




Research Article

Hybrid Novel Additive Manufacturing for Sustainable Usage of Waste

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Additive manufacturing (AM) encompasses many forms of technologies and materials as 3D printing is being used in almost all industries. The variety of materials used includes but is not limited to plastics, ceramics, resins, metals, sand, textiles, biomaterials, glass, and food. Currently, in 3D printing technology, the printing mode of direct writing forming is widely applied. The raw material used is ceramic powder, and the direct writing forming of the ceramic could be applied to various fields of materials, chemistry, chemical engineering, and the like. This work is aimed at printing the nanopowder of nonsegregated waste into conventional components. The work is related to a system for converting nonsegregated waste material into the synthesized dough, comprising of a chamber, an ultraviolet (UV) disinfectant unit, a shedder, and a storage unit. The nonsegregated waste material is stored inside the chamber which dispenses the nonsegregated waste material into the UV disinfectant unit; said UV disinfectant unit removes the harmful germs and water content in the nonsegregated waste material to form solid waste. The disinfected solid waste enters the shedder which powders the solid waste. The powdered solid waste is stored in the storage unit. The powdered solid waste is mixed with components in a mixer to form a synthesized dough. The synthesized dough as the printable source is sent to a 3D printer which prints desired final component. The hardness value obtained for the printed component is 70 Brinell hardness units.

1. Introduction

The major problem faced by today's world is the reuse of waste material as such (without segregating it). So, this proposed work focuses on collecting and disinfecting the waste

material, making it a 3D printer's resource material without any waste material being left out (complete conversion—zero waste). The proposed work comprises of continuous conveyor system wherein it is the stage by stage processing of materials that leads to the complete conversion of waste into

useful products. The core objective is the complete conversion of waste into useful products without polluting the vicinity by any means.

Acrylonitrile butadiene styrene (ABS) is among the most common 3D printing filaments as well as another very common E-waste plastic. ABS is still not usually handled by governmental programs. Thereby, ABS might be a strong contender in the distributed recycling for AM (DRAM) approach, which could boost recyclability by giving clients a financial reason to recycle more frequently. In order to manufacture 3D printing filament as well as printed parts in both North America along with Australia using ABS E-waste, this research is aimed at investigating the importance of such ABS E-waste sources as well as methodologies. E-waste has been converted into 3D printer filament using two open-source extruder systems. The quality of this filament was evaluated using standard tensile as well as compression testing. Findings show the potential of E-waste ABS recycling for consumer and industrial applications, with a small reduction in mechanical properties. Researchers also showed that DRAM can considerably lower the price of 3D printer filament, but the carbon emissions from transformation highlighted the necessity of improving technological effectiveness in electricity generation between countries. As a result of the varying characteristics of ABS E-waste, appropriate labeling of materials is needed to advance recycling [1].

3D printing had already become increasingly popular in a variety of industrial sectors as the technology continues to advance. There are increasing amounts of consumables, waste as well as pollution being produced by 3D printing, which seems to have a negative impact on the environment. The fuzzy PID methodology is used to melt, shape, and wire different kinds of 3D printing essential items at various temperatures using this framework, which is premised on a monomicrocomputer. Waste from 3D printing can be recycled as well as print replacement parts effectively, reducing pollution as well as printing costs [2].

With the advancement of emerging technologies, 3-dimensional printers presently hold a significant position in a plethora of fields. The filament is one of the raw resources used by 3D printers which provide layered manufacturing. These printers have various raw material requisites. In comparison to other raw materials, filament is the favored raw material for a 3-dimensional printing machine. It is possible that the additive manufacturing process device will print incorrectly or will print something other than what was intended. It is critical that the printed materials can be recycled. Reusable filament for layered fabrication is at the heart of this project. Mechanical, electronic, and software methods have been used to establish a device that produced filaments with said appropriate size using a structure that included crushers, extrusion equipment, and water cooling units, as well as air cooling units [3]. Many university library maker areas are now offering 3D printing solutions. Waste can always be generated by both failed prints as well as the printing method itself. The viability of recycling and disposal 3D plastic as well as repurposing it as a new 3D printer filament has been investigated and eval-

uated thanks to a grant out of a regional academic library conglomerate. Others on campus have inquired about recycling or donating their 3D printers' waste filaments. In such an attempt to promote 3D printing as more environmentally friendly, we will examine the process, advantages, and drawbacks of reusing 3D printing filament [4].

For a broad spectrum of application domains, plastics' chemical and mechanical properties make them an excellent choice. Sadly, the nondegradability of plastic waste poses a major threat to the ecological environment [5–7]. On a global scale, recycling rates for plastic packaging are still low (around 14 percent) [8]. There is only a 32.5 wt percent recycling rate in Europe, where environmental stewardship is more prevalent. Although such figures are based on accumulated plastic waste, they do not represent the cumulative percentage of plastic garbage in circulation [9]. The European Plastics there in circular economy (CE) strategy is gaining traction in the policy as well as business discussions surrounding the viable progress of industrial manufacturing in order to combat this waste accumulation problem [10, 11]. The current concept of “take, make, dispose of” (linear economy) and its harmful impacts on depletion of natural resources, generation of waste, species extinction, contamination (soil, air, and water), and nonsustainable economic history seem to be the focus of CE [12]. CE is aimed at addressing this issue head-on. One of the most important aspects of incorporating CE into the plastics value chain is the verification of waste plastics as secondary raw materials (technical, economic, and legal) [13]. Open as well as closed recycling methodologies and also functional strategies to upcycling as well as downcycling can provide avenues for validating secondary raw materials [14].

