Migration Letters

Volume: 20, No: S9(2023), pp. 1021-1033

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

Design and Characterization of Nano-Particular Catalysts for the Efficient Production of Bioplastics from Biomass

Cesar Augusto Ediberto Levano Salazar[1], Rosalio Cusi Palomino[2], Fernando Eduardo Cano Legua[3], Rosa Luz Galindo Pasache[4], Juan Alfredo Toledo Huamán[5], Raúl Gerardo Avila Meza[6]

Abstract

By means of this document, it was possible to analyze the main characteristics of the volume of scientific production related to the study of the variables Bioplastic Production and Biomass. A bibliometric analysis was proposed to analyze details such as Year of Publication, Country of Origin of the publication, Area of Knowledge in which the published research is carried out and the Type of Publication most frequently used by the authors of each document published in high-impact journals indexed in the Scopus database during the period between 2017 and 2022. Among the main findings, it was possible to determine that, for the execution of the different research methodologies, the report of 282 scientific documents related to the study of the aforementioned variables was achieved. The maximum number of publications made in a year was 94 papers submitted in 2022. The country of origin of the institutions that reported the highest number of records in Scopus was India with 44 documents. The area of knowledge with the greatest influence at the time of executing the research projects that resulted in scientific publications was Environmental Sciences, which contributed great theoretical material in a total of 126 publications. Finally, the type of publication most frequently used to publicize findings from the analysis of the aforementioned variables was the Journal Article, which represented 50% of the total scientific production.

Keywords: *Bioplastic Production, Biomass, Raw Material, Nanoparticular Catalysts.*

1. Introduction

The manufacture of bioplastics from biomass production has emerged as an efficient and sustainable solution to address the obvious environmental challenges associated with traditional petroleum-based plastics. At the same time that the strong international demand for bioplastics continues to grow, there is a growing need for efficient synthesis methods that are environmentally friendly. The so-called nanoparticle catalysts have made a great contribution to the industry as they have an extensive property in terms of catalytic efficiency, sustainable and selective for manufacturing processes and environmental care.

[1] Universidad Nacional "San Luis Gonzaga", cesar.levano@unica.edu.pe, https://orcid.org/0000-0002-5922-1305
[2] Universidad Nacional "San Luis Gonzaga", rosalio.cusi@unica.edu.pe, https://orcid.org/0000-0003-1075-5725
[3] Universidad Nacional "San Luis Gonzaga", fcano@unica.edu.pe, https://orcid.org/0000-0002-6881-4313
[4] Universidad Nacional "San Luis Gonzaga", rosa.galindo@unica.edu.pe, https://orcid.org/0000-0001-8696-5185
[5] Universidad Nacional "San Luis Gonzaga", juan.toledo@unica.edu.pe, https://orcid.org/0000-0003-2455-588X
[6] Universidad Nacional "San Luis Gonzaga", raul.avila@unica.edu.pe, https://orcid.org/0000-0002-8533-4258

Catalysts and nanoparticles signal a significant advance in the respective fields of catalysis, these catalysts have properties such as metal, metal oxide or other catalytic components, one of their main characteristics is based on their nanoscale dimensions which provide an intense relationship between surface and volume. This interesting feature allows for a more significant number of catalytically active sites, resulting in enhanced activity. It is important to note that this characteristic of nanoparticles can be controlled with great precision, which would allow the catalytic components to be fine-tuned for better adaptability to biomass conversion reactions in a specific way.

One of the main characteristics of nanoparticle catalysts in the manufacture of bioplastics from biomass is their ability to promote selective and highly efficient reactions. Raw materials derived from plants, such as biomass, are very complex and require chemical processing from the precursor production of bioplastics. Nanoparticle catalysts have the properties of a more effective transformation, reducing unwanted by-products and waste. This selectivity in production is essential as it allows a cost-effective and much more environmentally friendly production of bioplastics, as it reduces the additional purification of processing and with it a reduction in energy consumption.

Likewise, these nanoparticle catalysts impart significant advantages in terms of reaction kinetics. Its main feature at the nanoscale allows a rapid diffusion of the reactants to the sites with the highest catalytic, as these features lead to a shorter reaction and thus improve the overall efficiency of the processes. It is important to note that these qualities are of vital importance since, at the time of large-scale bioplastic production, where the conversion rate directly affects the economic viability of the process.

Importantly, another key advantage of nanoparticle catalysts in the production of bioplastics is their potential for sustainability. Many traditional catalysts employed in biomass conversion processes rely on expensive or toxic materials, raising environmental and economic concerns. Nanoparticle catalysts, on the other hand, can be designed using non-toxic, earth-abundant materials, reducing the environmental footprint of the process. For this reason, this article seeks to describe the main characteristics of the compendium of publications indexed in the Scopus database related to the variables Bioplastic Production and Biomass, as well. Such as the description of the position of certain authors affiliated with institutions, during the period between 2017 and 2022.

