SSRG International Journal of Mechanical Engineering
ISSN: 2348-8360/ https://doi.org/10.14445/23488360/IJME-V12I5P110

Volume 12 Issue 5, 87-95, May 2025
2025 Seventh Sense Research Group®

Review Article

A Systematic Review on the Reuse of Recycled Plastics in 3D Printing Filament Production

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Received: 13 March 2025 Revised: 12 April 2025 Accepted: 11 May 2025 Published: 31 May 2025

Abstract *- The use of recycled plastics in manufacturing 3D printing filaments has gained increasing relevance, driven by the need to adopt more sustainable practices in production processes. This study aims to conduct a systematic analysis of the development and implementation of recycled materials in 3D printing between 2014 and 2024. The PRISMA methodology was used to conduct a search in scientific databases such as Scopus, initially obtaining 499 documents, which were reduced to 240 after applying thematic filters. The results show that the United States, China, and Italy lead the scientific production in this field, while Latin America's participation is lower, with Colombia, Argentina, and Chile contributing a minimal number of publications. It is evident that the area of Materials Science leads this field with 36.8% of studies, followed by areas such as Chemistry and Engineering. Furthermore, 86% of the documents reviewed are scientific articles, highlighting the academic importance of the topic. In conclusion, the use of recycled plastics in 3D printing presents itself as a viable alternative to reduce the environmental impact of plastics, highlighting the need for interdisciplinary approaches and technological innovation to improve their properties and expand their application in various industrial sectors.*

Keywords *- Recycled, Plastics, 3D printing, Filament, Review.*

1. Introduction

The development of technologies that enable the reuse of recycled plastics in the production of 3D printing filament has demonstrated a significant economic impact, leading to the search for innovative solutions to address pollution and promote sustainability [1]. As a result, companies and projects have managed to reduce production costs by converting plastic waste into reusable raw materials, reducing dependence on virgin polymers.

Globally, the adoption of recycled filaments in 3D printing is constantly growing. A specific case is that 80% of marine plastic pollution comes from land-based sources, while the remaining 20% originates from marine activities [2]. On the other hand, countries with strong technological industries have implemented processes to improve the quality of recycled filament and expand its application in sectors such as manufacturing and industrial design. In particular, Polyethylene Terephthalate (PET) bottles are widely used in packaging and constitute a significant part of plastic waste [3], which shows that the use of technologies that convert recycled plastic into 3D printing filament represents a viable source that can transform manufacturing and industrial design [4].

On the other hand, another of the places most associated with this problem is Latin America, where the problem of plastics remains a challenge, and some countries have begun to implement initiatives to improve the recycling and reuse of these materials [5]. In this context, integrating innovative technologies, such as the production of 3D printing filament from recycled PET, offers an opportunity to advance sustainability and more effectively address the plastic waste crisis [6].

In Peru, plastic waste management remains a critical issue. PET bottles constitute a significant portion of urban solid waste, and their proper reuse could significantly contribute to reducing pressure on landfills and minimizing the environmental impact [7]. The production of 3D printing filament made from recycled PET emerges as a promising alternative for improving the management of this waste and fostering innovation in the country.

The objective of this systematic review is to examine the current state of research on the reuse of recycled plastics, and specifically PET, in the production of 3D printing filament. It seeks to provide a detailed overview of the most relevant research in this field, identifying trends, technological advances, and challenges in implementing this technology. Systematic reviews are essential tools in scientific research, as they facilitate the meticulous and organized synthesis of existing information. Within the framework of 3D printing with recycled filament, these studies allow for identifying efficient strategies, higher-performance materials, and opportunities for innovation that foster sustainability.

This article is structured into five chapters. First, the background to the problem and the study's objective are presented. Second, a comprehensive review of the literature on the topic is offered. Third, the methodology used is described, based on the Scopus database and complemented by the PRISMA methodology, in order to achieve the greatest rigor in the analysis. Fourth, the results are presented, including graphs and co-occurrence maps that reflect the progress made in this area. Finally, the discussions and conclusions are presented, comparing the results with previous studies and emphasizing recommendations for future research.

2. Literature Review

The reuse of recycled plastics in the production of 3D printing filament faces numerous challenges as new technologies and their use are concentrated in diverse areas. However, solutions with great potential are emerging and linked to other technologies that can be supportive, including application technologies in this area. This section examines studies related to related plastics.