Additive manufacturing (AM), as well known as 3D printing, has become increasingly important in the transformation from the sequential to the circular economy because of its direct production capacities. As a result of their capabilities to modify a mathematical method into points, lines, or areas of material to create a three-dimensional part, AM technologies are likely to revolutionize the manufacturing process [15–17]. Increased customer value, as well as the potential for disruption, has been generated by the expiration of its first patents [18, 19]. There will be a USD 23.33 billion global market for additive manufacturing in 2026 [20]. Traditional methods of production, on the other hand, have a hard time figuring out when as well as how to take benefit of the advantages. Product development could shift from conventional stage modeling techniques to iterative, agile methodologies by 2030, according to Jiang et al. [16].

AM can already be used to make a huge number of products, which has implications for global value chains in terms of geographic spread and density [21]. Since multimaterial and integrated functionality (e.g., electronics) can be produced to a large extent with AM printable products, it is anticipated that their reach would be somewhat significantly larger in the years ahead. Furthermore, on-site manufacturing of spare parts can change suppliers' roles in production lines [22]. Decentralized production types range from dispersed functionality to cloud manufacturing, according to Matt et al. Due to AM's ability to decentralize production

to locations near customers or, in the greatest extreme dispersed scenario, at the customer's premises [23–25], there is a need for transport that will be much more cautiously considered. AM technology also reduces market entry barriers, reduces capital requirements, and achieves an efficient minimal level production level to publicize dispersed, flexible production [26]; owing to this, the products can be tailored to meet the needs of specific niches or even individuals, rather than relying on economies of scale or scope [27, 28]. Because of these explanations, AM technique might lead to a transition in production from worldwide to local infrastructure. The industry and academia, as well as academic institutions, are working hard to move AM techniques away from rapid prototyping as well as tooling and toward direct digital manufacturing (DDM) [29, 30], which will have positive effects on the environment and society in general. It was found that the deployment of AM techniques in various industries was not primarily influenced by their environmental or social benefits, as demonstrated by Niaki et al. ([31]. When it comes to AM implementation, only the financial aspect is relevant, with expense and time savings being the most important factors to keep in mind.

AM's potential on CE is still being explored. Understanding the contributions and obstacles to integrating AM progress with CE requirements is critical. For the purposes of this discussion, we will focus on the potential of AM for plastic garbage concerns [32]. The sustainable development of AM requires to be taken into consideration at an early stage, as the technology's spread is expected to continue there in years ahead. If AM can be used to promote in situ recycling in conjunction with widely dispersed consumer waste, it could reduce transport services [33] as well as the ecological consequences of strenuous resource exploitation while also making it possible for using regional raw material distribution networks [9]. AM can thus have been seen as a reuse method to recycle thermoplastic wastages as well as impact the framework of material delivery to optimize resource utilization efficiency. Although the open-source technique would be a crucial factor there in the regional recycling method [33, 34], it is not the only factor. However, for additive manufacturing to progress, a deeper knowledge of the reuse chain is required. When it comes to dispersed reprocessing or through DRAM, there are a number of questions to be answered. There are a number of steps that must be taken to turn plastic waste into supplementary raw substances for additive manufacturing (AM). As a result, the research presented here is a comprehensive review of the existing literature. Which additive production methods for thermoplastic recycling have made progress and which have been hindered? This paper's first contribution is a proposal for an AM-specific closed global recycling chain. Foremost, the published research maps out the progress made at every phase of the recycling sequence so that prospects, as well as obstacles, can be seen. CE's guiding fundamentals are often referred to as the "R framework procedures" [35–37]. Local specialties of such R framework might be implemented at the local level using AM as a driving advanced technology.

Numerous engineering implementations utilize carbon fiber-reinforced polymer (CFRP), which would be a slightly

elevated composite material made of carbon fiber and polymer [38]. Examples include wind turbine blades, airframes, and automotive components. However, the widespread use of one such substance has contributed to considerable energy as well as material usage during the manufacturing process, which also generates substantial waste. The worldwide annual demand for carbon fiber composites can be expected to approach 199 kilotons by 2022, up from the 2018 usage of 128 kilotons [39]. By 2030, Japan's CFRP recycling market is expected to be worth roughly 100 billion yen [40].

CFRP effluent is presently being discarded in landfills or burned. Carbon fibers are lost as well as carbon pollution is released as a result of their discretion, that is, environmental concerns. According to some countries, the quantities of garbage that is deposited in landfills are reduced by charging landfill taxes and encouraging material recycling, particularly for CFRP waste. In addition to reducing greenhouse gas emissions, recycling as well as reprocessing reclaimed carbon fibers (rCFs) provides a cost-effective and resource-efficient method for producing high-value carbon fibers. In most cases, the use of recycled carbon fiber (rCF) in the fabrication of new composite materials is not restricted to reclaiming carbon fiber. Both the recovery of carbon fibers from CFRP waste (i.e., the extraction of rCF from CFRP waste) as well as the manufacturing of rCF-reinforced polymer (rCFRP) (i.e., CFRP fabrication using rCF) are required to recycle CFRP [41, 42]. Carbon fiber extraction from CFRP is difficult because of the material's high corrosion resistance and inertness. Degradation of the resin and fiber extraction are just two of many methods used to recover and obtain high-performance carbon fibers from CFRP waste. It is possible to categorize these technologies into mechanical, thermolytic, and solvolytic methods. Carbon fibers have been successfully reclaimed from CFRP waste, proving the viability of many reclamation technologies [43]. In order to reuse CFRP waste, Palmer et al. used an 8 mm classification model screen as well as a movable hammer mill granulator [44].

