

## Additive Manufacturing (3D Printing) of Biodegradable Polymers, Current Developments and Future Challenges: A review

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### ABSTRACT

Additive manufacturing (AM), also famously abbreviated as 3D printing, has made enormous advancement in facilitating arbitrary shaped structure where the waste of material and the design difference are minimized. The combination of biodegradable polymers with AM methods also brings huge benefits for applications in sustainable manufacturing and biomedical fields. This review aims to consolidate the progressive knowledge regarding 3D printing of biodegradable polymers covering most important materials such as PLA, PCL, and PHAs, processing challenges or shortcomings like thermal degradation, weak layer adhesion and the issue of dimension accuracy etc. Recent development also includes nanocomposites reinforcement, smart stimuli-responsive materials and the hybrid processing such as 4D printing. The applications range from tissue engineering, drug delivery, sustainable packaging to environmental remediation but no matter what the application is significant challenges concerning a balance of biodegradability, mechanical properties improvement and up-scaling for using in industry are left. Environmental and economic evaluations demonstrate the technology's potential to be part of the circular economy, but standardization protocols and a regulatory framework still need to be developed. This paper offers a complete overview of recent advancements and highlights key research areas that are needed to fully leverage the potential of biodegradable polymers for AM.

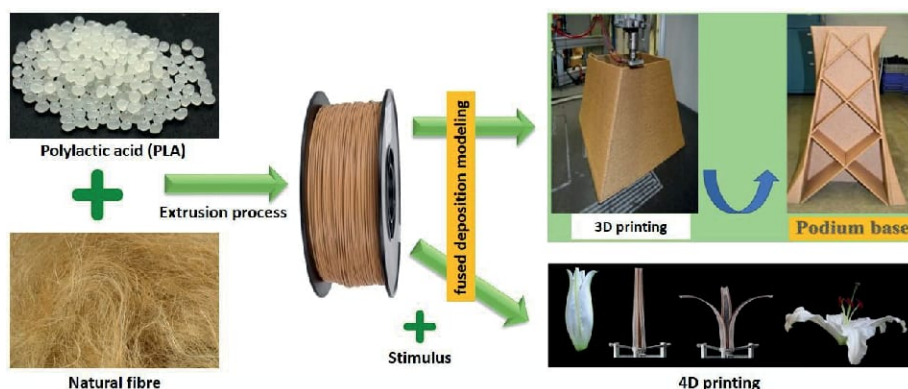


Figure 01: Graphical Abstract (Ilyas et al., 2021)

## 1.0 INTRODUCTION

Global plastic pollution has emerged as one of the most significant threat to the environment in twenty- first century, where approximately 368 million tonnes of plastics is produced per annum; several only few recycled or partially degraded (Subramani et al., 2024). The traditional petroleum-derived polymers remain for centuries in the environment, collecting in terrestrial and aquatic habitats and breaking down into harmful microplastics. The importance to find sustainable alternatives has led intensive research of biodegradable polymers as environmentally friendly materials which can be degraded into nontoxic substances. Additive manufacturing processes have transformed the traditional production through on-demand local fabrication, reduced material wastage, customization and decentralization of manufacturing (Jena et al., 2024). The combination of biodegradable polymer materials and AM technologies open up new possibilities for many applications, particularly the biomedical field in need of patient-specific biocompatible implants, packaging sectors looking for sustainable solutions. This review is aimed at pulling together the knowledge of 3D printing with biodegradable polymers that has been generated from 2015 to 2025, which reflects a work toward hunting down technical innovations as well as applications and challenging issues.

