °C to make the albumin partially unfold and expose hydrophobic residues. This rearrangement facilitates the reformation of intermolecular disulfide bonds and  $\beta$ -sheet aggregation, resulting in the formation of a physically crosslinked network (Meng et al., 2023). Therefore, the gelation is beneficial because it may avoid cytotoxic chemical crosslinkers. The thermal denaturation and protein network formation process involves several types, such as Chemical Crosslinking Strategies, Genpin Crosslinking and Carbodiimide Crosslinking (EDC/NHS). The Gelatin-albumin crosslinking is depicted in Figure 2.

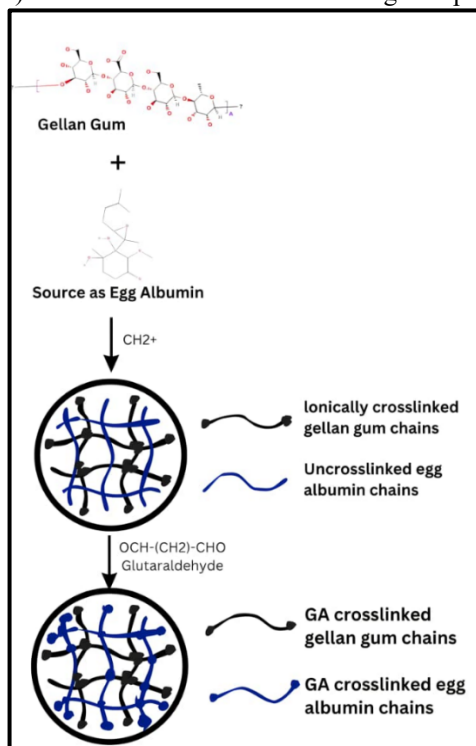


Figure 2: Gelatin-albumin crosslinking

## 5. Physicochemical, Mechanical, Biocompatibility and Bioactivity Properties

The functional performance of albumin-derived organic bioplastics in bone tissue engineering is governed by interrelated physicochemical, mechanical and biological parameters.

### 5.1 Physicochemical Characteristics

The physicochemical architecture of albumin-derived organic bioplastics is primarily dictated by protein denaturation behavior, crosslinking chemistry and inorganic phase incorporation. Native albumin is a globular protein (~66 kDa) composed predominantly of  $\alpha$ -helical domains stabilized by disulfide bridges. During bioplastic fabrication, thermal treatment, pH modulation or chemical crosslinking induces conformational rearrangement, leading to partial unfolding of the protein's tertiary structure. This exposure makes hydrophobic and reactive amino acids, such as lysine, cysteine and aspartate, available for intermolecular crosslinks or gel formation.

Furthermore, Fourier-transform infrared spectroscopy (FTIR) and circular dichroism experiments have shown that the content of  $\alpha$ -helices decreases during denaturation and curing, whereas the content of  $\beta$ -sheets increases. This leads to the formation of a stable polymeric protein matrix due to the transition of secondary structure elements of the proteins. The interaction of carboxyl groups in the albumin chains with calcium ions could be improved by adding an inorganic phase like a nano-hydroxyapatite.

### 5.2 Mechanical Properties

The mechanical properties of albumin-based bioplastics often limit their application within bone regeneration, as plain albumin scaffolds have low compressive strength (1-5 MPa) which suits low-load or non-load bearing applications. However, when incorporating mineral fillers such as hydroxyapatite at 20-40 wt%, the compressive strength can be increased to approach the lower mechanical limits of cancellous bone, reaching up to 8-20 MPa which increases the applicability of these composites in orthopedics. Young's moduli for composites with mineral content are generally between 0.5 and 2 GPa in optimal composites, while these values are considerably lower in scaffolds without mineralization..

### 5.3 Biocompatibility

Biocompatibility is often the first requirement for any biomaterial being proposed for implantation. Albumin-based bioplastics have consistently displayed high levels of cytocompatibility with fibroblast, osteoblast, and mesenchymal stem cell cultures. Surface proteinaceous chemistry improves and promotes cell attachment and spreading through integrin binding and focal adhesion formation. Hemocompatibility studies showed low hemolysis and platelet activation, suggesting surgical safety. Lower cytokine responses (e.g. TNF- $\alpha$ , IL-6) were seen in some studies than with some synthetic polymers.

### 5.4 Bioactivity and Osteogenic Potential

Beyond structural support, albumin-derived organic bioplastics exhibit intrinsic bioactivity that contributes to bone regeneration. The protein contains multiple ligand-binding domains capable of interacting with calcium ions, growth factors and small therapeutic molecules. This property enables localized mineral nucleation and sustained release of osteoinductive agents when incorporated into composite systems. In addition to its structural properties, albumin-based organic bioplastics also possess bioactive properties stemming from the different ligand-binding domains of the protein. These domains allow for interactions with calcium ions, growth factors and small therapeutic drugs, and enable local release of osteoinductive agents when albumin is entrapped within composite systems through the process of mineral nucleation. Mineralized nodules can be observed in albumin scaffolds in simulated body fluid (SBF) after 7-14 days, confirming their osteoconductive properties. At the molecular level, the albumin-hydroxyapatite composites induce an upregulation of osteogenic markers in mesenchymal stem cells (MSCs).