According to [8], the problem of plastic waste in Indonesia has led to the development of technologies for its reuse, such as the conversion of PET bottles into filament for 3D printing. Through the design and testing of a specialized machine, it was demonstrated that it is possible to produce filaments efficiently, promoting the circular economy and reducing plastic pollution. In a similar line, [9] addressed the problem of the excessive use of disposable PET bottles and the inefficiency of conventional recycling methods. Through the development of an Arduino-controlled pultrusion machine, it was possible to manufacture filament with a uniform diameter and optimal properties for 3D printing, validating the viability of this technique as a sustainable alternative. On the other hand, [10] evaluated the mechanical properties of recycled filaments compared to conventional materials such as PET-G, ABS, and PLA. Their findings indicated that recycled BPET from PET bottles presents similar thermal resistance and tensile strength performance, consolidating it as a viable option for practical applications in 3D printing. These studies reinforce the potential of PET recycling in filament manufacturing, contributing to reducing plastic waste and promoting sustainability in the manufacturing industry.

On the other hand, [11] addresses the recycling of plastics for the manufacture of 3D filaments, evaluating a granulation and extrusion process that allowed obtaining recycled filaments compared to commercial ones, capable of printing functional models such as screw and nut systems, highlighting their efficiency and sustainability. Similarly, [12] explored the integration of recycled waste, such as PET from bottles and nanoparticles from date palm leaves, in the production of 3D filaments applied in furniture design. Their findings indicate that adding 10% of nanoparticles improves resistance and thermal stability, consolidating this option as a viable alternative in the sustainable furniture industry. Finally, [13] focused on comparing mechanical properties between recycled PET and virgin PET for its application in 3D printing. Through tensile tests under ASTM standards, it was determined that recycled PET has mechanical characteristics similar to virgin PET, although with some difficulties in the printing process. These studies reinforce the viability of using recycled plastics in the manufacture of 3D printing filaments, promoting innovative solutions in various sectors and contributing to the reduction of plastic waste.

On the other hand, [14] analyzes the increase in plastic waste and the low recycling rate of PET bottles, proposing their reuse in the manufacture of 3D printing filaments by Material Extrusion (MEX). Their findings indicate that although recycled PET presents greater degradation and lower viscosity compared to virgin PET, its tensile strength exceeds that of PETG, validating its viability for functional applications. Complementarily, [15] investigates the improvement of the mechanical and thermal properties of 3D printing filaments by Incorporating Nanocellulosic Crystals (CNC) in a PLA matrix.

The results reveal that the optimal addition of CNC increases the tensile strength by 18.2%, improving the thermal stability and favoring its applicability in additive manufacturing. Likewise, [16] uses the ELECTRE method to evaluate various plastics, both virgin and recycled, to produce 3D filaments. Their study concludes that, although virgin LDPE is the most suitable for extrusion, recycled PET offers superior performance to virgin PET, reaffirming its potential as a sustainable alternative. These studies reinforce the importance of optimizing recycled materials in additive manufacturing, promoting environmental solutions for the 3D printing industry.

Along the same lines of research, [17] analyzes the recycling of HDPE for the manufacture of 3D printing filaments, highlighting its viability compared to ABS and PLA. Their study demonstrates that recycled HDPE can be transformed into filaments with competitive mechanical properties, contributing to sustainability and reducing plastic waste. Similarly, [18] investigates strategies to optimize the use of recycled materials in filament production, identifying best practices and challenges related to their quality and mechanical properties.

Their findings suggest that the use of recycled plastics in 3D printing can significantly reduce the environmental impact without compromising the performance of the final product. Finally, [19] compares FDM and SLS 3D printing methods in the manufacture of a textile swatch with the aim of minimizing waste. Although both processes offer advantages in terms of waste reduction, limitations were identified: PLA in FDM is biodegradable but slow to decompose, while in SLS, the powder can be reused in limited quantities.