## 2.0 LITERATURE REVIEW

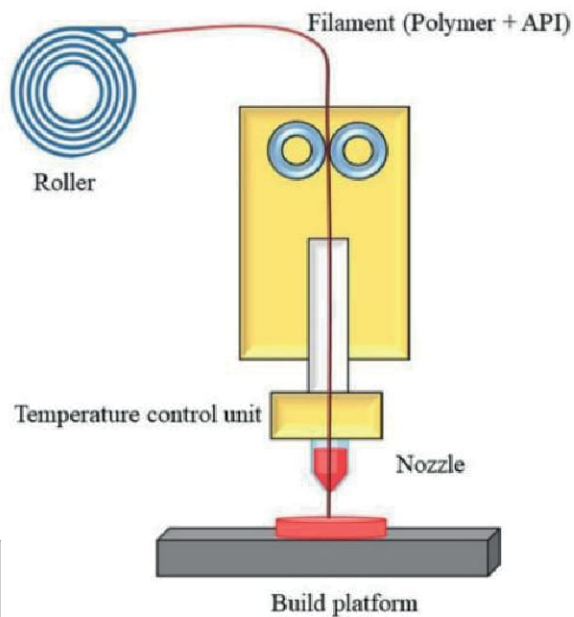
Additive manufacturing as a transforming tool allows creating of complex structures with minimum waste of the materials (Gupta & Shah; 2025) and biodegradable polymers for sustainable manufacturing have enormous potential to be used for biological applications in bio-medical engineering (Dipta; 2025). The market has moved to include critical materials such as polylactic acid (PLA), the most used biopolymer for fused deposition modeling (FDM) 3D printing, due to its easy processability and renewable nature from corn and sugarcane (Wu, 2025), polycaprolactone (PCL) that is known for flexibility and biocompatibility in tissue engineering applications (Patel et al., 2025), and polyhydroxyalkanoates (PHAs), which are a naturally synthesized biodegradable polyester derivative obtained through bacterial fermentation with adjustable mechanical properties (Mehrpouya, Vahabi, Barletta, et al., 2021). Recent developments in material science are focused on new composites that go beyond classical homopolymers,

involving nanocomposite reinforcement with cellulose nanocrystals, carbon nanoparticles or metallic fillers to achieve improved mechanical properties without negatively affecting biodegradability (Mariano et al., 2014). Smart stimuli-responsive materials and 4D printing methods are emerging frontiers which allow for structures that dynamically respond to environmental cues, such as temperature, light, or chemical signals (Sajjad et al., 2024), with light, or chemical signals (Sajjad et al., 2024), with the latest studies still concentrating on developing biodegradable photopolymers applicable to vat photopolymerization technique, including stereolithography (Sajjad et al., 20136). Reinforcing techniques of PLA/PCL and PBAT blends were performed to enhance the toughness and processability with use of reinforcement compared to neat polymers, where optimized compositions such as PLA/PCL blends exhibited equivalent mechanical properties and have induced an enhanced dimensional stability (Andrzejewski et al., 2020). Thermal degradation during extrusion and molding still represents one of the major problems in processing, since it occurs more specifically for PHAs and PLA, at high temperatures necessary for molten processes (Taubner & Shishoo, 2001). Poor layer adhesion product of insufficient molecular chain diffusion and entanglement between the deposited layers, this problem can to a certain extent be alleviated by proper nozzle temperature, printing speed, as well as adjustments of the substrate temperature (Costa et al., 2017). Lignin fillers added at 3-5% by weight appear as promising to enhance adhesion interlayer interaction and improving Young's modulus.-dynamic boronate ester has recently shown a ~150% increase in Z-axis strength (Mohan et al., 2021). Dimensional precision is challenging in the face of warping and shrinkage, especially in semi-crystalline polymers; however, application of combined infill patterns (e.g., Sierpinski models), controlled cooling rates and substrate surfaces treatments as well as careful adjustment of nozzle temperature and feed rate has proven effective for improving dimensional stability and surface roughness (Grubbs et al., 2023). Hygroscopicity of PLA and other biodegradable polymers demands the control of moisture during storage and processing, because the water uptake has a significant affect to mechanical properties and thermal stability (1% nanosilica loading reduced up to 40% in terms of moisture absorption; nano filled PLA, Seng et al., 2020).