The carbon fiber recyclization has been then divided into four grades. RCF was synthesized by heating carbon fiber-reinforced epoxy resin (CF/EP) to an elevated temperature of 800 degrees Celsius for 30 minutes, which left some left-over pyrolytic carbons upon that surface of the resin. The tensile strength deterioration of rCF was 18–36 percent [45] when Kim et al. used supercritical fluids at 405°C as well as 28 MPa to obtain rCF from CFRP. Carbon fiber has been derived from CFRP waste, but rCFs produced by such recycling techniques seem to be discontinuous, filamented, randomly and oriented and have low densities. This presents a new challenge for the industry. During CFRP production, continuous virgin carbon fibers (vCFs) are cut to the desired shape before they are recycled [46]. For continuous vCF fabrication, the current fabrication techniques are still not suitable [42]. With an efficient recycling method, carbon fibers can be restored with negligible mechanical characteristics as well as remanufactured into elevated engineering components. Wei et al. developed a method to incorporate nylon fibers into the amorphous rCF that also enhances its usefulness [47]. RCF was coated with polydopamine to improve its

dispersion in suspension, as well as a nonwoven mat has been created utilizing this technique [48]. In order to align discontinuous carbon fibers in a narrow gap between 2 parallel plates, the University of Bristol established the HiPerDiF (High-Performance Discontinuous Fiber) method. As nothing more than a result, 67% of short fibers were connected mechanical means in the dry preforms, with either a 3% range [49]. Remanufacturing mechanisms customized from conventional production mechanisms of fabric composite materials have been complicated as well as labor-intensive to manufacture rCFRP parts.

AM allows for fully automated significant forming of energy and material-efficient products and provides end-of-life remedies, as well as the selection of resource-efficient materials. Design liberty, digitization, production speed, and the reduction of waste are some of the reasons for the enhanced use of additive manufacturing [50, 51]. Although the 3D-printed thermoplastic components may possess complex geometries, their reduced mechanical properties, as well as the inability to function, are major concerns. As a result, the use of a carbon-fiber composite can help to resolve these issues [52]. To test the CFRP composite's flexural strength, modulus, and toughness, Ning et al. were using an FDM 3D printer to manufacture the component. The CFRP composite sample with 5 wt% carbon fiber content outperformed the genuine plastic sample by 11.82%, 16.82%, and 21.86%, respectively [53]. The printable composites had good electrical conductivity along with the oriented alignment of carbon fiber, as well as with volume internal resistance in the oriented alignment 6.8 times smaller than which in the direction perpendicular [54]. Huang et al. used an extrusion 3D printer to manufacture carbon fiber-filled resistive silicon rubbers. Carbon fiber has recently been shown to be an effective way to improve the effectiveness of 3D-printed components. As an outcome, the massive prices of 3D-printed elevated composite components seem to be large due to the use of carbon fiber in the AM process. The recent trend in the direct writing of the technique adapted in this work is printing of food stuffs like egg and meat, the printing of egg is successfully achieved [55], and similarly, more than 80% of conventional food is getting printed nowadays.

2. Comparison of Dough-Making Technique with Related Techniques

Table 1 shows the consolidation of existing work in dough-making process in AM which are collected from patents and other articles. From this, very few articles are selected and explained further to enable the novelty of the dough-making process. The 3D printing industry is experiencing rapid expansion. Many thermoplastic materials, which include recycled ones, can be used to make printable filaments. As a potential substitute to the current method of centrally collecting recyclable plastics, this article conducts a systematic review on the manufacturing of filaments for additive manufacturing processes using recycled polymers. The influence of processing mostly on physicochemical as well as mechanical characteristics of common thermoplastics was investigated. Widely viable filaments made from recycled

materials as well as devices that allow users to make their own filaments for 3D printing have been also examined in the study [56]. Table 2 lists and compares the existing dough-making techniques from waste plastic recycling.

Ramachandraiah reviewed and stated that in the article, they transform waste material into the dough as a printable source of 3D printing. In the extrusion process, fibrous meat food items have been deposited through a nozzle to create 3D structures of meat products. Extruders, which use a threaded conveyor or syringe structure and could still regulate temperature, hold an excellent guarantee for said 3D printing of meat food items also with required specification, despite the fact that other methodologies are still being developed. An extruder is used to create geometric 3D structures by extruding materials one layer at a time. The extrusion process, on the other hand, typically entails the utilization of semisolid mixtures, including such dough as well as chocolate. 3D-printed edibles such as dough, chocolate, and puree are now available for printing [57, 58]. Table 3 lists and compares the dough-making techniques from sustainable 3D-printed meat analogs.