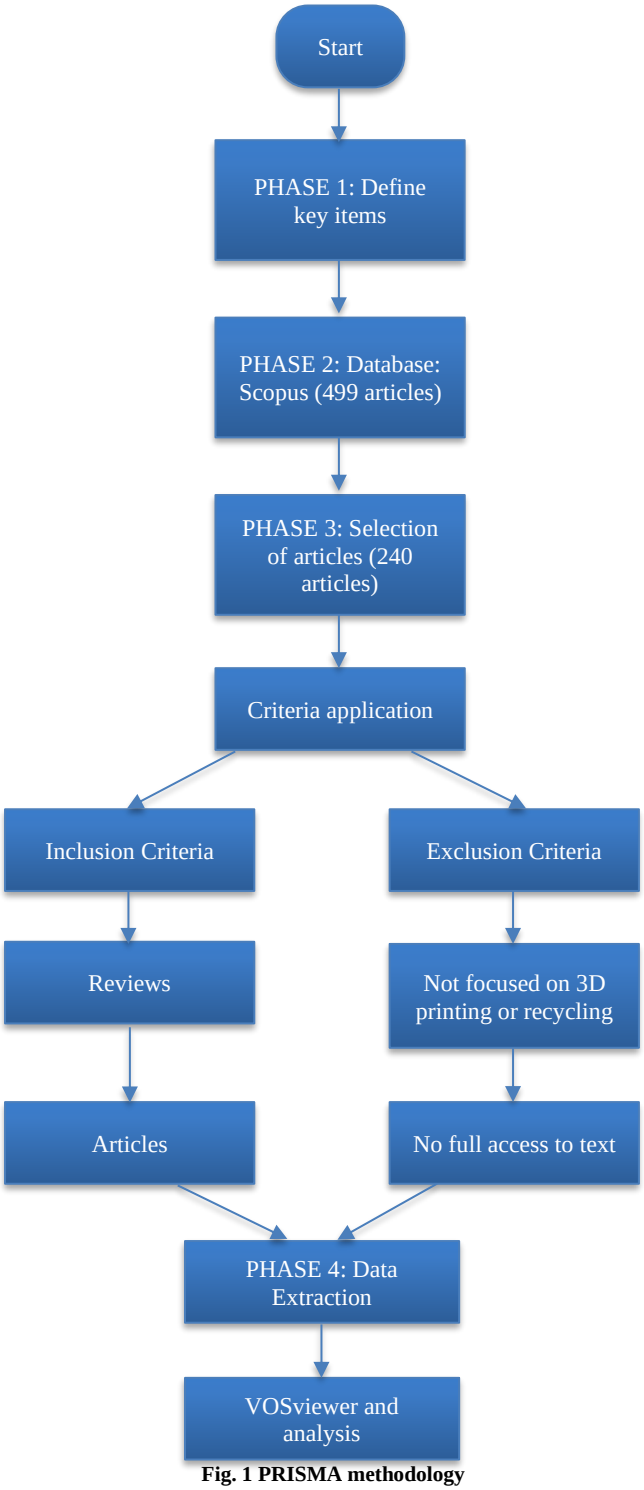

Fig. 1 PRISMA methodology

Overall, the reviewed literature demonstrates the potential of plastic recycling for producing 3D printing filaments, highlighting its benefits in terms of sustainability and performance. Despite challenges related to the quality and processability of recycled materials, the studies agree that their use in additive manufacturing represents a feasible strategy for reducing the environmental impact of plastic waste and moving toward a more circular model in the 3D printing industry.

3. Materials and Methods

This systematic review uses the PRISMA hybrid methodology to analyze the impact of plastics recycling on 3D printing filament manufacturing. Figure 1 illustrates the phases involved in this study. The data search phase involved an analysis of scientific databases, using Boolean operators to optimize results and ensure the inclusion of relevant studies. During data processing, filters were applied to exclude research unrelated to producing recycled filaments or not focused on 3D printing. The data analysis phase consisted of a detailed evaluation of the selected articles, prioritizing their validity and relevance to recycled materials' mechanical and thermal properties.

3.1. Data Search

The data collection process focused on gathering relevant information on plastic recycling and its use in 3D printing filament production. The primary objective was to identify studies that examined the reuse of recycled plastics. To this end, sources such as scientific articles, conference presentations, and systematic reviews were selected, providing a solid basis for examining the factors influencing the efficiency and sustainability of recycled filaments in 3D printing.

3.2. Data Processing

In this phase, a detailed analysis of the selected studies was conducted to assess the feasibility of recycling plastics for 3D printing filament production. Initially, the studies were classified and organized according to previously established criteria. A thematic analysis of keywords then identified common patterns in applications, challenges, and solutions within this field. Furthermore, the studies were structured to facilitate comparison and analysis. Finally, the most effective strategies for improving the quality and sustainability of recycled filaments were prioritized, ensuring a synthesis of the most relevant findings and opportunities for innovation in this area.

