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# Biodegradable Filament for Three-Dimensional Printing Process: A Review

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## Abstract

Three-dimensional (3D) printing is a transformative fabrication process that allows 3D objects to be formed by the layer deposition of the materials. At present, a fused deposition modeling 3D printer uses non-biodegradable materials to fabricate the filament for 3D printing. The innovative manufacturing strategies and possibilities accelerated the use of different kinds of biological materials in 3D printing or additive manufacturing. A lot of research has taken place on the development of biofilaments to replace modern/classic plastic filaments to mitigate the issue of sustainability. Moreover, the use of biofilament will reduce the cost of the filament which limits the use of a petroleum-based filament. This paper analyses the development of various 3D printing biofilaments and their fabrication process reported in the different literature.

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## 1. Introduction

The world demand for three-dimensional (3D) printing is rising quite quickly and will continue to develop in the coming decades. It is an evolving technology used in numerous fields, including aerospace, automotive, research, medical & healthcare, construction & architecture, food, and fashion industries.[1-4] The unique benefits of 3D printing include freeform processing, viable as well as effective production, and shorter time from concept to manufacturing than in conventional or subtractive manufacturing. The fast, flexible, cost-effective and often used 3D printing technology that makes a complicated component simpler and quicker in the additive production process is fused deposition modeling (FDM) or fuse filament fabrication (FFF).[5] FDM is a 3D printing process that facilitates to produce the objects from digital 3D model data layer-by-layer. FDM and 3D printing have gained popularity in recent years due to their high speed and low-cost process to manufacture parts of complex shapes and geometry.[5] It is the most commonly utilized additive manufacturing (AM) process which utilizes varied ranges of materials from neat thermoplastics to composites and even biocomposites.[6] A thermoplastic filament is well-formed, which is heated into the state of semi-liquid and then squeezed out on the build platform via a nozzle in FDM. The deposited layers solidify after fusing to produce the finished product needed.[7,8]

The market demand for 3D printing filament is estimated to reach up to Unites States dollars 1,865.2 million by 2027 at an 18.8% annual compound growth rate between 2020 and 2027. Filaments made of plastic led the industry of 3D printing filament in 2019 with an equity of 60.4%. The growth can be attributed to the high demand for 3D printing filament.[9] Maintaining applications of design prototyping and connectivity in the defense & aerospace industry are the main determinants of the 3D printing filament sector. Acrylonitrile butadiene styrene (ABS),[10] ethylene vinyl acetate,[11] polylactic acid (PLA),[12] and polyamides[13] are thermoplastic materials that are usually used for the production of FDM filaments. Not all FDM filaments are environmentally favorable, due to their release of toxic compounds during the printing process, and end up resulting in a harmful impact on health and the environment, as they are derived from petroleum.[14,15]

ABS polymer is considered one of the most common materials that are widely used as filaments in AM.[16] It comprises the combination of acrylonitrile, butadiene, and

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styrene monomers to form a single polymer with great mechanical performance, ease of print, and strong durability, but elasticity modulus and hardness are higher.[16] PLA is considered one of the most popular inexpensive with high modulus and strength thermoplastic polymers. It has a low melting point and requires lesser energy in 3D printing.[17] It is popularly used in many applications in the industry including AM due to its renewability and biodegradability. It also does not release any unwanted gases or unpleasant smells during the process.[18]

As we know, plastic is already contaminating vast land and ocean tracts. In addition, the increase in ownership of low-cost FDM 3D printing customers is triggering the danger of booming plastic waste further. Massive adoption of consumer 3D printers could gradually displace and replace some cheap plastic waste. Since under normal environmental conditions majority of them are non-biodegradable. This plastic waste accumulation posed a significant environmental and wildlife threat. Home and industrial waste dispersal pollute the soil, and this is primarily due to human activity. To address the problems described above, research in biofilament production for FDM thus draws much attention. It also brings down filament prices and also contributes to minimizing petroleum-derived plastics utilization. Although, many reviews were reported on biomaterials the majority of them are on biomedical applications.[19-23] This article reviews the literature on biofilaments of various polymers and their blends. Future scope and conclusions are detailed at the end of the article.