2. General Objective

To analyze, from a bibliometric approach, the characteristics in the volume of scientific production related to Bioplastics and Biomass Production, registered in Scopus during the period 2017-2022.

3. Methodology

This article is carried out through a research with a mixed orientation that combines the quantitative and qualitative method.

On the one hand, a quantitative analysis of the information selected in Scopus is carried out under a bibliometric approach of the scientific production corresponding to the study of the Production of Bioplastics and Biomass.

On the other hand, examples of some research works published in the area of study mentioned above are analyzed from a qualitative perspective, based on a bibliographic approach that allows describing the position of different authors on the proposed topic.

It is important to note that the entire search was carried out through Scopus, managing to establish the parameters referenced in Figure 1.

3.1 Methodological design

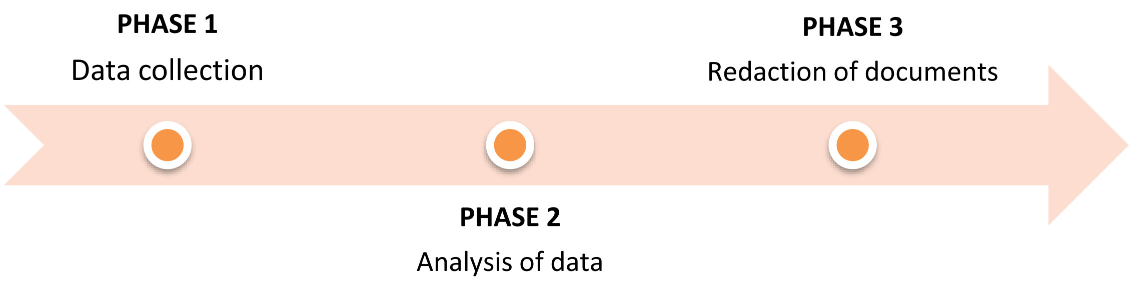

Figure 1. Methodological design

Source: Authors' own creation

3.1.1 Phase 1: Data collection

Data collection was carried out from the Search tool on the Scopus website, where 282 publications were obtained from the following filters:

➢ TITLE-ABS-KEY (production AND OF AND bioplastics, AND biomass) AND PUBYEAR > 2016 AND PUBYEAR < 2023

➢ Published documents whose study variables are related to the study of Bioplastics and Biomass Production.

➢ Works published in journals indexed in Scopus during the period 2017-2022.

➢ Without distinction by country of origin

➢ No distinction in areas of knowledge.

➢ No distinction of type of publication.

3.1.2 Phase 2: Construction of analytical material

The information collected in Scopus during the previous phase is organized and then classified by graphs, figures and tables as follows:

➢ Co-occurrence of Words.

➢ Year of publication.

➢ Country of origin of the publication.

➢ Area of knowledge.

➢ Type of Publication.

3.1.3 Phase 3: Drafting of conclusions and outcome document

In this phase, the results of the previous results are analysed, resulting in the determination of conclusions and, consequently, the obtaining of the final document.

4. Results

4.1 Co-occurrence of words

Figure 2 shows the co-occurrence of keywords found in the publications identified in the Scopus database.

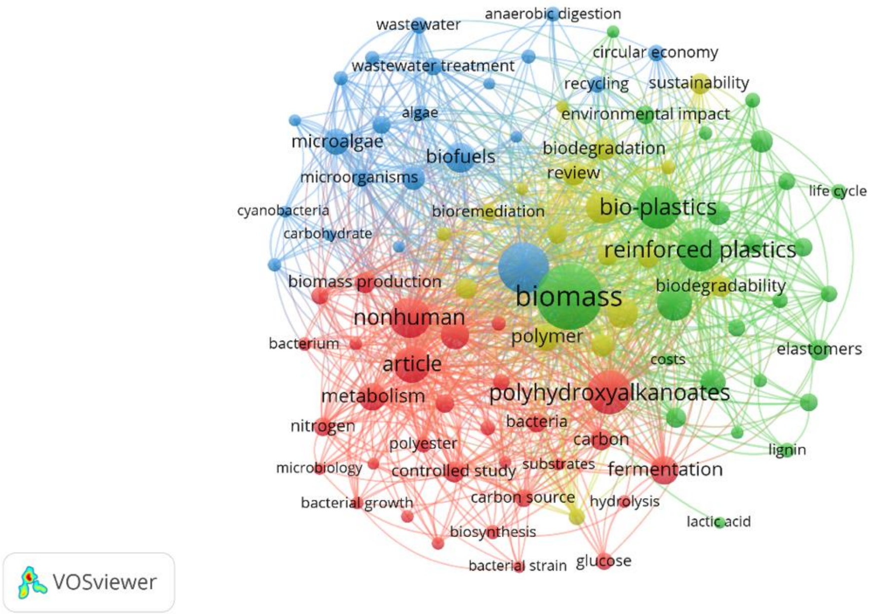

Figure 2. Co-occurrence of words

Source: Authors' own elaboration (2023); based on data exported from Scopus.