1) Inclusion Criteria: This study considered documents that met specific criteria to ensure their relevance and quality. Research published between 2014 and 2024, obtained from scientific databases such as Scopus, was included. Articles with full access and exploring practical or theoretical solutions to improve the sustainability and efficiency of using recycled plastics in 3D printing were selected.
2) Exclusion Criteria: Documents not meeting the previously established inclusion criteria were discarded. This included publications in editorials, reviews, commentaries, patents, unpublished theses, and brief notes. Likewise, studies not directly related to manufacturing recycled filaments for 3D printing, such as

those focusing on unrelated topics, were excluded. Duplicate, incomplete, or insufficiently documented research methods were also excluded.

3.3. Data Analysis

This section presents the systematic review's findings on the use of recycled plastics for 3D printing filaments, highlighting advances, applications, and challenges in this area. Various visualization techniques were used, such as comparative tables and relationship maps. The comparative tables facilitated the organization of the selected research by publication year, author, and document type. Furthermore, the relationship maps demonstrated the connection between key terms, which represent the most prominent themes in the field of filaments, and the solutions proposed in the analyzed studies.

3.3.1. Search Tools

Scopus

Scopus is a scientific database that facilitates access to a wide collection of academic articles, conference papers, and peer-reviewed reviews [20, 24, 25]. Its main function is to simplify searching and selecting relevant literature for research. In this study, Scopus was used to identify publications related to plastics recycling and its application in manufacturing 3D printing filaments. Furthermore, its bibliometric analysis capacity allowed us to recognize trends in the optimization of recycled materials and their applications in additive manufacturing, ensuring an adequate selection of relevant studies.

VOSviewer

VOSviewer is a software specialized in creating and analysing bibliographic networks, which is useful for examining the connection between authors, publications, and keywords in the recycling and 3D printing [21, 22]. Data obtained from Scopus were used to map research trends and identify the most relevant areas in the development of recycled filaments [23, 26, 27]. The combination of Python with VOSviewer enabled data collection and analysis automation, increasing the results' accuracy and simplifying the detection of fundamental patterns in the selected studies [30].

Likewise, to ensure a representative and reliable analysis, a statistical formula was used to determine an adequate sample, considering a high level of confidence and an acceptable margin of error. This procedure was applied to all selected documents, ensuring that the sample was representative of the current panorama in the development of recycled filaments for 3D printing [28, 29]. From the obtained sample, a thematic analysis was carried out to identify the predominant trends in the research, highlighting the elements that influence the optimization of the characteristics of recycled filaments and their viability in additive manufacturing.

4. Results

The primary objective of data collection was to analyze studies on the reuse of recycled plastics in the production of 3D printing filaments.

4.1. Data Search

At this stage, a specific Scopus search algorithm, which consisted of Boolean algebra, was developed, including logical operators AND and OR, to improve results and ensure the appropriate inclusion of studies.

The search algorithm included key terms such as ‘3D printing,’ ‘plastics,’ ‘filament,’ and ‘polymers,’ some of which were combined with wildcards (*) to identify variations of important terms. A time filter was also applied, limiting the search to studies published between 2014 and 2024.

The selection criteria for the documents were based on the following algorithm: (TITLE -ABS-KEY (3d AND printing) AND TITLE-ABS-KEY (recycl*) AND TITLE-ABS-KEY (plastics) OR TITLE-ABS-KEY (filament) AND TITLE-ABS-KEY (sustainability) OR TITLE-ABS-KEY (polymers)) AND PUBYEAR > 2013 AND PUBYEAR < 2025

As a result of the initial search in Scopus, 499 studies were identified without additional filters. This constitutes a preliminary basis for the subsequent analysis, including a comprehensive analysis of trends and discoveries related to plastic recycling in manufacturing 3D printing filaments.

Table 1. Filters by Subject Area

Exclusion of Sources by Subject Area	
Excluded areas	**Number of documents**
Physics and Astronomy	73
Computer Science	53
Business, Management and Accounting	25
Math	18
Social Sciences	17
Economics, Econometrics and Finance	13
Decision Sciences	11
Biochemistry, Genetics and Molecular Biology	9
Medicine	8
Earth and Planetary Sciences	8
Agricultural and Biological Sciences	8
Multidisciplinary	5
Arts and Humanities	4
Dentistry	2
Pharmacology, Toxicology and Pharmacy	1

4.2. Data Processing

- *Exclusion:* To ensure consistency with the objectives of the systematic review and prevent the inclusion of research that deviates from the focus, the results obtained in the initial search were excluded by means of a subject area filter, giving priority to those studies that addressed the topic from the perspective of this study. Table 1 shows the sources excluded by the Subject Area filter.
- *Inclusion:* Inclusion criteria were established by document type, limiting the inclusion of studies to scientific articles and systematic reviews. This selection was deemed necessary to ensure the academic rigor of the included studies, excluding books, conference proceedings, or other types of studies not considered appropriate for this research.