## 2. Biodegradability of polymers

Biodegradable polymers can be categorized based on their application, economic importance, processing method, origin, chemical composition, synthesis method, *etc*. In this study, they are categorized according to their origin into three groups—natural biodegradable, semi-synthetic, and synthetic as shown in Fig. 1. Natural biodegradable polymers are obtained from natural resources, semi-synthetic polymers are designed to be biodegradable and synthetic polymers are non-biodegradable produced from oil. Examples of the first type are starch, chitosan, cellulose, and protein; the second type is microbial polymers (polyhydroxyalkanoate (PHA), cellulose), synthetic polymers from monomers (PLA, polyglycolic acid (PGA), polybutylene succinate (PBS)); for the third type are polyvinyl alcohol (PVA), aliphatic and aromatic polyesters (polybutylene adipate terephthalate (PBAT), PBS, polycaprolactone (PCL), poly trimethylene terephthalate (PTT)).

Since the day of their invention, plastics are commonly been used for manufacturing and life, due to their extraordinary properties of lightness, toughness, low cost, and resilience. Global plastics production including thermosets, thermoplastics, elastomers, polyurethanes, polypropylene fibers, sealants, coatings, and adhesives hit nearly 350 million tonnes, in the case of Europe alone, it was 64 million tonnes.[24] Bioplastics (including biodegradable and bio-based plastics) account for less than 1% of the plastics manufactured annually. In 2018, 43% of biodegradable plastics were produced in about 2.11 million tonnes of bioplastics and 57% of non-biodegradable/bio-based plastics, respectively. Eventually, the global manufacturing capacity of bioplastics is anticipated to rise to 2.62 million tonnes by 2023.[25,26] The paper[26] presented the various technological approaches to processing industrial plastics.

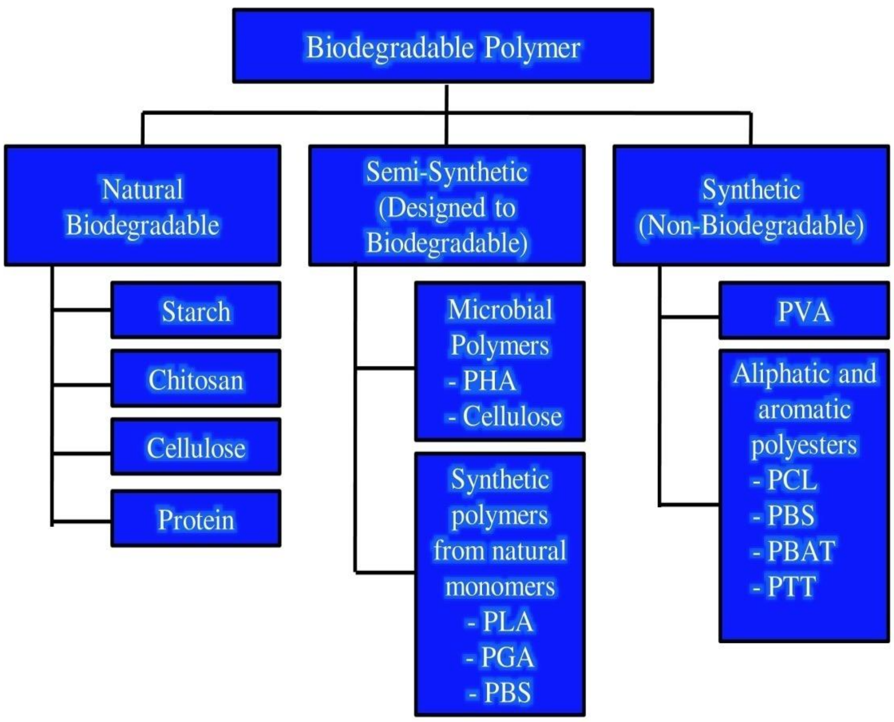


**Fig. 1** Classification of biodegradable polymers.

 