Biomass was the most frequently used keyword within the studies identified through the execution of Phase 1 of the Methodological Design proposed for the development of this article. Bioplastics are among the most frequently used variables, associated with variables such as Reinforced Plastic, Biodegradability, Polymer, Environmental Impact, Nanoparticles, Bioremediation. From the above, he says, nanoparticle catalysts hold immense promise for the efficient production of bioplastics from biomass. Their unique properties, including large surface area, catalytic activity, selectivity, adaptability, and sustainability, make them invaluable tools for advancing the field of green plastics. As research in this area continues to grow, nanoparticle catalysts are poised to play a critical role in realizing the full potential of bioplastics as a sustainable alternative to conventional plastics, contributing to a more environmentally friendly and economically viable future

4.2 Distribution of scientific production by year of publication

Figure 3 shows how scientific production is distributed according to the year of publication.

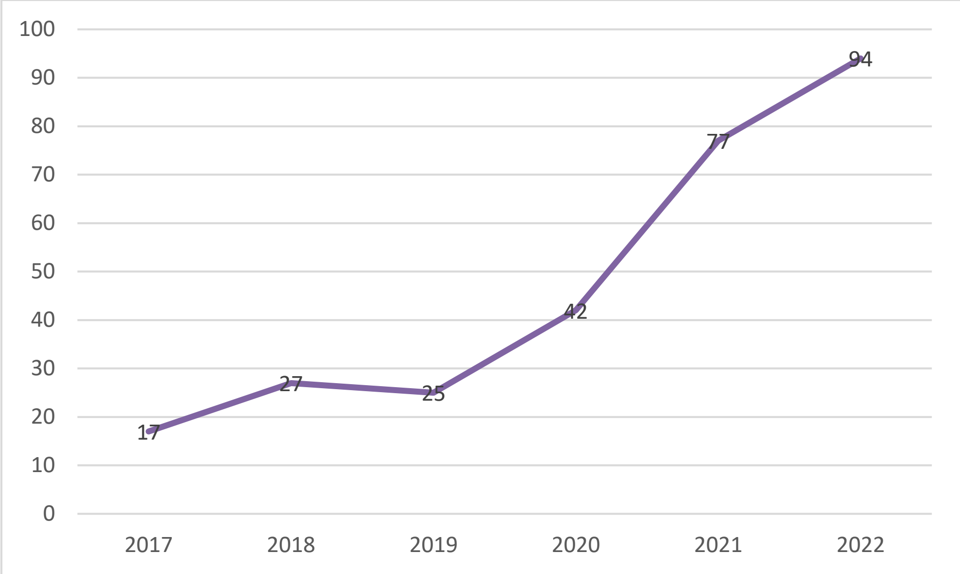

Figure 3. Distribution of scientific production by year of publication.

Source: Authors' own elaboration (2023); based on data exported from Scopus

Among the main characteristics evidenced through the distribution of scientific production by year of publication, the number of publications registered in Scopus was in 2022, reaching a total of 94 documents published in journals indexed on this platform. This can be explained by articles such as the one entitled "Revealing the phenotypic and genomic background for the production of PHA from crude glycerol from rapeseed biodiesel using Photobacterium ganghwense C2.2" This study aimed to create an in-depth view of the utilization of Photobacterium ganghwense C2.2 for PHA production by linking a wide range of characterization methods: Annotation of the strain's genome-wide metabolic pathway, high-throughput phenotypic testing, and biomass analysis through plate and culture assays in flasks and bioreactors. We confirmed, under PHA production conditions, urea catabolization, fatty acid degradation and synthesis, high pH variation, and tolerance to osmotic stress. With urea as the nitrogen source, pure glycerol and crude rapeseed biodiesel were comparatively analysed as carbon sources for fermentation at 20 °C. Flask cultures produced 2.2 g/l and 2 g/l of PHA at 120 h, respectively, with molecular weights of 428,629 g/mol and 81,515 g/mol. The batch culture in a bioreactor doubled the biomass accumulation (10 g/L and 13.2 g/L) in 48 h, with a PHA productivity of 0.133 g/(L·h) and 0.05 g/(L·h). Therefore, phenotypic and genomic analyses determined the successful use of Photobacterium ganghwense C2.2 for PHA production using crude urea and glycerol and 20 g/L NaCl, without pH adjustment, providing the basis for a viable fermentation process.(Lascu, 2022)

4.3 Distribution of scientific production by country of origin.

Figure 4 shows how the scientific production is distributed according to the nationality of the authors.