In this article, they convert food waste into foodstuff. The food waste can be probably reduced in the case of 3D food printing technologies. It can be used in restaurants, buffets, hospitals, and even in houses. Where else, the instant work discloses about synthesized dough prepared from non-segregated waste material as source material for 3D printing. The nonsegregated waste material includes food, plastics, and E-waste. In D3, the food waste synthesis is preprocessed; where else in the instant work, the waste material synthesis is an in-built process and only on the specific blending improves the strength of the final product. More specifically, the system of the instant work converts entire waste material without leaving the toxic elements out [59, 60].

In this patent, they disclose an electronic waste-plastic waste recovery resource regeneration system and a method wherein electronic waste and plastic waste are alone segregated and converted into source material for 3D printers. It also discloses about recycling of plastic and E-waste using pulverizing and conveyor units, even though the 3D printing terminal of the material is not converted to source material for 3D printers. Recycling is a simple breaking down process, which is automated, but the instant work converts entire nonspecific waste material into the synthesized dough without toxicity leaving out and printing it into the final product. The system synthesizes the nonspecific waste material into useful products without any human intervention and without polluting the atmosphere [61].

This patent article discloses a paste metallic composite material for 3D printing, wherein metal paste and silicone are made into paste form and have the binding ability. It relates to paste metallic composite for 3D printing comprising of metal dust 80-90 part, silicone 5-10 part, tackifier 1-3 part, dispersant 1-2 part, and curing catalysts 0.1-0.5 part, wherein described metal dust is metallic tin powder and copper powder, at least one in metallic aluminum powder, metal iron powder, stainless steel powder, metal nickel powder, metallic titanium powder, and metal zinc forms so that weight ratio 1-3:10 is composite. Where else, the instant

TABLE 1: Consolidation of related works from patents and other articles.

S. No.	Date of filing or publishing	Title	Article/patent application number
1	2020-08-26	3d printing filament as a second life of waste plastics—a review	Journal
2	2020-06-30	Preparation method and application of slurry for ceramic 3d printing	CN111777405A
3	2019-18-12	A juice bar transforms orange peels into 3D Printed cups – Source - https://www.3dnatives.com/en/orange-peels-3d-printed-cups	Web article
4	2018-01-07	Wood paste and objects made therefrom	WO2019135245
5	2017-09-05	A kind of 3d printing environmental protection consumptive material	CN107556769A
6	2016-11-16	3d printing process with increased strength of the manufactured object	DE102016222558A1
7	2016-08-29	A kind of 3D printing discarded object cam-type processing equipment for pulverizing	CN106111243B
8	2016-07-11	A kind of green construction material printed for 3d and method of printing thereof	CN106186974A
9	2016-05-29	Additive manufacturing of rubber-like materials	US20190224914
10	2016-02-05	3d prints high-definition ecological plate	CN205395331U
11	2015-08-04	Paste metallic composite material for 3d printing and manufacturing method of paste metallic composite material for 3d printing	CN105108134A
12	2015-02-16	Method for preparing 3d printing material by use of recycled waste high-density polyethylene plastics	CN104629152A
13	2015-02-16	With reclaiming the method that 3d printed material prepared by the discarded raw material containing plant fiber	CN104711887B
14	2015	3d printing with biomaterials towards a sustainable and circular economy – doi:10.3233/978-1-61499-486-2-i	Book
15	2014-10-29	A kind of biomass wood plastic composite for 3d printing and preparation method thereof	CN104356618B
16	2014-09-02	A kind of 3d prints compositions and its production and use	CN104230289B
17	2014-08-10	Methods and devices for three-dimensional printing or additive manufacturing of bioactive medical devices	WO2016025388
18	2014-07-07	Sewage treatment device based on 3d printing biological stuffing	CN104045170A
19	2014-04-03	Electronic waste-plastic waste recovery resource-regeneration system and method	CN104191541A

work discloses synthesized dough prepared from nonsegregated waste material as source material for 3D printing. The nonsegregated waste material includes food, plastics, and E-waste [62]. Table 4 lists and compares the dough making with a metallic paste composite manufacturing using 3D printing.

3. Printer Modification

The aim is to convert the waste into useful products is being proposed which includes the 3D printer being a part of it. The methodology adapted in the proposed work is shown in Figure 1 as process flowchart.

All the existing prior art explains specifically recycling the same kind of waste (for example, porcelain and orange peel) into useful products. In the proposed work, the system is developed for the nonsegregated waste comprised of food waste, plastic bags, E-waste, metal, and other materials, which is the value-added over the existing prior arts. This process started in the year 2017, initially planned to develop the 3D printer to print the light denser material as waste leaves as in par with light denser applications, for which patent filed in the year 2017, but the methodology adopted was different in our patent and then the material synthesized as per the printer modified by us. Therein, our product gives

similar strength. The core hurdle faced in this work is converting the waste leaf into machine printable form. The next phase started in the year 2018, wherein the material chosen was with higher density, that is, waste foundry sand. Processing of sand gave challenges like identifying the nontoxic binder and synthesizing it. Finally, after trying out several binders, we chose an organic and an inorganic binder which provided the better binding ability. Therein, the print is made and tested it is on par with the existing paste metallic composite printer as well as the ceramic slurry or paste printers, which are filed for a patent since 2015; this work uses waste foundry sand which also gave better strength. The proof of concept developed over 3 years, 2018, 2019, and 2020, is highlighted below.