Table 2. Filters by document type

Inclusion of Sources by Document Type	
Document Type	**Number of documents**
Article	209
Revision	33

After applying these criteria, a total of 240 documents were screened. This corresponds to the inclusion and exclusion filtering, where documents related to the topic were obtained for further analysis.

4.3. Data Analysis

This section presents the findings from the analysis of the extracted documents and their relationship to trends and discoveries related to plastics recycling. Figure 2 shows the evolution of research on using recycled plastics in manufacturing 3D printing filaments, and in this case, on the documents derived between 2016 and 2024. During the first years, activity in this field was limited, with only one study registered in 2016. However, starting in 2017, a significant growth in the number of research studies was observed, increasing from 4 studies in 2017 to 14 in 2019. In 2020, interest in this area began to expand significantly, reaching 30 studies in 2021 and 35 in 2022. The growth increased in the last two years, with a notable increase to 52 studies in 2023 and a maximum of 87 in 2024. This growing trend evidences the interest in developing recycled materials for 3D printing, driven by the need for sustainable solutions in additive manufacturing.

Figure 3 shows the distribution of research on the use of recycled plastics in manufacturing 3D printing filaments by subject area. Materials Science leads the field with 167 studies, reflecting its fundamental role in the innovation and optimization of 3D printing materials. Chemistry follows with 107 studies demonstrating its relevance in developing new additives to improve the properties of recycled filaments. With 77 studies, engineering also has a strong presence, focusing on extrusion and additive manufacturing processes. On the other hand, Environmental Sciences and Chemical Engineering have 41 and 40 studies, respectively, indicating a growing interest in the sustainability and environmental impact of plastics recycling. Finally, with 22 studies, the energy sector has a lower share, suggesting that the use of recycled plastics in energy applications is still developing.

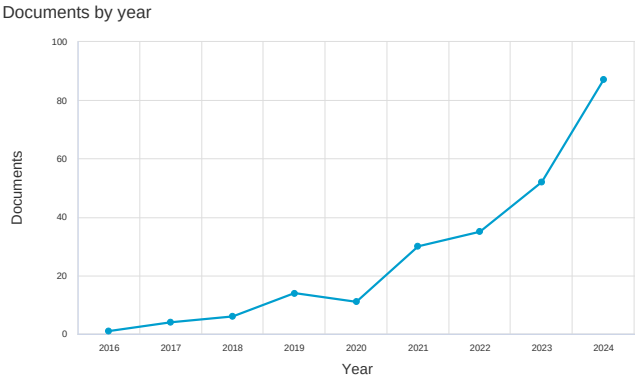

Fig. 2 Document Analysis by Year

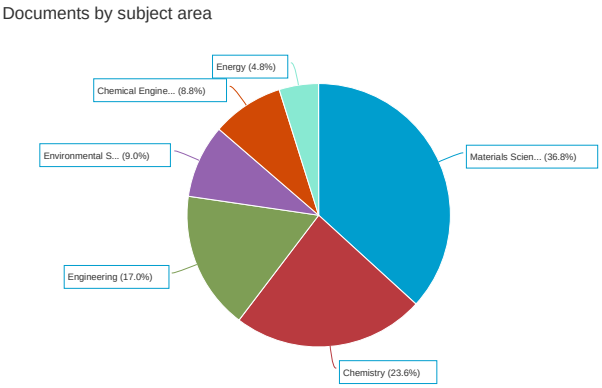

Fig. 3 Document Analysis by Area

Figure 4 shows the number of papers published in various academic sources between 2014 and 2024 on using recycled plastics to manufacture 3D printing filaments. The journal Polymers stands out as the main source of publications, with 47 studies reflecting its focus on polymeric materials and their innovative applications. This is followed by ACS Applied Polymer Materials and Additive Manufacturing, both with 10 articles demonstrating an interest in improving materials for additive manufacturing. Other journals, such as ACS Applied Materials and Interfaces and Journal of Polymers and the Environment, with 8 studies each, demonstrate the balance between materials innovation and sustainability. Finally, Rapid Prototyping Journal (7 studies) and ACS Sustainable Chemistry and Engineering (6 studies) contribute to the discussion from rapid prototyping and sustainable chemistry perspectives, respectively. The diversity of sources indicates a multidisciplinary approach to developing and optimising recycled filaments for 3D printing.