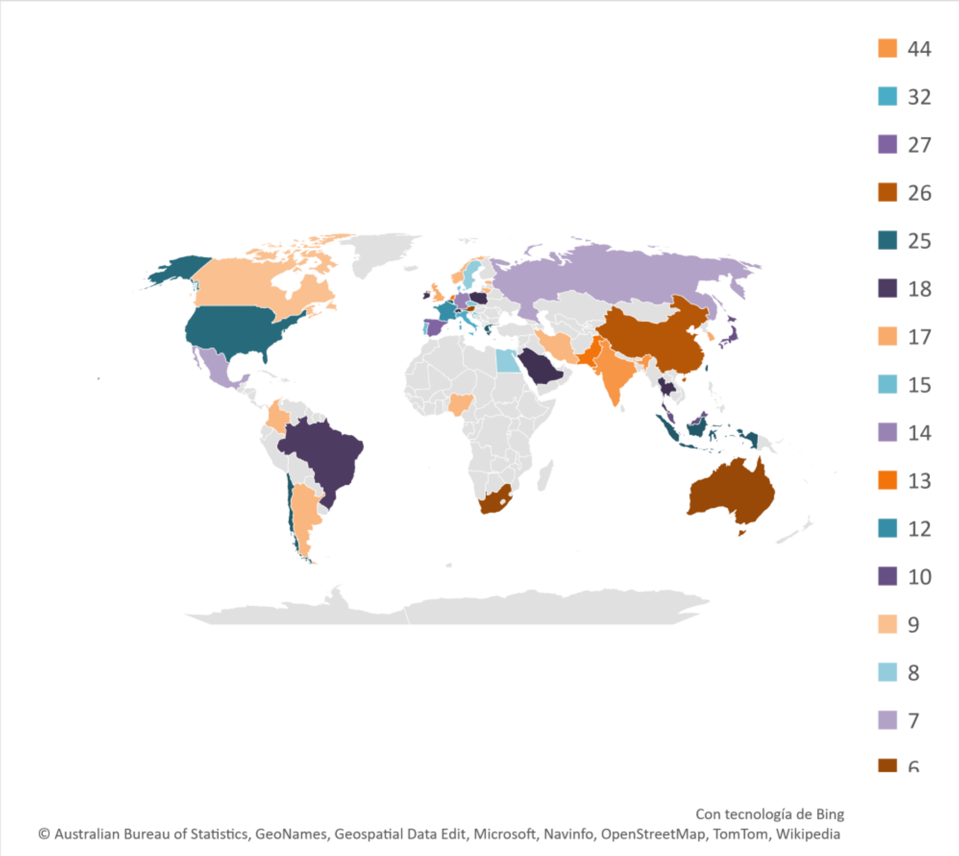

Figure 4. Distribution of scientific production by country of origin.

Source: Authors' own elaboration (2023); based on data provided by Scopus.

Within the distribution of scientific production by country of origin, the registrations from institutions were taken into account, establishing India as the country of this community, with the highest number of publications indexed in Scopus during the period 2017-2022, with a total of 44 publications in total. In second place, Italy with 32 scientific papers, and Spain occupying the third place presenting to the scientific community, with a total of 27 papers among which is the article entitled "Process conditions affect the properties and results of polyhydroxyalkanoate accumulation in municipal activated sludge." The scope of study is to systematically compare commonly reported process conditions for PHA accumulation using large-scale municipal activated sludge. A biomass acclimatization step combined with a pulsed feeding strategy resulted in maximum average PHA contents and product yields. pH control and active nitrification produced no observable effects on PHA productivity. Under these conditions, a high molecular weight polymer (1536 ± 221 kDa can be produced). Polymer extraction recoveries were influenced by the molecular weight of PHA. A standard protocol for an activated sludge PHA accumulation test has been developed that includes further processing and standardized extraction and is available as a supplementary material.(Estévez-Alonso, 2022)

4.4 Distribution of scientific production by area of knowledge

Figure 5 shows the distribution of the elaboration of scientific publications based on the area of knowledge through which the different research methodologies are implemented.