### 3.0 METHODOLOGY

#### 3.1. Fused Deposition Modeling (FDM)

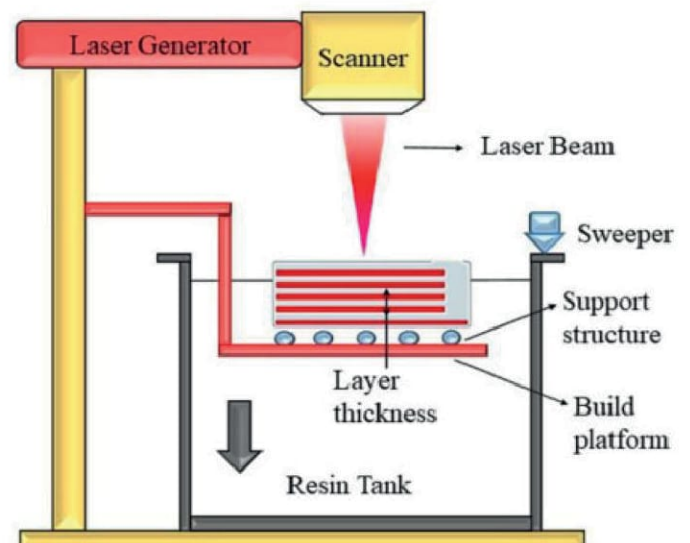
Fused deposition modeling (FDM) is currently the most commonly-assuming AM for biodegradable polymers because of its simplicity, low cost and material diversity flexibility (Eryildiz et al., 2025). In the FDM process, filaments of thermoplastic are heated to above the glass-transition temperature and then deposited on a build platform layer-by-layer. Recent studies show that the FDM parameters, in particular nozzle temperature, layer height and print speed [5], as well as infill density [6] have a clear influence over mechanical properties. It has been shown that tensile strength of the product is enhanced as a result of optimizing extrusion temperature ranging between 200-220 °C for PLA but higher unnecessary temperatures deteriorate thermal stability (Ghaffar, 2024). The infill ratio also plays a significant role in the fabric properties; higher levels (e.g., 80-100 %) of infill results in more tensile and bending strength than lower ratios at the expenses of material usage and printing time.



**Figure 02:** Fused Deposition Modeling (FDM)  
(Ben Said et al., 2025)

#### 3.2. Stereolithography (SLA) and Digital Light Processing (DLP)

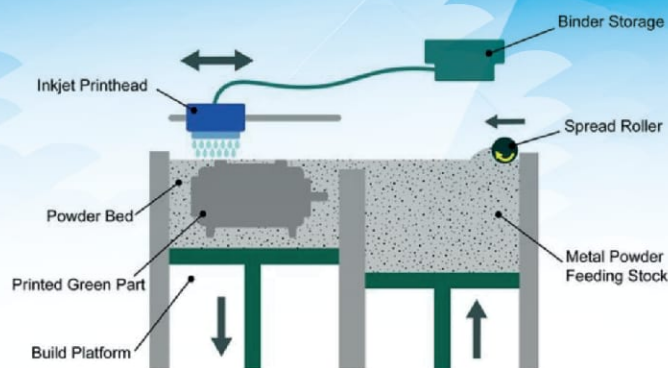
Vat polymerization, such as SLA and DLP methods permit good resolution scaffold manufacturing by photoinitiated cross-linking of photopolymer resins (Kadam et al., 2025). These methodologies feature better dimensional accuracy and feature resolution ( $<100\ \mu\text{m}$  in general) than extrusion-based methods, leading to the construction of intricate 3D microarchitectures for tissue engineering. Nevertheless, the small palette of biodegradable photopolymers is still a major limitation, which would imply the development of tailored monomers with proper photoreactivity and biodegradability (Yi et al., 2025).