Biodegradation has two stages: Fragmentation and mineralization.[25] Polymer chains under pressure, moisture, single light, and/or enzymes will be reduced and weakened resulting in the fragmentation of plastic content. The microbial community allowing full assimilation in the disposal environment of plastic fragments is mineralization. Complete biodegradation is required for a plastic product to view as biodegradable (both fragmentation and mineralization).[25] Potential environmental threats may occur until plastic fragments are thoroughly assimilated within a comparatively short time by the microbial communities in the disposal system.[27,28] There is a widespread (false) conviction that anything produced from biomass will be biodegradable too. The inclusion of bio-feedstocks, however, may not inherently contribute to a biodegradable end product. There are non-bio-based biodegradable plastics (*e.g.*, PCL-fossil-based) and bio-based plastics (*e.g.*, polyethylene (PE)) that are non-biodegradable. Many biodegradable polymers are developed by researchers to address the sustainability issue of 3D printing.[29]

## 3. Bio-filaments

### 3.1 Bio-filaments using polymers

Owing to numerous environmental factors, substantial attention has been paid to the production and implementation of biodegradable or bio-based polymers. Numerous properties of biodegradable polymers are, although, not so strong as a traditional polymer material, including mechanical and thermal properties for 3D printing.[25] Although PLA is known for its biodegradability over some time, at room temperature and pressure, PLA takes even longer time to degrade. PLA lasts for several years in a normal room. Sunlight does not accelerate biological decay (excluding heat), and ultraviolet light only allows the substance to shed its color and become pale. This is evident that PLA needs circumstances that are not in the daily world in which we live to degrade in nature. Due to this various biodegradable polymers including PLA are also considered to develop for 3D printing such as PHA, hydroxypropyl methylcellulose (HPMC), polybutylene succinateran adipate (PBSA), and PBS.[21] Few researchers adopted these biodegradable polymers to develop biofilaments.[30]

The rheological and thermal features of PBS and PBSA are associated with the performance of both samples in 3D printing by the FFF method. Excellent filaments are obtained for both polymers, which is compatible with the rheological results.[31] The effect of the number of layers on thermal, molecular weight properties, and mechanical and the relationship among them are investigated.[32] The PLA, impact PLA Grey, and HD PLA Green are used[33] to examine tensile properties. The tensile strengths of PLA, impact PLA Grey, and HD PLA Green are 51.01, 33.88, and 46.22 MPa respectively. The results obtained of PLA are in the same range while impact PLA Grey and HD PLA Green have lower values. Semisolid tablets of theophylline with varying drug loading in the range of 75–125 mg are manufactured in association with HPMC K4M or E4M hydrogels by Cheng and coworkers, who used the technique of extrusion-based semisolid 3D printing. The hydrogel with high excipient concentration is found to have relatively high yield stress, hardness, and storage modulus.[34] The tensile properties of PLA material are studied with a slow strain rate.[35] Improved tensile with good elongation properties at break is obtained for PLA samples. PHA filling into PLA exhibited significant losses in elongation at break, which is associated with the embrittlement behavior of the samples. The surface of the printed PLA samples under the simulated marine condition showed no degradation. The 3D printing of biofilaments that are made of biodegradable polymers with process parameters and the key findings of the literature is provided in Table 1.

### 3.2 Bio-filaments using composites

Similar to biodegradable polymers, major research is also focused on biofilaments with polymer composites. Various polymer composites are being developed by researchers to attain the requirement of the biodegradability of 3D printing filaments. Various raw materials like soy protein and cocoa shell waste are reinforced with different polymers and plasticizers to evaluate their potential to use as biofilaments for 3D printing. The incorporation of such bio fillers into these polymers improves the importance of bio fillers and also minimizes the utilization of petroleum-based polymers. Fig. 2 shows the composite extruded biofilament using cellulose nanofibrils (CNF) powder and the 3D printed specimen printing using it.