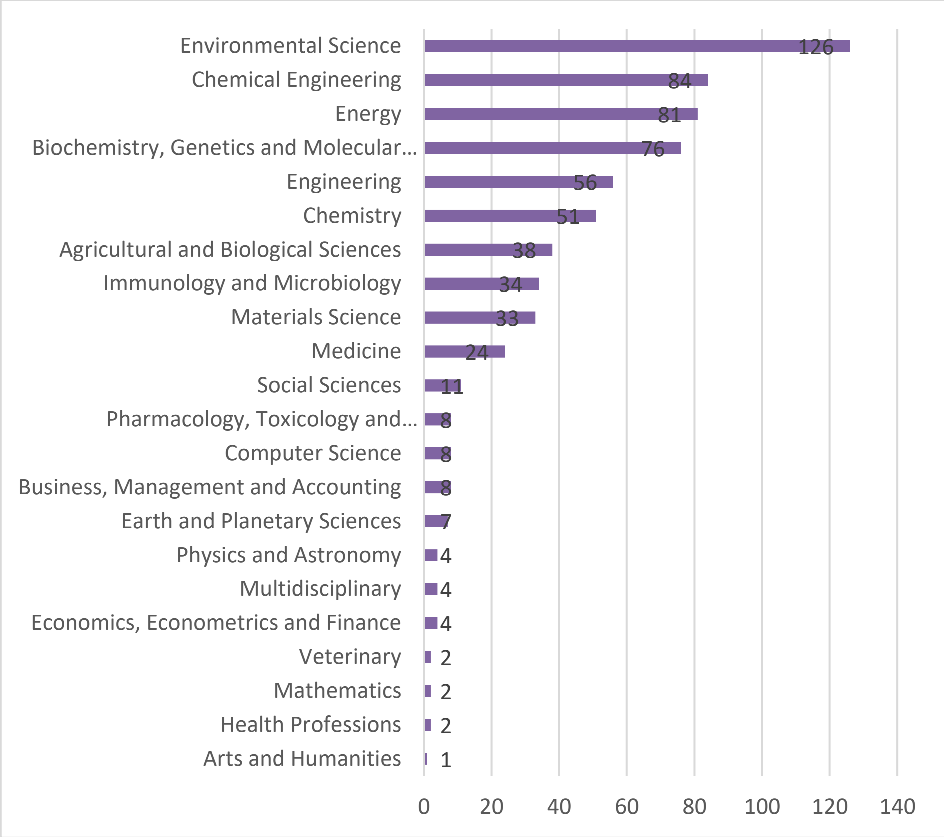

Figure 5. Distribution of scientific production by area of knowledge.

Source: Authors' own elaboration (2023); based on data provided by Scopus.

Environmental science was the area of knowledge with the highest number of publications registered in Scopus, with a total of 126 documents that have been based on their variable methodologies: Production of Bioplastics and Biomass. In second place, Chemical Engineering with 84 articles and Energy in third place with 81. The above can be explained thanks to the contribution and study of different branches, the article with the greatest impact was registered by the Environmental Science area entitled "Improvement of thistle biomass in mixtures based on polyhydroxybutyrate: a holistic approach for the synthesis of biopolymers and additives" This work investigates the valorization of different components of thistle in high value-added products, which are eventually recombined into novel improved bioplastics. Bioprocesses were established for the production of polyhydroxybutyrate (PHB) and medium-chain length polyhydroxyalkanoates (mcl-PHA) from root inulin and seed oil, respectively, highlighting the effect of process conditions on polymer properties. The ternary mixture, in which mcl-PHA and epoxidized thistle oil were added to the PHB polymer matrix, evidenced a synergistic effect of both additives in the modulation of the structural and thermal properties of PHB, promoted by the physical interaction that occurs between the components. This proof of concept frames the article in the holistic approach of the circular economy applied to the production of bioplastics.(Turco, 2022)

4.5 Type of publication

In the following graph, you will see the distribution of the bibliographic finding according to the type of publication made by each of the authors found in Scopus.