**Figure 03:** Stereolithography (SLA) (Ben Said et al., 2025)

#### 3.3. Selective Laser Sintering (SLS) and Binder Jetting

Powder based materials could also be processed using SLS and binder jetting technologies, affording freedom of choice in the selection of materials such as biodegradable polyesters, polymer ceramic composites. Selective laser sintering of agro-waste filled PBAT-based composites has also shown the potential to be used for complex parts with good dimension accuracy but subject to thermal degradation and particle agglomeration challenges (Polozov et al., 2020). More recently, binder jetting methods have shown potential for processing biodegradable polymers at lower thermal loads, but mechanical properties and surface topology remain to be optimized.



**Figure 03:** Binder Jetting process (Ben Said et al., 2025)

### 3.4. Comparative Assessment for Biodegradable Materials

FDM remains the most commercially viable technique for biodegradable polymers due to its scalability, affordability, and compatibility with thermoplastic materials. However, SLA and SLS techniques enable superior precision and complex geometries that FDM cannot achieve. Material selection should consider specific application requirements; tissue engineering scaffolds may benefit from high-resolution SLA approaches, while functional components prioritize FDM for mechanical robustness and cost-effectiveness (Abbasi et al., 2025).

## 4.0 BIODEGRADABLE POLYMERS USED IN 3D PRINTING

### 4.1. Polylactic Acid (PLA)

PLA is the most commercially available biodegradable polymer currently used in AM that can be synthesized from renewable sources, such as corn starch and sugarcane (Rajeshkumar et al., 2021), it is easy to process, cost-effective and enables the tuning of degradation kinetics. Even with its high acceptance,

PLA possesses intrinsically a brittle nature and a low thermal stability above 200°C that restricts the mechanical behaviour. Recent developments include nano-reinforcements such as boron nitride nanoplatelets and cellulose nanocrystals (with tensile strength increases up to 44% while preserving printability). Furthermore, the application of bio-fillers including date palm fibers and orange peel powder shows potential to fabricate partially or fully bio-based composites with better environmentally friendly parameters (Rajeshkumar et al., 2021).

### 4.2. Polycaprolactone (PCL)

Comparatively, PCL possesses better mechanical and thermal properties than PLA and has a glass transition temperature of approximately -60°C along with a melting point around 60°C, which can be processed at lower temperatures with no significant aforementioned limitations (Ferri et al., 2016). In particular, PCL is considered to be biocompatible (i.e., it does not produce much immune response) and has tunable degradation characteristics in a scope from months to years, that render such polymer suitable especially for tissue engineering applications. Hybrid materials based on mixtures of PCL and PLA have become important in an effort to find a compromise between mechanical properties, owing to the interest as biomaterial of both PCL (a thermoplastic polyester rubber) and environment-friendly biodegradable polylactide copolymer, which is also readily available with good mechanical performances when modified through blending (commonly 70:30-80:20), show shape memory effect [Archer et al., 2021].

### 4.3. Polyhydroxyalkanoates (PHAs and PHB)

Polyhydroxyalkanoates, which are produced by microorganisms via fermentation under growth unbalanced conditions are polymers fully of biological origin and biodegradable alternative to the petrochemical polymers. Biocompatible PHB and copolymers, such as PHBV possess better mechanical properties tunable by composition ratio. Yet, PHB has poor thermal stability and melt strength which makes FDM process challenging (Nigmatullin et al., 2015). Recent work with chain extenders and plasticizers has greatly enhanced processability; the addition of PHBV to PLA blends has compressive strength values close to the human trabecular bone (around  $1.48 \pm 0.13$  MPa) (Nanda et al., 2011).