Biocomposite filaments for FDM 3D printing are developed using CNF and PLA.[36] The results demonstrated that CNF enhanced the thermal stability of these composites and provided a new potential for the high-value utilization of CNF in 3D printing in consumer product applications. Different physical strengthening methods are studied[37] to increase the mechanical properties of soy protein-based bioplastics without worsening their functional properties and assess the reinforcement of soy protein-based bioplastics. PLA/316L composite scaffolds with stainless steel particle contents from 5 vol% to 15 vol% using the FFF process are fabricated and studied.[38] The results demonstrated that the dimensional accuracy is enhanced and yielded a lower coefficient of thermal expansion than pure PLA. A new type of eco-friendly polyhydroxy butyrate (PHB)/PLA/plasticizers blends is created.[39] The addition of appropriate plasticizers into neat PHB/PLA blends has improved the poor mechanical properties of neat PHB/PLA blends. The innovative and fully biodegradable filament development for FDM is investigated.[40] Poly-L-Lactid Acid (PLLA), PLLA/ PBS 50/50%-wt, and PBAT polymer matrices are tested and a filler content of 30-wt% is obtained using flax shives with PBAT.

A fully biodegradable polymeric composite filament by combining PLA with PCL is investigated, produced, and tested.[41] The results demonstrated that the diameter and

 