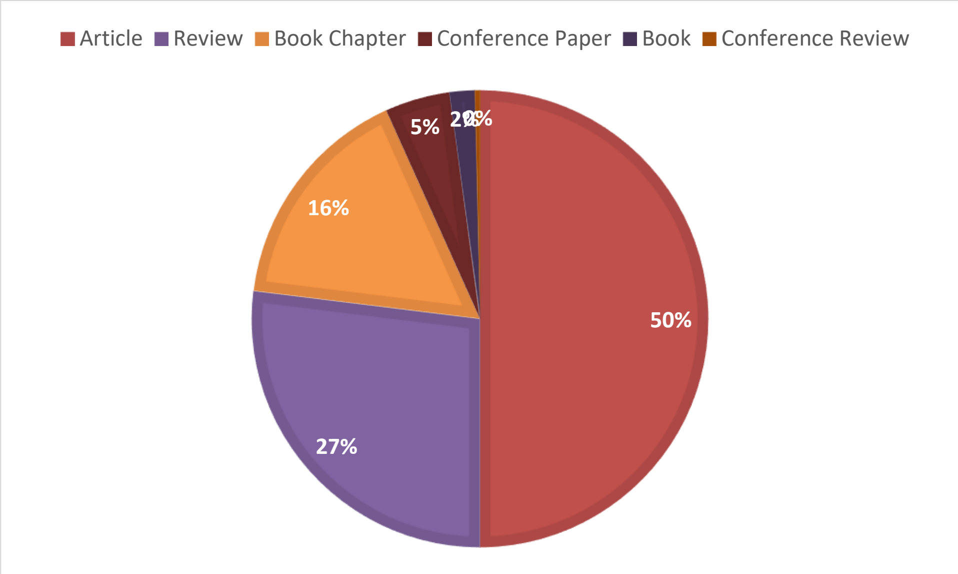

Figure 6. Type of publication.

Fountain: Authors' own elaboration (2023); based on data provided by Scopus.

The type of publication most frequently used by the researchers referenced in the body of this document was the one entitled Journal Articles with 50% of the total production identified for analysis, followed by Journal with 27%. Chapter of the book are part of this classification, representing 16% of the research papers published during the period 2017-2022, in journals indexed in Scopus. The aim of this work was to test a combination of MCCs and CNCs obtained from giant reed biomass (Arundo donax L.), kenaf (Hibiscus cannabinus L.) and miscanthus (Miscanthus × giganteus Greef et Deu.) as reinforcement. agents in Ch. MCC and CNC extraction was carried out using an alkaline pretreatment approach followed by acid hydrolysis. The particles were incorporated into Ch in different proportions (1.5%, 2% and 2.5% w/w chitosan), and the resulting biocomposites were fully characterized in terms of their morphology, mechanical and optical properties, permeability (oxygen and water vapour).), water wettability, thermal analysis, X-ray diffraction and FT-IR. For comparison, chitosan films reinforced with commercial nanocellulose were tested at the same rates. Improvement was observed in most samples following the incorporation of MCC/CNC, as anticipated. The MCC/CNC sample isolated from the giant cane was the one that most improved the properties of the film. Among the amounts added, the 2.5% level had the most encouraging effects, significantly improving strength and stiffness and reducing oxygen and water vapour permeability, which are essential characteristics in the use of bio-based films, for example. the food packaging industry. For this MCC/CNC ratio, the films demonstrated the potential of the film with 2% commercial CNC. (Pires, 2022)

5. Conclusions

Through the bibliometric analysis carried out in this research work, it was established that India was the country with the highest number of published records for the Bioplastics Production and Biomass variables. with a total of 44 publications in the Scopus database. In the same way, it was possible to establish that the application of theories framed in the area of Environmental Science, were used more frequently in relation to the production of bioplastics from biomass, the characterization of nanoparticle catalysts is an important step towards obtaining sustainable and environmentally friendly plastic alternatives. However, recent research in the world of nanocatalysts, which have been fundamental pillars for catalyzing the conversion of raw materials extracted from plants, such as biomass, into biopolymers. This article highlights these key characteristics of nanoparticle catalysts, including their tunable properties, superior characteristics, and higher selectivity, which are essential for the manufacture of customized bioplastics with the properties desired by the various markets. While we face challenges related to the environmental impact of conventional plastics, the use of nanoparticle catalysts in the production of bioplastics is promising. The increased efficiency achieved with these catalysts not only increases the economic viability of bioplastics, but also significantly reduces greenhouse gas emissions and dependence on fossil fuels.

Although significant advances have been made in nanoparticle catalysts for the production of bioplastics, there are still areas to be explored and improved. Ongoing research into catalyst design, synthesis methods, and scalability is critical to exploiting the full potential of these catalysts. In addition, a holistic approach that considers the entire life cycle of bioplastics, from the procurement of the feedstock to its management, is critical to ensuring their true sustainability.

References

Estévez-Alonso, Á. A.-A.-S. (2022). Process conditions affect the properties and results of polyhydroxyalkanoate accumulation in municipal activated sludge. Netherlands.

Lascu, I. T. (2022). Revealing the phenotypic and genomic background for PHA production from crude glycerol from rapeseed biodiesel using Photobacterium ganghwense C2.2. ROMANIA.

Pires, J. R. (2022). Micro and nanocellulose extracted from energy crops as reinforcing agents in chitosan films. Portugal.

Turco, R. C. (2022). Enhancement of thistle biomass in polyhydroxybutyrate-based mixtures: a holistic approach to the synthesis of biopolymers and additives. ITALY.