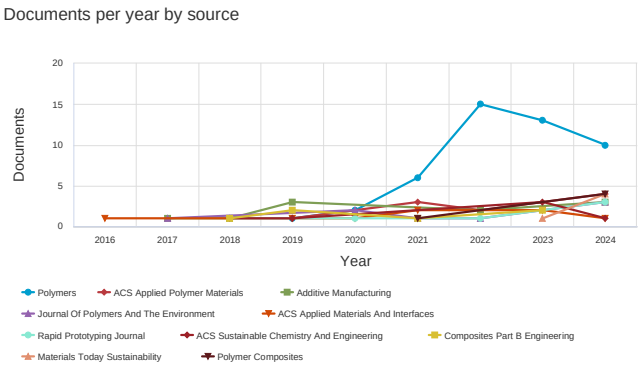

Fig. 4 Analysis of documents by journal

Figure 5 shows the distribution of scientific papers on the use of recycled plastics in manufacturing 3D printing filaments by publication type. A large number of studies are scientific articles, with a total of 207 publications representing the main channel for disseminating advances in this area. On the other hand, systematic reviews include 33 documents, representing a lower percentage compared to scientific articles. This difference suggests that research in this area focuses primarily on the creation of new knowledge and the experimental development of recycled materials, while reviews play a complementary role in consolidating the current state of the art and identifying future trends.

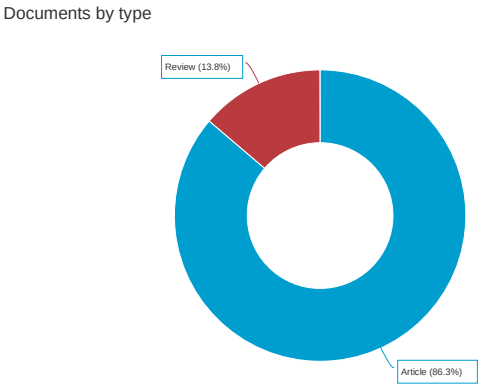

Fig. 5 Document Analysis by Type

Figure 6 shows the geographic distribution of research on the use of recycled plastics in 3D printing filament manufacturing from 2014 to 2024. The United States leads with 29 publications, followed by China with 27 and Italy with 26, reflecting the strong interest of these countries in developing sustainable materials for additive manufacturing. India and the United Kingdom also represent significant participation, with 20 studies each, while Germany, Australia, and Canada contribute 15, 13, and 12 publications, respectively. Countries such as Brazil, Colombia, Argentina, and Chile are less represented in Latin America, ranging from one to three studies each. These data suggest that research in this area is mainly concentrated in countries with a strong tradition in materials science and 3D printing, although a minimal but noticeable expansion is noted in other regions.

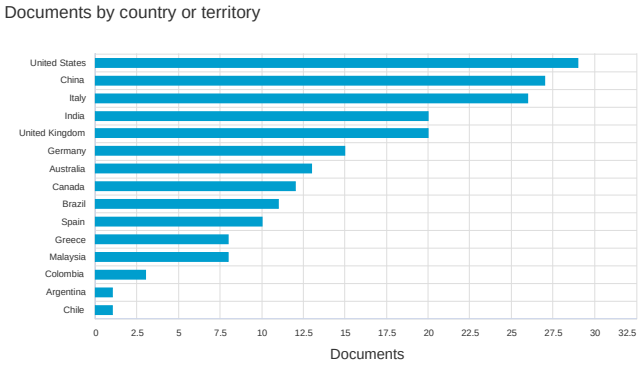

Fig. 6 Document Analysis by Country

Figure 7 shows that Banks, CE, and Crapnell, RD, are the highest-producing authors in the field of plastics recycling for 3D printing filament manufacturing, with a total of 7 publications each. Their work has been key to developing and optimising sustainable materials in additive manufacturing. Patti, A. stands out next with 6 publications, while Acierno, S., and Cicala, G. have contributed 5 studies each. Finally, Acierno, D. has 4 publications in this field. These findings demonstrate the presence of a group of scientists highly committed to exploring and optimizing the use of recycled plastics in 3D printing, consolidating significant advances in materials and processes for additive manufacturing.