4. Novel AM Method

Referring to Figure 2, the system comprises a chamber, an ultraviolet (UV) disinfectant unit, a shedder, a storage unit, a mixer, and a 3D printer. The nonsegregated waste material is collected and stored inside the chamber. It is Said nonsegregated waste material includes but is not limited to food, plastics, and E-waste. The chamber dispenses the nonsegregated waste material as per requirement into the UV disinfectant unit via a conveyor; said UV disinfectant

TABLE 2: Comparison of dough making with a review article on waste plastic recycling [59].

S. No.	Reference document	Dough-making technique
1.	As an alternative to the current method of plastic recycling, filaments for 3D printers can be made from recycled polymers. Only plastic-based recycling is disclosed.	The instant work deals with nonsegregated waste recycling.
2.	One specific waste recycling.	<p>The instant work discloses synthesized dough prepared from nonsegregated waste material as source material for 3D printing. The nonsegregated waste material includes food, plastics, and E-waste.</p> <p>The technical advancement lies in the making of synthesized dough from nonsegregated waste material, wherein versatile materials are collected and processed mixed with components in the right quantity at the right stage to form the dough state to achieve 3D printing.</p> <p>The system converts the nonsegregated waste material into the synthesized dough without human intervention.</p>
3.	<p>Firstly, the material is separated as well as washed, and then, ground plastic is extracted.</p> <p>Extrusion at high temperatures is the next step in the process of preparing the ground material for use (the temperature should be set based on type of the polymer).</p> <p>With the extrusion method, granulated or polymer powder is fed into an extruder where it is heated and transformed into a homogeneous filament with precisely defined parameters for use in 3D printing (adapted to the size of the printer element and standardized diameter).</p> <p>The 3D printer accepts the freshly prepared filament.</p> <p>Analyses are conducted on the printed material (mechanical, structural, and rheological characteristics).</p> <p>Milling of the tested specimen is carried out for the second time.</p> <p>When it comes to modifying a material, an additional step is required: First, the mixture is mixed with an additional component as well as a binder (such as silicone oil), and then, it is extruded.</p> <p>By contrast, the second method calls for dissolving the ground element in an organic solvent along with a reinforcing component and then evaporating the solvent to obtain the ground material itself.</p>	<p>Nonsegregated waste material that includes food, plastics, and E-waste was collected and stored inside the chamber.</p> <p>The chamber dispenses nonsegregated waste material into the UV disinfectant unit via a conveyor; said UV disinfectant unit removes the harmful germs and water content in the nonsegregated waste material to form solid waste.</p> <p>The disinfected solid waste then enters the shedder which powders the solid waste.</p> <p>The powdered solid waste is then stored in the storage unit.</p> <p>The powdered solid waste is mixed with components one by one in the mixer to form the dough. Said components include waste foundry sand 5%, waste stone powder 5%, and binder 30%. The powdered solid waste is mixed with waste foundry sand and mixed well in the mixer to form a first mixture. The waste stone powder is then added to the first mixture and mixed well in the mixer to form a second mixture. Araldite is then added to the second mixture and mixed well in the mixer to form the synthesized dough.</p> <p>The synthesized dough which is used as a printable source is then sent to the 3D printer which prints the final component as per the requirement.</p> <p>The 3D printer includes UV lamp units fixed to the printing head on either side which disinfects the dough and as well as dries the dough. Drying the dough leads to the achievement of good binding of materials.</p> <p>The dough hardness is around 70 Brinell hardness units.</p>

unit removes the harmful germs and water content in the nonsegregated waste material to form solid waste. The disinfected solid waste then enters the shedder which powders the solid waste. The powdered solid waste is then stored in the storage unit. The powdered solid waste is mixed with components in a mixer to form the synthesized dough. Said components consist of waste foundry sand, waste stone powder, and binder. The synthesized dough is then sent to the 3D printer which prints the final component as per the requirement. The synthesized dough is used as a printable source for 3D printing. The 3D printer includes UV lamp units fixed to the printing head on either side which disinfects the dough and as well as dries the dough. Drying the dough leads to the achievement of good binding of materials. In an aspect, the binder is Araldite.

5. Testing

Figure 3 shows the proof of concept developed for the novel additive manufacturing. Testing phase is initiated with varying by the proportionate of the materials selected. The materials are nonsegregated waste material, waste foundry sand, waste stone powder, and Araldite binder. It is to iterate and figured the best possible combination for higher strength of the composite material. Specifically, the hardness test is only performed.

5.1. Processing Method 1. About 55% of collected nonsegregated waste material is stored inside the chamber. The chamber dispenses nonsegregated waste material into the UV disinfectant unit via a conveyor; said UV disinfectant

TABLE 3: Comparison of dough making with a review article on sustainable 3D-printed meat analogs [59].