### 4.4. Natural Polymer Blends

Natural polymers, such as chitosan, gelatin, starch and cellulose elsewhere integrated within synthetic polymer matrices generate 100% biodegradable composites exhibiting both bioactivity and mechanical properties. Chitosan scaffolds possess natural antibacterial properties, good biocompatibility with the human body and comparatively low mechanical strength, so they have a difficult shape to work with alone on bone substitute application (synthetic polymer or ceramic fillers). Cellulose, being one of the most available and renewable natural polymer has been recently explored as a potential filler to form PLA based composites (Nanda et al., 2011).

**Table 1. Comparison of Biodegradable Polymer Types**

| Polymer Type            | Composition                                                                     | Key Properties                                                                                                        | Challenges                                                                              | Recent Developments                                                                                                                                                                 | Typical Applications                                       | Reference                               |
|-------------------------|---------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|-----------------------------------------|
| Poly(lactic Acid) (PLA) | Derived from renewable resources (corn starch, sugarcane)                       | Easy to process; cost-effective; tunable degradation; good printability                                               | Brittle; limited thermal stability ( $>200^{\circ}\text{C}$ )                           | Nano-reinforcements (e.g., boron nitride, cellulose nanocrystals) increase tensile strength up to 44%; natural fillers (date palm fiber, orange peel powder) improve sustainability | Packaging, biomedical scaffolds, sustainable composites    | Rajeshkumar et al., 2021                |
| Polycaprolactone (PCL)  | Synthetic aliphatic polyester                                                   | Superior mechanical strength; good thermal stability; biocompatible; slow, controllable biodegradation (months–years) | Low stiffness; lower melting temperature ( $\sim 60^{\circ}\text{C}$ ) limits some uses | PLA/PCL blends (70:30–80:20) show shape memory and improved fracture resistance; ideal for medical use                                                                              | Tissue engineering, drug delivery, shape-memory devices    | Ferri et al., 2016; Archer et al., 2021 |
| Natural Polymer Blends  | Natural polymers (chitosan, gelatin, starch, cellulose) with synthetic matrices | Fully biodegradable; biocompatible; some show antimicrobial activity (e.g., chitosan)                                 | Poor mechanical strength alone; often need reinforcement                                | All-cellulose 3D printing and composites with PLA or ceramics enhance strength and bioactivity                                                                                      | Biomedical scaffolds, wound dressings, bioactive materials | Nanda et al., 2011                      |

## 5.0 PROCESSING AND PRINTING CHALLENGES

### 5.1 Thermal Degradation and Viscosity Control

Biodegradable polymers have a poor thermal stability at the extrusion temperatures for AM. PLA depolymerizes at a temperature higher than  $220^{\circ}\text{C}$ , which generates decreased molecular weight and viscosity, as well as weaker mechanical properties. Sufficient melt fluidity for processing (extrusion) requires a finely balanced range of processing temperatures that are not too high to cause degradation, this narrow processing window limits process robustness and the degree of freedom in operational parameters compared with typical thermoplastics (Signori et al., 2009).

In the case of biodegradable polymers FDM-printed preforms, insufficient diffusion across layer interfaces leads to poor interlayer bonding and in anisotropic porosity such that tensile strength along printing direction is 15-35% lower versus perpendicular directions. Tuning of print temperature for chain fusion and nozzle speed/functionality high nozzle temperatures throughout promote polymer interactions (fusion) and lower speeds ensure enough time for heat dissipation.

### 5.2. Layer Adhesion and Anisotropy

Also raster angle and infill type have a considerable influence on mechanical properties, with the recommended orientations (usually  $45/45^{\circ}$  angles) having better multidirectional properties (Signori et al., 2009).

### 5.3 Dimensional Accuracy and Warping

Rapid cooling resulting in thermal contraction also creates residual stress and warping, especially evident in plastics such as PLA. High-value, carefully-managed post-processing with heat treatment results in 112–121% reduction of warpage coefficient but also risks further molecular degradation. Optimal bed temperature preserves the material as plastic during deposition of each layer, minimizing contraction-related distortion. State-of-the-art bimodal processing, thin-layer with well-designed infill, reaches dimensional accuracies better than  $\pm 3\text{--}5\%$  to nominal (Siegmann et al., 1982).