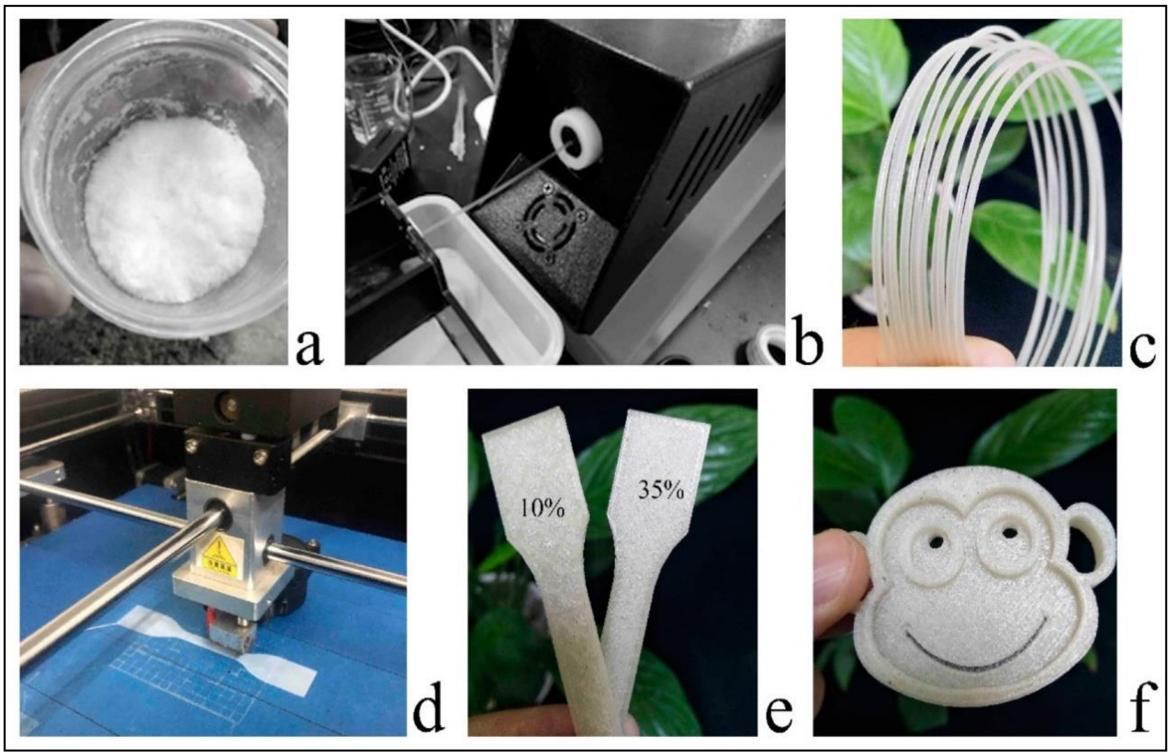


**Fig. 2** (a) CNF powder; (b) Extruding composite biofilament; (c) Extruded composite biofilament; (d) FDM printing using composite biofilament; (e) 35% and 10% infill 3D-printed samples; (f) Monkey face 3D-printed sample, reproduced from [36], open access article distributed under the Creative Commons Attribution License, Copyright 1996-2021 MDPI (Basel, Switzerland).

**Table 1**. Polymer biofilaments printing process and their key findings.

| S. No | Polymers | 3D Printer | 3D printing Parameters | Key findings | Ref. |
|---|---|---|---|---|---|
| 1 | PBS and PBSA | TUMAKER Voladora V1 FFF machine | LH = 0.3 mm, ID = 100 % and Infill pattern = rectilinear 0°, Orientation = on-edge build. | Excellent filaments are obtained using PBS and PBSA polymers. PBS is noticed with troubling warpage phenomenon, but PBSA demonstrates outstanding FFF viability | [31] |
| 2 | PLA | Ultimaker3 system | BT = 60 °C, ET = 210 °C, Raster Angle = 0º to the x-direction, PS = 80 mm/s, Layer Thickness = 0.1 mm, Line Width = 0.36 mm, ND = 0.4 mm | Prerequisite work is provided for the degradation studies mostly for medical applications, which require specific process parameters for biodegradable PLA in FDM. | [32] |
| 3 | Impact PLA Gray, HD PLA Green, and PLA | Raise3D Pro2 PLUS equipment | NT (°C) = 220/215/220, BT (°C) = 60/65/65 | Biodegradability PLA has shown higher rigidity and strength than ABS | [33] |
| 4 | HPMC K4M | Velleman K8200 3D printer | Extrusion Multilayer = 0.05, PS = 5 mm/s, ND = 0.437 mm, Number of layers = 12 | Environmentally friendly K4M HPMC Hydrogel demonstrated excellent printable capability with an FDM 3D printer. | [34] |
| 5 | PLA and PLA-PHA | Leapfrog Creatr HS printer | PLA/40% PD, PLA/80% PD, PLA-PHA/40% PD, PLA-PHA/80% PD | Parameters like the ratio of wet/dry periods, overall crystallinity, and surface roughness are very important to accelerate the degradation rate of biodegradable marine structures. | [35] |

**Nomenclature:** PS-Printing Speed, ND-Nozzle Diameter, NT-Nozzle Temperature, BT-Bed Temperature, LH-Layer Height, ID-Infill Density, NS-Nozzle Size, ET-Extruder temperature, PD- Printing Density.

 

ultimate tensile stress gradually reduced with the increase of PCL content, whereas the surface roughness gradually improved. The optimal comprehensive performance is exhibited on the printed parts with the addition of 20% of PCL composite filament. PLA-hydroxyapatite-chitosan (PLA-HAp-CS) based composite material is utilized for the manufacture of biodegradable and biocompatible feedstock filament using the twin-screw extrusion process.[42] The feedstock filament of these composites can be utilized in FDM open-source 3D printers.

The mechanical performance of biocompatible and biodegradable WS2 inorganic nanotubes in PLA and its dispersion through melt-extruded filaments is created and first demonstrated.[43] Then, this filament is processed by the FFF 3D printer, and the morphology and its characteristics before and after printing are compared. The printing process enhanced the dispersion of WS2- inorganic nanotubes in the PLA filament. The multifactor optimization for the development of biodegradable and biocompatible composite material-based feedstock filament of FDM is presented.[44] The optimization results are supported by mechanical tensile testing, thermal analysis, and scanning electron microscope-based photomicrographs.