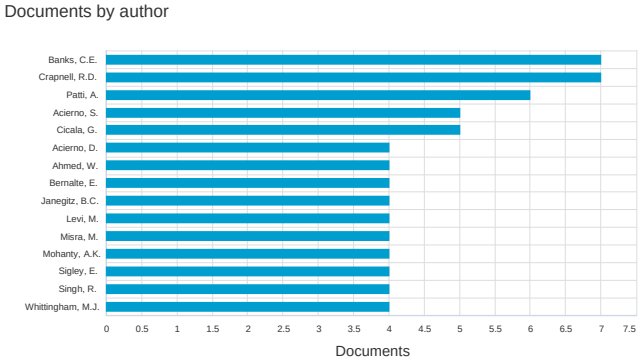

Fig. 7 Document Analysis by Author

4.3.1. Bibliometric Analysis

Furthermore, Figure 8 presents the co-occurrence of key terms in 2,367 keywords indexed in the analyzed publications. It can be seen that the keywords' 3D printing,' 'recycling,' 'additive manufacturing,' and 'plastic recycling' are the most prominent in their different color nodes.

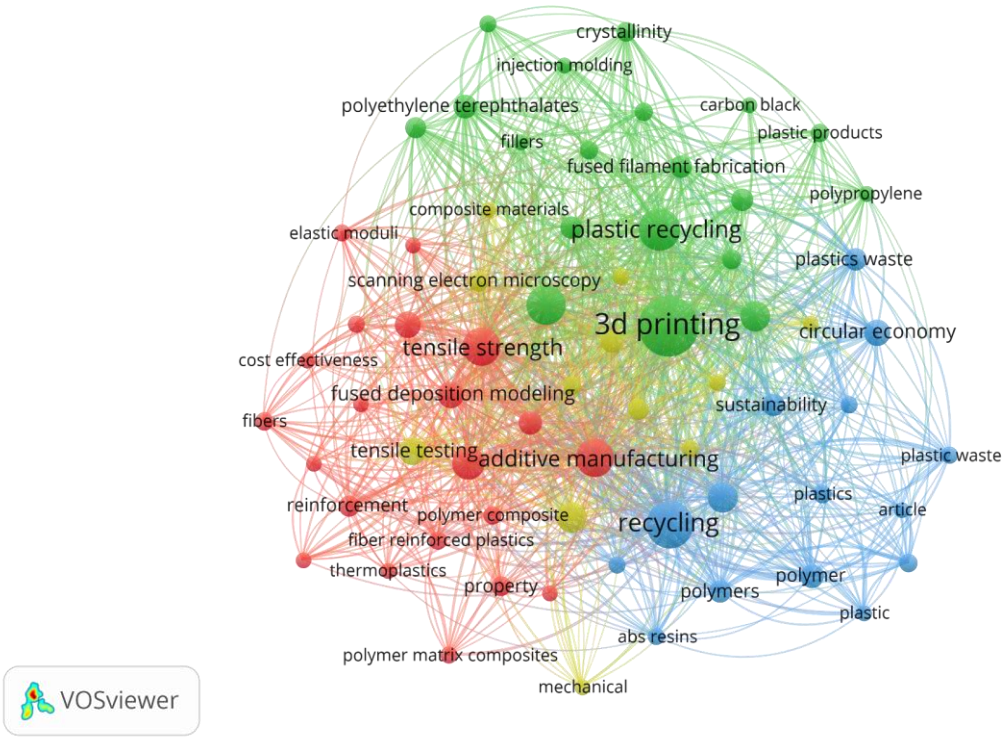

Fig. 8 Co-occurrence of keywords

In this regard, 67 occurrences were identified, distributed across four clusters: Cluster 1 (21 occurrences), Cluster 2 (19 occurrences), Cluster 3 (15 occurrences), and Cluster 4 (12 occurrences). Each set of keywords was illustrated with different colors using the VOSviewer visualization tool, facilitating the identification of thematic patterns. In this analysis, Cluster 1 (red) stands out for having "additive manufacturing" as its main node, grouping keywords such as "tensile strength" and "thermoplastics." Cluster 2 (green) stands out with its main node of "3D printing," grouping keywords such as "plastic recycling" and "additives." Meanwhile, Cluster 3 (blue) stands out with its main node of "recycling," grouping keywords such as "polymers" and "sustainability." These findings facilitate the identification of key themes and allow us to understand the dynamics of research on the use of recycled plastics in manufacturing 3D printing filaments.