S. No.	Referenced document	Dough-making technique
1	<p>They transformed waste material into the dough as a printable source of 3D printing. Materials obtained from somewhere in vitro cell culture, insects, and meat byproducts/waste, as well as plants, have been proposed as potential sources for long-term 3DP meat alternatives.</p> <p>In the extrusion process, fibrous meat materials have been deposited via a nozzle to create 3D structures in meat food items.</p>	<p>The instant work deals with nonsegregated waste recycling.</p>
2	<p>Only meat analogs recycling.</p>	<p>The instant work discloses synthesized dough prepared from nonsegregated waste material as source material for 3D printing. The nonsegregated waste material includes food, plastics, and E-waste.</p> <p>The system converts the nonsegregated waste material into synthesized dough, wherein versatile materials are collected, assessed, and processed to form the dough state to achieve 3D printing.</p>
3	<p>Waste recycling using meat material into scaffold</p>	<p>Making synthesized dough with nonsegregated waste material into 3D printable form with better strength requires appropriate input at various stages.</p> <p>Complete blending and combining can be accomplished only therein, proper specific proportionate.</p> <p>Nonsegregated waste material that includes food, plastics, and E-waste was collected and stored inside the chamber.</p> <p>The chamber dispenses nonsegregated waste material into the UV disinfectant unit via a conveyor; said UV disinfectant unit removes the harmful germs and water content in the nonsegregated waste material to form solid waste.</p> <p>The disinfected solid waste then enters the shedder which powders the solid waste.</p>
4	<p>By straightforwardly exploiting freeze-dried cells because of both active biocatalysts and fillers, Qian and his colleagues developed a high-performance bioink with significantly increased cell loading density while also supplying favorable rheological properties for AM. Baker's yeast (<i>Saccharomyces cerevisiae</i>) loading density had been enhanced to 750 g/l cell dry weight as the first bioink prototype (orders of magnitudes higher than that in liquid culture). In the ink, the cells were crammed so closely together that they were almost touching. This study also found that by adding nanocellulose as just a selectable secondary filler, the researchers were able to control ink rheology (such as a critical parameter characterizing the elasticity of polymeric liquids and plateau modulus) as well as cell density (0–8.6109 cells/ml) over a diverse variety for tailored implementations.</p>	<p>The powdered solid waste is then stored in the storage unit.</p> <p>The powdered solid waste is mixed with components one by one in the mixer to form the dough. Said components include waste foundry sand 5%, waste stone powder 5%, and binder 30%. The powdered solid waste is mixed with waste foundry sand and mixed well in the mixer to form a first mixture. The waste stone powder is then added to the first mixture and mixed well in the mixer to form a second mixture. Araldite is then added to the second mixture and mixed well in the mixer to form the synthesized dough.</p> <p>The synthesized dough which is used as a printable source is then sent to the 3D printer which prints the final component as per the requirement.</p> <p>The 3D printer includes UV lamp units fixed to the printing head on either side which disinfects the dough and as well as dries the dough. Drying the dough leads to the achievement of good binding of materials.</p> <p>The dough hardness is around 70 Brinell hardness units.</p>
5	<p>Extruders, which use a threaded conveyor or syringe structure and can also regulate temperature, represent a promising for the 3D printing of meat food items with the desired design, despite the fact that other methods have been still being developed. A nozzle is used to extrude materials in a layer-over-layer fashion to create geometric 3D structures. In addition, semisolid pastes like dough, chocolate, and meat purees are commonly used in extrusion. Dough, chocolate, and puree are among the 3D-printed edibles.</p>	<p>This work discussed not simply printing it, synthesizing dough is novel, and thereby it is getting the print to provide better hardness. It cannot print dough of any nature to gain the required strength.</p>

TABLE 4: Comparison of dough making with a metallic paste composite manufacturing using 3D printing [63].

Referenced document	Dough-making technique
<p>The method for the paste metallic composite comprising of</p> <ol style="list-style-type: none"> 1) Dispersant of the metal dust of 80-90 weight portion and 1-2 weight portion is uniformly dispersed in high-speed disperser, for subsequent use 2) Metal dust of step1 dispersion treatment, the silicone of 5-10 weight portion, and the tackifier of 1-3 weight portion are added airtight stirred tank, setting stirred tank temperature is 60-65 DEG C; by the rotating speed mixing 20-30 min of 200-400 rpm, obtain metal powder and silicone is the body of paste of key component 3) Curing catalyts of 0.1-0.5 weight portion being added step-2 metal powder that obtains and silicone be the body of paste of key component, open the vacuum of the airtight stirred tank, vacuum pressure 0.1-0.3 MPa, and mix with the rotating speed of 50-100 rpm; curing catalyts are dispersed in metal powder completely, and silicone is in the body of paste of key component 4) By the material discharge that airtight for step-3 stirred tank obtains and seal and preservation, be a kind of paste metallic composite printed for 3D. 	<p>Nonsegregated waste material that includes food, plastics, and E-waste was collected and stored inside the chamber. The chamber dispenses nonsegregated waste material into the UV disinfectant unit via a conveyor; said UV disinfectant unit removes the harmful germs and water content in the nonsegregated waste material to form solid waste.</p> <p>The disinfected solid waste then enters the shedder which powders the solid waste.</p> <p>The powdered solid waste is then stored in the storage unit.</p> <p>The powdered solid waste is mixed with components one by one in the mixer to form a dough. Said components include waste foundry sand 5%, waste stone powder 5%, and binder 30%. The powdered solid waste is mixed with waste foundry sand and mixed well in the mixer to form a first mixture. The waste stone powder is then added to the first mixture and mixed well in the mixer to form a second mixture. Araldite is then added to the second mixture and mixed well in the mixer to form the synthesized dough.</p> <p>The synthesized dough which is used as a printable source is then sent to the 3D printer which prints the final component as per the requirement.</p> <p>The 3D printer includes UV lamp units fixed to the printing head on either side which disinfects the dough and as well as dries the dough.</p> <p>Drying the dough leads to the achievement of good binding of materials.</p> <p>The dough hardness is around 70 Brinell hardness units.</p>