Biofilaments based on cocoa shell waste and PCL employing a single-screw extruder is prepared.[5] Scanning electron microscopy results demonstrated that micronized cocoa shell waste is homogeneously dispersed in the polymer during the extrusion process and can be utilized in the 3D printing of various objects. The identification of an appropriate biomaterial for support structures that will get rid of the challenges of toxic waste generated and poor dissolvability by the current material is presented.[45] Three biodegradable cellulose derivatives—methylcellulose (MC) A4M, HPMC K4M, and HPMC E4M with different degrees of substitution of hydroxyl group are utilized. MC and HPMC biopolymers used as support material in the material extrusion process for 3D printing help in moving closer towards sustainable manufacturing.

The mechanical properties, biodegradability, and fabrication of 3D printing filaments of composite materials are assessed.[46] These composite materials are prepared by using coupling agent-treated palm fiber and maleic anhydride-grafted PHA, which showed better tensile strength and interfacial adhesion than PHA/palm fiber. The PBAT is added to PLA as a toughening agent and ethylene-methyl acrylate-glycidyl methacrylate terpolymer to enhance interfacial adhesion with hemp fiber flour.[47]

The 3D printed biocomposite scaffolds obtained from PLA/PBAT-immobilized biomass of chlorella pyrenoidosa are utilized to develop the biosorption process for the removal of methylene blue (MB). The findings denote that the PLA/PBAT-immobilized biomass of chlorella pyrenoidosa is a promising material for dye removal.[48] Table 2 provides a summary of the various raw materials and their composites along with their parameters of printing.