CHARIGUAMÁN C., J. A. Characterization of Starch Bioplastic Elaborated by the Casting Method Reinforced with Passion Fruit Albedo (Passiflora Edulis Spp.). [online] Escuela Agrícola Panamericana, Zamorano, 2015, Available at: https://bdigital.zamorano.edu/server/api/core/bitstreams/06a5dc04-9bc7-4253-a0ad-30c4c6c160be/content.

CHEN, Q., et al. Recent Progress in Chemical Modification of Starch and Its Applications. RSC Advances, vol. 5, no. 83, 2015, pp. 67459–74, doi:10.1039/C5RA10849G.

CHI, H., et al. Effect of Acetylation on the Properties of Corn Starch. Food Chemistry, vol. 106, no. 3, Feb. 2008, pp. 923–28, doi:10.1016/j.foodchem.2007.07.002.

COLUSSI, R., et al. Acetylation of Rice Starch in an Aqueous Medium for Use in Food. LWT - Food Science and Technology, vol. 62, no. 2, July 2015, pp. 1076–82, doi:10.1016/j.lwt.2015.01.053.

CONTRERAS C., R. Development of a Film from Purple Sweet Potato Acetylated Starch as a Potential Alternative in the Development of Biofilms for Food Coating. [online]. Universidad Michoacana de San Nicolás de Hidalgo, 2021, Available at: http://bibliotecavirtual.dgb.umich.mx:8083/xmlui/bitstream/handle/DGB_UMICH/6401/FQFB-M-2021-0349.pdf?sequence=1&isAllowed=y.

CRISTIANINI, M., and GUILLÉN S., J. S. Extraction of Bioactive Compounds from Purple Corn Using Emerging Technologies: A Review. Journal of Food Science, vol. 85, no. 4, Apr. 2020, pp. 862–69, doi:10.1111/1750-3841.15074.

DECONINCK, S, AND BRUNO W. Benefits and Challenges of Bio- and Oxo-Degradable Plastics [online]. 2013. Available in: https://www.ows.be/wp-content/uploads/2013/10/Final-Report-DSL-1_Rev02.pdf.

DELLA V, D. G., et al. EFFECT OF REACTION TIME ON BANANA STARCH ACETYLATION. [online], Revista Mexicana de Ingeniería Química, vol. 7, no. 3, 2008, pp. 283–91, Available at: https://www.redalyc.org/pdf/620/62011164012.pdf.

DELLA V., D. G. Effect of the Level of Acetylation on the Morphological and Molecular Characteristics of Banana Starch (Musa Paradisiaca L). [online] National Polytechnic Institute, 2007, Available at: https://tesis.ipn.mx/bitstream/handle/123456789/4174/della_valle_denisseguerra.pdf?sequence=1&isAllowed=y.

DENAVI, G. A., et al. Structural and Functional Properties of Soy Protein Isolate and Cod Gelatin Blend Films. Food Hydrocolloids, vol. 23, no. 8, Dec. 2009, pp. 2094–101, doi:10.1016/j.foodhyd.2009.03.007.

ECURED. Purple corn. [online] EcuRed, 2017, p. 5, Available at: https://www.ecured.cu/Maíz_morado#Composici.C3.B3n_qu. C3. ADmica.

ENRÍQUEZ C., M., et al. COMPOSITION AND PROCESSING OF BIODEGRADABLE STARCH-BASED FILMS. [online], Biotechnology in the Agricultural and Agroindustrial Sector, vol. 10, no. 1, 2012, pp. 182–92, Available at: http://www.scielo.org.co/pdf/bsaa/v10n1/v10n1a21.pdf.

ESCOBAR, D., et al. Biodegradable and Edible Films Developed Based on Whey Protein Isolate: A Study of Two Manufacturing Methods and the Use of Potassium Sorbate as a Preservative. INNOTEC, vol. 4, May 2011, pp. 33–36, doi:10.26461/04.07.

ESPINOZA A., F. H., and PUGLISEVICH R., D. C. Influence of Glycerol Percentage on Tensile Strength and Deformation of Starch-Based Biodegradable Plastics of the Manihot Esculenta Crantz Tuber. [online], UNIVERSIDAD NACIONAL DE TRUJILLO, 2019, Available at: https://dspace.unitru.edu.pe/bitstream/handle/UNITRU/12561/ESPINOZA ARROYO%2C Franco Herbert%3B PUGLISEVICH RUIZ%2C Diana Carolina.pdf?sequence=1&isAllowed=y.

FIGUEROA F., J. A., et al. ACETYLATION OF NATIVE SWEET POTATO STARCH (Ipomeas Batata L). [online] ProQuest, Vol. 23, 2016, pp. 174–79, Available at: https://www.proquest.com/openview/11a540a534b2053583220828fe7bb688/1?pq-origsite=gscholar&cbl=1806352.