4.3.2. Statistical Analysis

In this review, a statistical formula is used to determine the representative sample size. This formula allows us to determine the appropriate number of documents to analyze, ensuring the reliability of the results and minimizing the risk of error. The equation used was the following:

$$n = \frac{N * Z^2 * p * q}{e^2 * (N-1) + Z^2 * p * q} \quad (1)$$

$$n = 147.95 \approx 148$$

Where:

$N = tamaño\ de\ población = 240$

$Z = nivel\ de\ confianza\ 95\% = 1.96$

$p = proporción\ de\ éxito = 0.5$

$q = proporción\ de\ fracaso = 0.5$

$e = margen\ de\ error = 0.05$

The sample size estimate resulted in 148 documents, ensuring adequate statistical representation of the total population with a 95% confidence level and a 5% margin of error. This procedure ensures the findings accurately reflect trends and advances in using recycled plastics for 3D printing filament manufacturing.

To select these 148 documents, a preliminary evaluation was conducted based on specific criteria related to plastics recycling and its application in additive manufacturing. This process allowed for identifying key patterns in material reuse and filament optimization for 3D printing. Furthermore, the selection was random, ensuring an equitable distribution of the studies and allowing for a representative analysis without compromising the validity of the research.

The analysis of the collected data showed that using recycled plastics in 3D printing is a viable and sustainable alternative, with competitive mechanical properties compared to conventional polymers such as ABS and PLA. However,

significant challenges were identified, such as variability in the quality of the recycled material, the need to improve extrusion processes, and the lack of standardized regulations for their use in 3D printing. To maximize the potential of these materials, it is essential to overcome these limitations by developing more efficient technologies and implementing strategies that promote sustainability in additive manufacturing.

5. Discussion and Conclusion

The findings of this study highlight the evolution and relevance of research into the use of recycled plastics for 3D printing filament manufacturing. In that context, the implications of this study have a focus for researchers dedicated to the analysis of the use of recycled plastics, which can make this study a crucial reference in the field of research. Eighty-six percent of the documents examined were scientific articles, reflecting the importance of academic literature in developing this discipline. Regarding thematic areas, Materials Science leads the field with 36.8% of publications, followed by Chemistry and Engineering, reflecting a multidisciplinary approach to optimizing recycled materials for additive manufacturing.

The United States leads the scientific output at the country level with 29 publications, followed by China (27) and Italy (26). This indicates considerable investment in research by leading economies in manufacturing and technology. However, the participation of Latin American countries is significantly lower, with Colombia contributing three publications and Argentina and Chile each contributing one publication. This distribution indicates the research disparities in that continent, which may be caused by a number of factors, including lack of international collaboration with technological countries, lack of budget and incentives to researchers, suggesting the need to strengthen research in the region, encouraging initiatives that promote the reuse of plastics in 3D printing as a sustainable alternative.

Compared with previous studies, the growing importance of recycling in additive manufacturing is confirmed. Previous studies have shown that using recycled polymers presents challenges in terms of uniformity and mechanical properties and opportunities to improve their performance through optimized extrusion processes. Furthermore, variability in material quality remains a key barrier, reinforcing the need to establish standardized regulations to ensure the viability of these materials in industrial applications.

Regarding publication trends, a clear tendency towards publishing scientific articles (207) compared to reviews (33) is reflected, suggesting that the area represents active experimentation with new recycled filament formulations. This prevalence of experimental studies highlights the need to continue evaluating the performance of these materials under real-life printing and usage conditions.

For future research, we recommend further analyzing the environmental impact of recycled filament production, considering its life cycle and energy efficiency compared to virgin polymers. It is also essential to explore the development of methodologies to improve the quality and consistency of recycled material, enabling its adoption in large-scale industrial applications. Furthermore, we suggest expanding collaboration between academic institutions and industrial sectors to promote implementing these technologies in emerging markets, particularly in areas with high plastic waste production.

This analysis underscores the need to continue promoting research into recycled plastics for 3D printing as a fundamental strategy for transitioning toward more sustainable manufacturing. This is because, even with current advances, challenges remain regarding material standardization, scalability, and performance, presenting opportunities for innovation and the development of solutions that maximize this technology's environmental and economic benefits.

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