**Table 2**. Composite-based biofilaments compositions, printing process, and their key findings.

| Sr. No. | Filament | Composition | Printer Parameters | Printer | Key findings | Ref. |
|---|---|---|---|---|---|---|
| 1 | Soy protein isolate, glycerol | Mass ratio = 1:1 | Post-injection pressure = 200 bar for 300 s, injected for 20 s at 500 bar, Mold and cylinder temperature = 70 and 40 °C, | Thermo Haake Mini Jet Piston Injection Molding System II (Germany) | The ability of soya protein-based injection molded bioplastics to replace traditional plastics is demonstrated. | [37] |
| 2 | PLA pellets, 316 L Stainless Steel Powder | Pure PLA, PLA/316L 5%, PLA/316L 10%, and PLA/316L 15% | NT = 205 °C; BT = 70 °C; PS = 60 mm/s; LH = 0.2 mm; ID = 50 %; NS = 0.5 mm | Desktop 3D printer (TAZ 6, Lulzbot Corp., Colorado, USA) | No major degradation rate variations between PLA/316L composite and PLA scaffolds were observed in in-vitro degradation studies. | [38] |
| 3 | PLA, PHB, plasticizer blends | PHB = 60 wt %, PLA = 25 wt %, Plasticizer blends = 15 wt %) | At 190 °C the dogbones were printed without external bed heat and air conditioning under the ambient conditions. | PRUSA i3 MK2 3D printer | The thermophilic disintegration of the PHB/PLA/plasticizer samples lasted 65 days. | [39] |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | CNF, Virgin PLA, Polyethylene Glycol (PEG) 600 | PLA/PEG/CNF 5 wt.%, PLA/PEG/CNF 2.5 wt.%, PLA/PEG/CNF 1 wt.%, PLA/PEG, Virgin PLA | ND = 0.4 mm. ET = 210 °C, PS = 40 mm/s. | M3036 FDM desktop 3D printer | The composite filament, with 2.5 wt % of CNF content, is shown to satisfy desktop FDM 3D printing requirements. | [36] |
| 5 | Flax fiber, PLLA, PBAT, and PBS | PLLA-10%-wt flax fibers, PLLA/PBS 50/50-10%-wt flax fibers, PLLA/PBS 50/50-10%-wt flax shives, and PBATflaxfibres at 10, 20 and 30%-wt | ET (PLLA & PBAT composites) = 190 °C and 150 °C, PS (for all blends) = 0.8 1.5 m $min^{-1}$, Z amplitude = 0.6–1.0 mm, PST = 70 °C. | Prusa i3 Rework 3D printer | Reinforced 3D printed components of flax fibers and shives show promising results, demonstrating their ability for completely biodegradable filaments to be successfully produced. | [40] |
| 6 | PLA, Lignin | PLA wt.%/ Lignin wt.% = 95/(5, 10, 15, 20%) | ET = 205 °C, IP = Rectilinear, IA = 90°, ID = 100% | Zmorph 2.0 S | The composition with 5 wt.% lignin content is suitable to develop 3D-printed filament | [18] |
| 7 | PLA, PCL | PLA/PCL: 100/0, 90/10, 80/20, 70/30, 60/40 | PCL% /ET (°C) = 0/220, 10/220, 20/210, 30/210, 40/200, Build layer = 0.1mm, PS = 60 mm/s, Filling rates = 100% | Makerpi-M2030 FDM 3D printer | The printed parts were found to demonstrate the optimum detailed efficiency with the inclusion of 20 percent PCL composite filament. | [32] |
| 8 | PLA-HAp-CS | PHA 84%- HAp 4%- CS 12%, PHA 80%- HAp 8%-CS 12%), PLA 91%- HAp 8%-CS 1%, PHA 90%-HAp 8%- CS 2% | NA | NA | The composite PLA 91% -HAp 8%-CS1% is ideally suited for the production of biocompatible/biodegradable feedstock filament. | [42] |
| 9 | PLA, PLA/$WS_2$ inorganic nanotubes | PLA/ $WS_2$ inorganic nanotubes 0.5 wt% | Brass ND = 0.4 mm, Platform temperature = 55 °C, PS = 60 mm/s, LH = 0.15 mm, PT = 205 °C | Sigma R19 FFF printer | The findings demonstrate the advantages and printing flexibility of the PLA/$WS_2$ inorganic nanotubes composite printed FFF. | [43] |
| 10 | PLA-HAp-CS | PLA 91%–HA 8%–CS 1%, PLA 90%–HA 8%–CS 2% | NA | NA | Based on the cell growth point of view, the composite PLA 91% -HAp 8%-CS1% is ideally suited for the production of biocompatible/biodegradable feedstock filament. | [44] |

 

**Continued**

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | PCL, Micronized cocoa shell waste | PCL/Micronized cocoa shell waste powder 30wt % | LH = 300 μm, Resolution = 30% of in-fll density, Printing bed temperature = room-temperature, PS = 50 mm s−1 | Prusa i3 Hephestos | This research reveals that the principle of food/plant waste valorization is efficient to produce cost-effective, environmentally sustainable material for applications such as additive manufacturing. | [5] |
| 12 | MC A4M, HPMC K4M, HPMC E4M | DS of methoxyl groups for HPMC K4M, HPMC E4M, and MC A4M: 19-24%, 28-30%, 27.5-31.5%. DS of the hydroxypropyl group for K4M and E4M: 4-12% and 7-12%. | PS: 5 mm/s; ND: 0.437 mm | Customized Dual-Extruder 3D Printer | Support structures are successfully 3D Printed at 12% w/v hydrogels of MC A4M and HPMC K4M hydrogels. | [45] |

**Nomenclature:** PS - Printing Speed, ND -Nozzle Diameter, NT- Nozzle Temperature, BT- Bed Temperature, LH-Layer Height, ID-Infill Density, NS-Nozzle Size, ET-Extruder temperature, PST-Printing surface temperature.

### 3.3 Filament fabrication

The filament is an integral part of additive production: it is FDM 3D printing's 'food supply. The number of available filaments has also increased as the industry. Table 3 represents the summary of various filament materials, filament extruders, and their extruded diameters.