## 6. Biomedical Applications and Case Studies

In the field of bone regeneration, albumin-based bioplastics have progressed between 2020 and 2026 from proof-of-concept protein binders to preclinically validated biomaterials for defect-filling scaffold, osteoconductive composite matrix, guided bone regeneration membranes and bioactive drug delivery platforms. Egg-derived albumin crosslinked with minerals such as hydroxyapatite or beta-tricalcium phosphate has gained particular interest due to better mechanical integrity and osteogenic capacity, tested in vitro and in vivo.

### 6.1 In Vitro Osteogenic Applications

In vitro evaluations for the suitability of albumin-derived organic bioplastics in bone tissue engineering involve cell culture with different cell types consist of osteoblast-like cell lines and human mesenchymal stem cells consistently demonstrate favorable adhesion, proliferation and differentiation on albumin-based matrices. A proteinaceous surface chemistry allows for the integrin-mediated attachment, cytoskeletal organization and focal adhesion formation of cells within the first 48-72 hours of culture.

### 6.2 In Vivo Bone Regeneration Models

Preclinical in vivo studies have also provided translational potential evidence for mineralized albumin composites in rat calvarial and femoral defect models, where composites demonstrated accelerated bone formation when compared to controls. Histological data further suggests an improved trabecular structure, increased neovascularization and less fibrous tissue encapsulation of protein-based scaffolds. Micro-computed tomography studies found an increased bone

volume fraction and bone mineral density after 8-12 weeks following implantation.

### 6.3 Drug Delivery and Multifunctional Systems

An obvious advantage of albumin matrices is the intrinsic capacity of albumin to bind multiple ligands (growth factors, peptides, small bioactive molecules) making them ideal candidates for scaffold-based controlled release applications. The local sustained release of osteoinductive agents following incorporation of BMPs into these matrices eases bone regeneration within the timeframe of the different phases of bone repair. The combination of mechanical stability, bioactivity, and targeted delivery of drugs suggests albumin-based bioplastics may have promise in regenerative medicine.

## 7. Role and Advantages of Albumin-Derived Organic Bioplastics in Bone Healing

Bone healing is a coordinated process, comprising modulation of the inflammatory response, recruitment of specific cell types to the defect, deposition of ECM, followed by mineralization and remodeling. Therefore, biomaterials for bone regeneration have to be designed to provide both mechanical properties and biochemical signals and microenvironments. Albumin-based organic bioplastics display unique multifunctional properties, acting as structural scaffolding, bioactive surface interfaces and molecular drug delivery vehicles, subsequently altering the regenerative cascade.

### 7.1 Immunomodulatory Contributions

Bone healing progresses through various inflammatory phases that act as important modulators for bone regeneration. Albumin-based scaffolds modulate immune cell response via macrophage polarization. In balance, the immune response favors angiogenesis and early matrix deposition, establishing good biointegration with the defect site.

### 7.2 Osteogenic Stimulation and Matrix Formation

Composites derived from albumin possess osteogenic tendencies via biochemical and physicochemical mechanisms: surface amino acid residues provide integrin binding sites for cell adhesion, and mineral coatings increase calcium source availability to osteoblasts. Similar trends in the upregulation of osteogenic activity have also been observed with mineralized albumin composite systems. **Mechanical Limitations for Load-Bearing Applications:** Despite the addition of mineral reinforced formulations, mechanical constraints of albumin-based organic bioplastics impede their use in load-bearing skeletal applications. The addition of hydroxyapatite or  $\beta$ -tricalcium phosphate improves compressive strengths and elastic moduli, but mechanical properties achieved using these composites are typically within the lower range of cancellous bone. Furthermore, the mechanical requirements of cortical bone exceed the capabilities of these formulations (Zhang et al., 2021; Kumar and

Sharma, 2023). However, unlike collagen-rich bone extracellular matrix, the intrinsically globular albumin lacks a hierarchical fibrillar structure, which together with its intrinsic globularity, results in low tensile strength and low anisotropic load. Other options including fiber reinforcement, incorporation of nanocomposites, and 3D-printed structures have also been proposed for defects that are larger, or weight-bearing (Li et al., 2022). However, these can complicate fabrication and scalability (Rahman et al., 2024).

## 8. Degradation Control and Crosslinking Optimization

Controlled biodegradation is a dominant mechanism in scaffold-mediated bone regeneration, but it is difficult to control degradation of albumin matrix. Albumin-based scaffolds are vulnerable to proteolytic degradation due to their proteinaceous structure. Although chemical or natural crosslinkers (e.g. genipin) can considerably strengthen the structure, a high degree of crosslinking may prevent cells from infiltrating the structure or leave behind potentially toxic crosslinker residues (Chen et al., 2020; Iqbal et al., 2022).