### 5.4 Optimization of Processing Parameters

Optimization based upon a design of experiments (Taguchi, Plackett-Burman, response surface methodology) has established significant correlations between process parameters and mechanical properties. The layer height, infill density, and nozzle temperature dominate the mechanical property variation where strength variation is mainly associated with layer height while infill density contributes approximately 68% (24%) of variation in tensile strength. With the recent development of several machine learning models, e.g., CatBoost and Gaussian process regression, it has become feasible for high-accuracy ( $R^2 > 0.98$ ) prediction of mechanical properties from processing parameters in order to allow rapid optimization toward some specific applications (Dong et al., 2017).

### 5.5. Post-Processing and Sterilization Effects

Post-treatments such as heat treatment, UV exposure and chemical treatment are observed to modulate the mechanical properties and degradation kinetics. Eto sterilization reduces tensile strength by around 15 – 20% with little to no effect on toughness, while UV does show more profound reductions. When it comes to biomedical applications that need regulatory approval, sterilization processes as well as post-processing are crucial (Krug et al., 2024).

## 6.0 APPLICATIONS OF BIODEGRADABLE POLYMERS IN 3D PRINTING

### 6.1. Biomedical Applications

**Tissue Engineering Scaffolds:** 3-D printing degradable scaffolds provide a disruptive technology for regenerative medicine. Personalized bone scaffolds with designed porosity (50-80%), pore size (200-2000  $\mu\text{m}$ ), and interconnection are fabricated from PLA/PCL, which hold mechanical properties in the range of human trabecular bone (5-20 MPa). Inclusions of bioactive ceramics, like hydroxyapatite and beta-tricalcium phosphate, also provide enhanced osteoconductivity and cell differentiation (Zhang et al., 2021). Cardiovascular applications exploit elastomeric biodegradable polymers and neural tissue engineering benefits from fiber-based scaffold architectures to direct axonal extension.

**Drug Delivery Systems:** 3D-printed biodegradable polymers can be used for the formulation of patient-specific drug solutions, controlling both degradation kinetics and release profiles of the active pharmaceutical ingredients. New developments incorporate nanoparticles into polymer matrices and create intelligent 4D-printed systems triggered by physiological factors such as the pH, temperature, or glucose levels. The Internet-of-Thing in 3D-printed and implantable devices will enable real-time telemedicine for remotely controlled drug formulation, but regulatory pathways are not well developed yet (Zhu et al., 2025). **Biodegradable Implants:** PLA/PCL blends can be used as custom-made stiffening implants offering temporary mechanical support and stimulate tissue-regeneration without explantation. PLA/PCL with an optimized ratio (80:20) has been designed into spinal fusion cages with shape memory properties that enable their minimally invasive insertion by percutaneous means (Eryildiz et al., 2025).

### 6.2. Packaging Applications

Sustainable 3D-printed packaging made of biodegradable polymers that minimizes materials and opens the door to new protective shapes. PLA based composites with environmental agents and antimicrobial ingredients afford tailored packaging applications having less migrated total in accordance with food contact requirements (Kumar et al., 2025). More sophisticated design involves varying the thicknesses and pore sizes to simultaneously achieve maximum load-carrying capacity and minimum plastic usage.

### 6.3. Environmental Applications

3D-printed sensors and adsorbent materials (which are also degradable) can be specialized to collect pollutants at pollutant-diffused areas. Multi functional Abiotic Stresses and Agroecosystems 341 composites, obtained by blending waste particles of agriculture and fertilizer granules, allow for contextualized nutrients release as well as absorption of metal ions for agriculture sustainability purposes (Scaffaro et al., 2024).