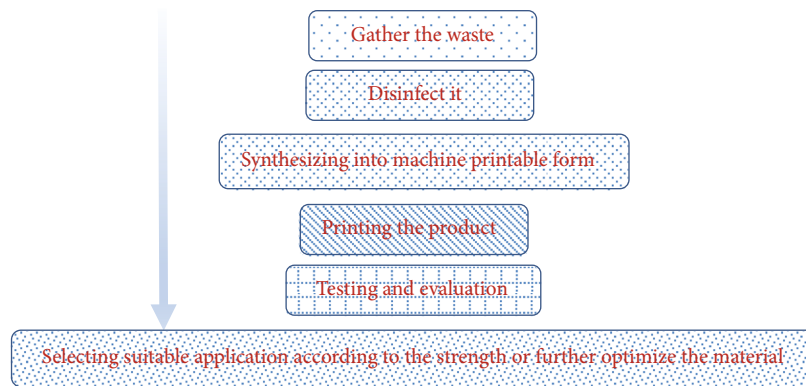


FIGURE 1: Process flowchart for the proposed work.

unit removes the harmful germs and water content in the nonsegregated waste material to form solid waste. The disinfected solid waste then enters the shedder which powders the solid waste. The shedder includes two stages of metal blades, first stage of metal blades sheds the solid waste into bigger granules, and the next stage of metal blades sheds the bigger granules into fine powder. The powdered solid waste is then stored in the storage unit. The powdered solid waste is mixed with components one by one in the mixer to form a dough. Said components consist of waste foundry sand 5%, waste stone powder 5%, and binder 30%. The powdered solid waste is mixed with about 5% of waste foundry sand and mixed well in the mixer to form a first mixture. About 5% of waste stone powder is then added to the first mixture

and mixed well in the mixer to form a second mixture. About 30% of Araldite is then added to the second mixture and mixed well in the mixer to form the synthesized dough. The synthesized dough is then sent to the 3D printer which prints the final component as per the requirement. The dough is used as the printable source for 3D printing. The 3D printer includes UV lamp units fixed to printing head on either side which disinfects the dough and as well as dries the dough. Drying the dough leads to the achievement of good binding of materials. The dough hardness is around 59 Brinell hardness units.

5.2. *Processing Method 2.* About 60% of collected nonsegregated waste material is stored inside the chamber. The

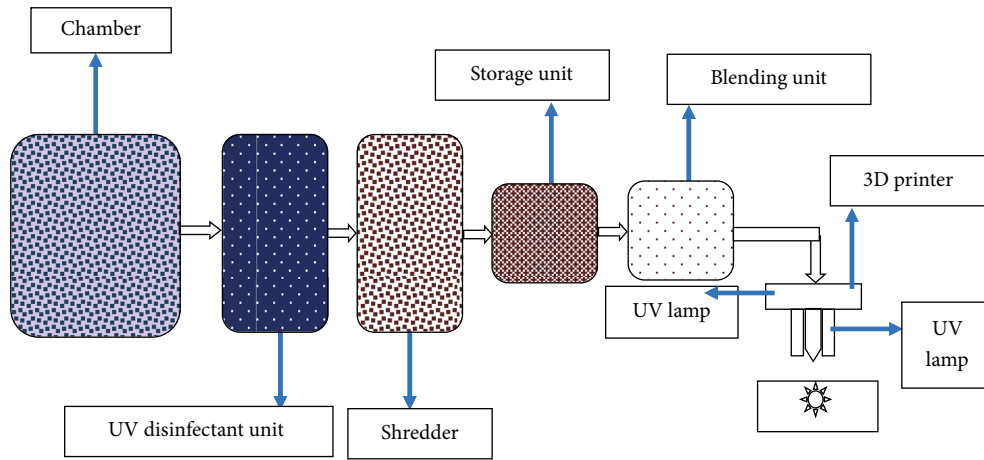


FIGURE 2: Novel AM system [64].