### 8.1 Manufacturing Scalability and Regulatory Considerations

Scale-up from laboratory production to the scale of industry has its own set of challenges, including those associated with freeze-drying and solvent casting, which are desirable for prototype development but considered economically or technically infeasible for commercial production (Rahman et al., 2024). Furthermore, because proteins denature on heating, sterilization using  $\gamma$ -irradiation or ethylene oxide treatment can have the potential to destabilize the protein structure and negatively affect mechanical properties (Kumar and Sharma, 2023). Albumin-derived composites intended for different indications may be subject to medical device, biologically derived material, or combination product classifications based on their physical-chemical properties, and undergo wide-ranging biocompatibility, toxicology, and performance evaluations in accordance with international guidelines (ISO 10993; U.S. Food and Drug Administration, 2022). The inclusion of growth factors or drug delivery components in the composition of products increases development cost and complexity of regulatory requirements.

### 8.2 Economic and Market Adoption Barriers

Despite the albumin being a biologically sourced product from non-food agricultural by-products, the downstream costs of purification, crosslinking and composite fabrication, plus the comparative cost-effectiveness of albumin scaffolds with existing products (e.g., collagen-based scaffolds, synthetic polymer graft substitutes) remains to be studied (Singh et al., 2023). It will be necessary to improve the

efficiency of fabrication and integrate with the supply chain

### 9. Future Perspectives and Research Directions

Further development of albumin-based bioplastics could focus on better tuning the hierarchical structure to mimic the bone in a multiscale manner, as currently the obtained reinforcement is limited by the HA content. Strategies combining HA with nano-structuring in multiple levels of architecture are required to achieve anisotropic mechanical properties and toughness. Emerging fabrication technologies such as 3D bioprinting and electrohydrodynamic processing offer greater control over pore geometry, fiber

configuration and mineral distribution (Rahman et al., 2024) and could allow better tuning of micro- and nano-architecture for mechanical reliability and osteointegration, particularly for implantations in critical-sized defects. An effective strategy to stabilize albumin bioactivity while retaining the mechanical properties include the formation of hybrid composites of albumin with biodegradable polycaprolactone (PCL), or polylactic acid (PLA) (Li et al., 2022). The incorporation of bioactive nanoparticles, such as silica-based or magnesium-containing phases may also improve osteogenic signaling and vascularization (Zhang et al., 2021). The 576etails of the future work to focus on has been proposed in the Table 2.

**Table 2:** Future directions for the albumin-derived biopolymers

Research Domain	Current Barriers	Proposed Strategy	Future	Expected Output
Composite Optimization	Suboptimal mineral–protein interfacial bonding	Controlled hydroxyapatite and polymer–protein hybridization	nano-dispersion	Enhanced mechanical stability and osteoconductivity
Structural Engineering	Limited mechanical strength for load-bearing applications	Hierarchical architecture design using 3D bioprinting and electrospinning	micro/nano-	Improved anisotropic strength and fracture resistance
Immuno engineering	Limited mechanistic understanding of immune modulation	Surface functionalization to regulate macrophage polarization	functionalization	Improved inflammatory resolution and tissue integration
Smart Functionalization	Passive scaffold behavior in early regeneration phase	Development of stimuli-responsive drug delivery systems	stimuli-responsive	Controlled release of osteogenic and angiogenic factors
Manufacturing Scalability	Laboratory-scale fabrication methods	GMP-compliant processing and sterilization optimization	scalable and optimization	Regulatory approval readiness and commercialization feasibility
Standardization	Variability in reporting and evaluation metrics	Development of consensus characterization guidelines	of characterization	Improved reproducibility and cross-study comparability
Long-Term Validation	Insufficient long-term large animal studies	Extended in vivo studies (>6 months) with standardized biomechanical testing	in vivo studies	Reliable translational and clinical performance data
Sustainability	Limited quantitative environmental assessment	Life-cycle analysis and circular bioeconomy integration	analysis and integration	Reduced environmental footprint and improved cost-efficiency

The incorporation of albumin and eggshell-derived CaPs may further promote a circular bioeconomy. In future research, new methods should be developed for the sustainable, large-scale extraction and purification of such components with minimal energy and chemical input. Life-cycle assessment studies comparing albumin-based materials with petroleum-derived polymers would provide much-needed quantitative data on their environmental impact (Singh et al., 2023).

## 10. Conclusion

Albumin-derived organic bioplastics are a new and extremely promising class of protein-based biomaterials for bone tissue engineering and regenerative medicine. Albumin is a renewable, biological source of organic bioplastic for bone tissue engineering applications and has an array of structural and biochemical properties that make it promising. Controlled denaturation, crosslinking and mineralization of albumin can produce mechanically-reinforced composite scaffolds that ease osteogenic cell activity and guided bone regeneration. Derived from albumin, organic bioplastics can fill a niche in regenerative orthopedic medicine. Despite needing further optimization and validation of their properties and biocompatibility, their bioactive, biodegradable and eco-friendly to nature properties provide them with an advantage over synthetic and collagen-based scaffolds within this field of regenerative orthopedic biopolymer medicine. Future developments may depend upon the extent to which the advances of translational research will find a place in bone repair.

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