## 7.0 RECENT DEVELOPMENTS AND INNOVATIONS

### 7.1. Nanocomposites and Reinforced Biopolymers

The integration of nanoscale fillers (e.g., graphene oxide, carbon nanotubes, cellulose nanocrystals and metal nanoparticles) can dramatically improve the mechanical and functional properties of 3D printed biodegradable polymers. PLA/BNNP composites obtain 44% improvement of tensile strength at low level of reinforcement (0.04 wt%) but CNCs enhanced elongation at break from 6.76 to 40.25% (Abubakre et al., 2023). But such additives show aggregation and inadequate dispersion at high concentrations which limit the performance; this makes necessary a careful design of the formulation and optimization of processing.

### 7.2. Smart and Stimuli-Responsive Materials

Four-dimensional (4D) printing techniques create materials with shape changing behaviour in time driven by environmental stimuli. The thermoresponsive shape memory effects of PLA/PCL blends can produce mechanically active implants with adjustable degrees of form recovery ratios (from 61% to 76%) and fixity (from 96% to 99%), rendering the minimally invasive medical instruments that are adapt for organisms features (Mehrpooya, Vahabi, Janbaz, et al., 2021). Intelligent polymer networks or hydrogels containing pH-sensitive segments or glucose-responsive moieties have the potential for use in precision medicine.

### 7.3. Green Synthesis and Recycled Biopolymers

The possibility of circular economy by reuse and reprocessing/recycling of 3D-printed biodegradable polymers was shown to be feasible, but the decrease in mechanical properties is observed after several extrusion cycles. Dopamine coatings and natural fiber reinforcement provide mechanical properties recovery in door curtain of recycled PLA to 49.3 % (Zhu et al., 2021). Moreover, the use of agro and industrial waste residues as fillers and reinforcements, can lead to fully bio-sourced multi-waste composites complying with the concept of sustainability.

### 7.4. Hybrid Manufacturing Approaches

The combination of 3D printing with other techniques such as electrospinning, bioprinting, and extrusion results in substrate with hierarchical structure that combines bulk mechanical properties with a fibrillary surface micro-architecture favorable for cell adhesion and tissue integration. Three-dimension

al printed PLA structures with electrospun fiber networks show improved tissue engineering performance over monolithic structures, with lower storage modulus and higher cellular response (Danlei et al., 2022).

## 8.0 ENVIRONMENTAL AND ECONOMIC PERSPECTIVES

### 8.1. Life Cycle Assessment (LCA)

Full-LCA studies have shown that 3D printing using biodegradable polymers has a significantly less adverse environmental effect compared with petroleum plastics and traditional manufacturing. FDM has an energy demand of 10-20 MJ/kg material, which is similar to or lower than injection molding if waste can be reduced. Yet, the environmental advantages are highly dependent on end-of-life management -the time to compost PLA ranges from 12-24 months in industrial composting facilities and is extended to decades under ambient conditions (Osadolor et al., 2024)-. For enhanced environmental gains weight optimization targeting energy-efficient processing and proper waste stream handling would be necessary (Osadolor et al., 2024).

### 8.2. Cost Analysis and Market Trends

Bio-based polymer scaffolding is currently sold at 50-150% price premium when compared to traditional thermoplastics, limiting the applications in which it can be adopted commercially. But the economics of TCO is becoming increasingly attractive towards biodegradable material when you start factoring waste disposal, regulations and environmental externalities. Biodegradable polymer 3D printing is in the spotlight due to regulatory pressures, consumer awareness and technological advances, with market predictions forecasting compound annual growth rates of 15-20% towards 2030 (Narancic et al., 2020).

### 8.3. Policy and Regulatory Frameworks

Regulations of 3D-printed bioresorbable medical devices are relatively recent, and there is lack of clarity on its use in biomedical applications. The development of standardized test protocols, biocompatibility testing methods and the evaluation of degradation kinetics is necessary for clinical translation. Additionally, harmonization of regulation among geographies could aid market growth and innovation speed (Voelker, 2018).