## 4. Conclusions and future scope

3D printing is a transformative fabrication process that allows 3D objects to be formed by the layer deposition of the materials. The 3D printing employs Fused Deposition Modeling (FDM) facilitates fast prototyping and manufacture

**Table 3**. Filament extrusion extruders and their materials with final biofilament diameters.

| No. | Filament material | Filament Extruders | Filament Diameter | Ref |
|---|---|---|---|---|
| 1 | PBS and PBSA | Collin Teach-line ZK-25 twin-screw co-rotating extruder | 1.75 mm | [31] |
| 2 | PLA/316L | Single-screw extruder (EX2, FilaBotCorp., Barre, VT, USA) | 2.85±0.15 mm | [38] |
| 3 | PHB/PLA/plasticizer blends | Single screw extruder HAAKETM Rheomex OS (Haake Technik GmbH, Vreden, Germany) | 1.75 mm | [39] |
| 4 | PLA/PEG600/CNF | Wellzoom desktop single screw extruder | 1.75 ± 0.05 mm | [38] |
| 5 | Flax fiber, PLLA, PBAT, PBS | Single-screw Scamex extruder | 2.85 ± 0.1 mm | [40] |
| 6 | PLA/Lignin | Boston-Mathews single-screw extruder | 1.78 ± 0.04 | [18] |
| 7 | PLA/PCL blends | Wellzoom-B desktop extruder | 1.75± 0.1 mm | [41] |
| 8 | PLA-HAp-CS | HAAKE Mini CTW, Germany | 1.86 | [42] |
| 9 | PLA/$WS_2$ inorganic nanotubes | EUROLAB Digital 16 'Prism' | 2.85 mm | [43] |
| 10 | PLA-HAp-CS | HAAKE Mini CTW, Germany | 1.86 ± 0.05 | [44] |
| 11 | Micronized cocoa shell waste and PCL | Single-screw Rheoscam extruder | 1.75 mm | [5] |
| 12 | maleic anhydride-grafted PHA and Coupling agent-treated palm fiber | Model TUSe194T; Atlas Electric Devices Company, Chicago, IL, USA | 1.75 ± 0.05 mm | [46] |

of parts with complex geometries. But the materials appropriate for FDM 3D printing are petroleum-based and non-degradable polymers. The innovative manufacturing strategies and possibilities accelerated the use of biodegradable materials to fabricate the filament for 3D printing (or) Additive Manufacturing. The use of biofilament reduces the cost and use of a petroleum-based filament. The printed components of biodegradable plastics can also be recycled to make new filaments or by composting. This review paper analyzed the development and fabrication process of various 3D printing biofilaments of various polymers in the literature.

Biodegradable polymers have lower mechanical properties and limited life cycles. The biofilaments with tailor-made properties can be developed from composite materials using different fibers and fillers along with biopolymers which can be produced with a mixture of polymers and many other raw materials utilizing plasticizers for 3D printing. The different varieties of biofilaments can be made available worldwide to supplement the existing petroleum-based non-biodegradable filaments by the use of biopolymers and their composites and blends. So, further development, fabrication, and testing of 3D printing filaments are required to enhance the mechanical properties and composite.

The object manufactured by biodegradable filaments requires considering the environmental conditions such as temperature, UV radiation, and exposure that can negatively affect the filament extrusion or the swelling of components. The different types of micro-organisms significantly contribute to various phenomena which include plastic depletion in the natural world. The interface of such micro-organisms may offer insight into future work on plastic biodegradation which may directly help in the development of biofilaments.

Regardless of much research and development on biodegradable filaments for 3D printing, they are not widely accepted by industries due to their lower mechanical strength, poor dimensional accuracy according to design specifications, and poor layer adhesion. These problems need to be overcome in order to accept biodegradable filaments widely. The development of recycling approaches for biodegradable materials is therefore going to be necessary if they become high-volume production materials.

## Conflict of interest

There are no conflicts to declare.

## Supporting information

Not applicable.

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