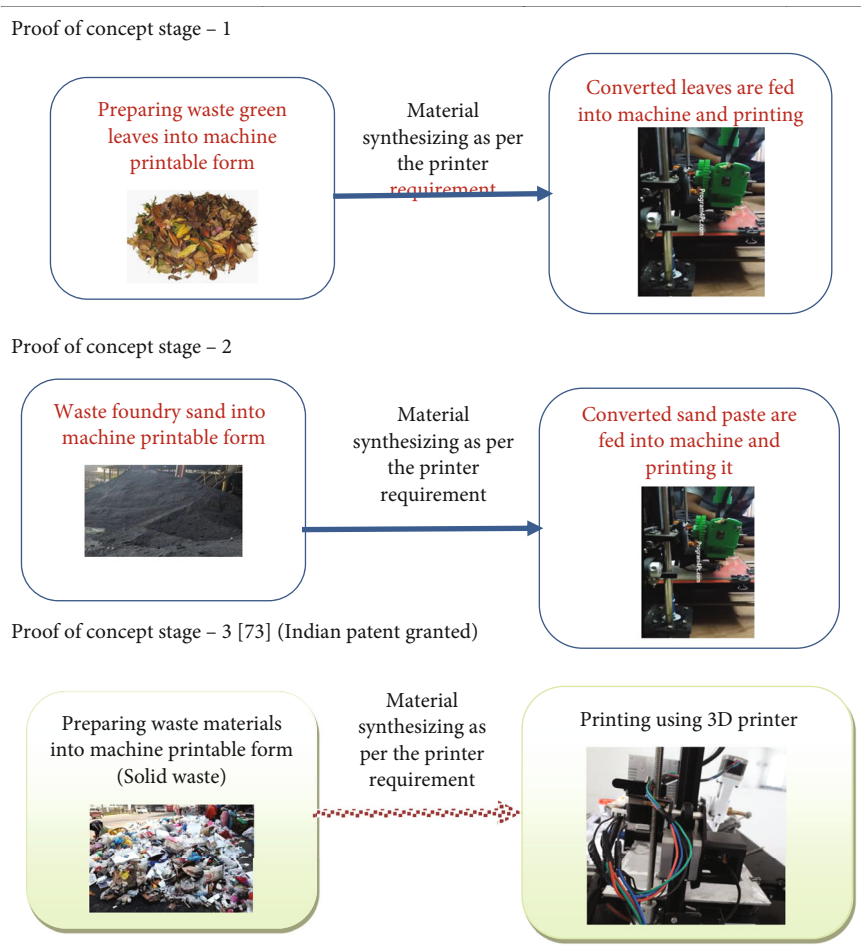


FIGURE 3: Proof of concept developed for the novel AM.

chamber dispenses nonsegregated waste material into the UV disinfectant unit via a conveyor; said UV disinfectant unit removes the harmful germs and water content in the nonsegregated waste material to form solid waste. The disinfected solid waste then enters the shredder which powders the solid waste. The powdered solid waste is then stored in the

storage unit. The powdered solid waste is mixed with components one by one in the mixer to form a dough. Said components include waste foundry sand 5%, waste stone powder 5%, and binder 30%. The powdered solid waste is mixed with about 5% of waste foundry sand and mixed well in the mixer to form a first mixture. About 5% of waste stone

powder is then added to the first mixture and mixed well in the mixer to form a second mixture. About 30% of Araldite is then added to the second mixture and mixed well in the mixer to form the synthesized dough. The synthesized dough is then sent to the 3D printer which prints the final component as per the requirement. The dough is used as the printable source for 3D printing. The 3D printer includes UV lamp units fixed to the printing head on either side which disinfects the dough and as well as dries the dough. Drying the dough leads to the achievement of good binding of materials. The dough hardness is around 70 Brinell hardness units.

5.3. Processing Method 3. About 65% of collected nonsegregated waste material is stored inside the chamber. The chamber dispenses nonsegregated waste material into the UV disinfectant unit via a conveyor; said UV disinfectant unit removes the harmful germs and water content in the nonsegregated waste material to form solid waste. The disinfected solid waste then enters the shredder which powders the solid waste. The powdered solid waste is then stored in the storage unit. The powdered solid waste is mixed with components one by one in the mixer to form the dough. Said components include waste foundry sand 5%, waste stone powder 5%, and binder 30%. The powdered solid waste is mixed with about 5% of waste foundry sand and mixed well in the mixer to form a first mixture. About 5% of waste stone powder is then added to the first mixture and mixed well in the mixer to form a second mixture. About 30% of Araldite is then added to the second mixture and mixed well in the mixer to form the synthesized dough. The synthesized dough is then sent to the 3D printer which prints the final component as per the requirement. The dough is used as the printable source for 3D printing. The 3D printer includes UV lamp units fixed to the printing head on either side which disinfects the dough and as well as dries the dough. Drying the dough leads to the achievement of good binding of materials. The dough hardness is around 54 Brinell hardness units.

From the above synthesis, it is clear that dough composition with waste material: 60%, waste foundry sand: 5%, waste stone powder: 5%, and binder: 30% achieves hardness around 70 Brinell hardness units.

The nonsegregated waste material is stored inside the chamber, said chamber dispenses the nonsegregated waste material into the UV disinfectant unit via a conveyor, and said UV disinfectant unit removes the harmful germs and water content in the nonsegregated waste material to form solid waste. The disinfected solid waste enters the shredder which powders the solid waste. The powdered solid waste is stored in the storage unit, the powdered solid waste is mixed with components in a mixer to form synthesized dough, and the synthesized dough as the printable source is sent to the 3D printer which prints desired final component. The shredder includes two stages of metal blades, the first stage of metal blades sheds the solid waste into bigger granules, and the next stage of metal blades sheds the bigger granules into fine powder. The UV lamp units are fixed to the printing head of the 3D printer on either side, and said

UV lamp units disinfect the dough and dry the dough. The components consist of waste foundry sand and waste stone powder, and binder is Araldite. The synthesized dough composition consists of the following components in weight percent, waste material: 60%, waste foundry sand: 5% waste stone powder: 5%, and binder: 30%.

6. Conclusion

Process of making dough and 3D print of it is explained in detail in this article. Initially, we gathered the related works, narrowed down it to most related articles, and then compared with this process. Thereby it shows the novelty of this process. Next, this process is explained in detail along with the various stages of developing proof of concept for this process. It provides path and tests the material printed for strength wherein the highest strength achieved is 70 Brinell hardness units. It is proposed as the best strength can be obtained in this technique.

Data Availability

The data used to support the findings of this study are included in the article. Should further data or information be required, these are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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