## 9.0 FUTURE CHALLENGES AND RESEARCH DIRECTIONS

### 9.1. Balancing Printability with Biodegradability

Future materials have to strike a balance in the processing demands and biodegradability. Innovative strategies are dynamic chemistry and molecular engineering to develop materials with tunable thermal stability and meltability while preserving environmental degradability. Nevertheless, they need to be carefully optimized due to the plasticizers, chain extender and secondary polymeric phase should be incorporated in PU materials for avoiding the formation of persistent degradation by-products (Olonisakin et al., 2025).

### 9.2. Improving Mechanical Strength

Enhancements in the mechanical performance are still needed for load-bearing applications such as implants of orthopedic and structural devices. Hierarchical and superposed reinforce strategy for all scales, micro-, nano- and molecular-scale reinforcements, is the most promising one in having a chance to work toward traditional metallic strength/weight ratio while it also has simultaneous biodegradability. Further property enhancements might be achieved by in situ crosslinking upon deposition and post-deposition cure methods (Chaudhari et al., 2025).

### 9.3. Scalability and Industrial Adoption

The translation of such findings in the laboratory into larger scale industrial processes has been limited by the absence of such durable, fast processing equipment with reduced thermal history which demonstrates enhanced consistency. In a thermal point of view and for the versatility of materials, systems working with pellet as material source is more convenient than working from preformed filaments but precision issues are still to be solved. Integration of AI-based DI and real time quality monitoring as a part of Industry 4.0 technologies (Sadhya et al., 2022), would enhance the industrial adoption.

### 9.4. Integration with Circular Economy Models

The closed loop recycling networks of 3D printed compostable polymer are crucial for the sustainability in manufacturing. Chemical recycling strategies allow to fully depolymerize the monomers and such techniques ensure processes that can be inserted in a real circular economy approach, but both still need to be upscaled and present high investment costs, as well as process adaptation (Cruz Sanchez et al., 2020).

### 9.5. Standardization and Testing Protocols

Absence of universally-adopted testing protocols and performance guidelines in the market also hinder market growth, discouraging clinical translation. It is also important to develop worldwide standards in the area of biodegradation assessment, mechanical property evaluation and biocompatibility testing procedures for the regulatory jurisdictions that would facilitate open-innovation, as well as market expansion (Gujjar et al., 2025).

## 10.0 CONCLUSION

Three-dimensional printing techniques of biodegradable polymers have been developed as a disruptive technology with great potential to revolutionize the way we manufacture and deploy devices for sustainable manufacturing and health-care. Material science, process optimization and hybrid processes Recent developments in material engineering and manufacturing have increased the technical possibilities extensively. PLA and PCL continue to lead the way in commercial dominance, but new PHAs and natural polymer hybrids are providing superior sustainability and bioactivity properties. Issues as thermal degradation, structural integrity and mechanical anisotropy have been considerably tackled through methodical parameter optimization; however trade-offs between printability and biodegradability are still in place. The versatility of the technology is also demonstrated by its applications in areas as diverse as tissue engineering, drug delivery, sustainable packaging and water purification. The conventional and future scenarios of circular economy integration models, emerging nanocomposites, smart stimuli-responsive materials placed 3D printing of biodegradable polymers as a centre piece in “next generation manufacturing models” towards 21st century. Its potential is theoretically maximal, but further researches are required for the enhancement of mechanical properties, industrial scalability and regulatory structure framework, determination of standardization guideline.

Interdisciplinary work that cuts across materials science, biomedical engineering, manufacturing technology and regulatory affairs requires investment to enable the UK develop independent capacity. Furthermore, the establishment of circular economy recycling chain and unified international standards will help expand the markets, environment and society benefits. 3D printing based on biodegradable polymer is a promise to change the production mode from a novelty approach to an industrial way and a resolution for some environmental sustainable issues.

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