FUKAMACHI, K., et al. Purple Corn Color Suppresses Ras Protein Level and Inhibits 7,12-Dimethylbenz a Anthracene-Induced Mammary Carcinogenesis in the Rat. Cancer Science, July 2008, doi:10.1111/j.1349-7006.2008.00895.x.

GARG, S., and JANA, A. K. Characterization and Evaluation of Acylated Starch with Different Acyl Groups and Degrees of Substitution. Carbohydrate Polymers, vol. 83, no. 4, Feb. 2011, pp. 1623–30, doi:10.1016/j.carbpol.2010.10.015.

GEISSMAN, T. A. Principles of Organic Chemistry. Edited by S.A. REVERTÉ, SECOND ED., 1973.

GODÍNEZ C., M. F., et al. BIOPLASTICS: ENVIRONMENTAL SOLUTIONS. [online], Instituto Asunción de México, vol. 1, no. 1, 2016, pp. 1–17, Available at: https://vinculacion.dgire.unam.mx/vinculacion-1/Memoria-Congreso-2016/trabajos-ciencias-biologicas/biologia/11.pdf.

GOVINDARAJU, I., et al. Investigation of Physico-Chemical Properties of Native and Gamma Irradiated Starches. Materials Today: Proceedings, vol. 55, 2022, pp. 12–16, doi:10.1016/j.matpr.2021.11.641.

GRANADOS, C., et al. Functional properties of starch. Biotechnology in the Agricultural and Agroindustrial Sector, 2014, pp. 90–93.

GUERRA D. V., D., et al. EFFECT OF REACTION TIME ON THE ACETYLATION OF PLANTAIN STARCH. [online], Revista Mexicana de Ingeniería Química, vol. 7, 2008, pp. Available at: 283–90, http://www.scielo.org.mx/pdf/rmiq/v7n3/v7n3a13.pdf.

GUNARATNE, A. Effect of Heat–Moisture Treatment on the Structure and Physicochemical Properties of Tuber and Root Starches. Carbohydrate Polymers, vol. 49, no. 4, Sept. 2002, pp. 425–37, doi:10.1016/S0144-8617(01)00354-X.

HAN, F., et al. Synthesis, Optimization and Characterization of Acetylated Corn Starch with the High Degree of Substitution. International Journal of Biological Macromolecules, vol. 59, Aug. 2013, pp. 372–76, doi:10.1016/j.ijbiomac.2013.04.080.

HERNANDEZ M., M., et al. Physicochemical Characterization of Starches from Tubers Grown in Yucatan, Mexico. Food Science and Technology, vol. 28, no. 3, Sept. 2008, pp. 718–26, doi:10.1590/S0101-20612008000300031.

HUANG, J., et al. Acetyl Substitution Patterns of Amylose and Amylopectin Populations in Cowpea Starch Modified with Acetic Anhydride and Vinyl Acetate. Carbohydrate Polymers, vol. 67, no. 4, Feb. 2007, pp. 542–50, doi:10.1016/j.carbpol.2006.06.027.

JAMARANI, R., et al. How Green Is Your Plasticizer? Polymers, vol. 10, no. 8, July 2018, p. 834, doi:10.3390/polym10080834.

JOAQUI D., D. F., and VILLADA C., H. S. OPTICAL PROPERTIES AND PERMEABILITY OF WATER VAPOUR IN FILMS PRODUCED FROM STARCH. [online], Biotechnology in the Agricultural and Agroindustrial Sector, vol. 2, 2013, pp. 59–68, Available at: http://www.scielo.org.co/pdf/bsaa/v11nspe/v11nespa07.pdf.

LAWAL, O. Composition, Physicochemical Properties and Retrogradation Characteristics of Native, Oxidised, Acetylated and Acid-Thinned New Cocoyam (Xanthosoma Sagittifolium) Starch. Food Chemistry, vol. 87, no. 2, Sept. 2004, pp. 205–18, doi:10.1016/j.foodchem.2003.11.013.

LAWAL, O. S. Succinyl and Acetyl Starch Derivatives of a Hybrid Maize: Physicochemical Characteristics and Retrogradation Properties Monitored by Differential Scanning Calorimetry. Carbohydrate Research, vol. 339, no. 16, Nov. 2004, pp. 2673–82, doi:10.1016/j.carres.2004.08.015.

LEDESMA U., A. A., et al. Corn Starch and Quinoa Bioplastics for Use as Biodegradable Food Wraps. [online], Technical and Applied Sciences, vol. 7, no. 4, 2021, pp. 39–56, Available at: https://www.dominiodelasciencias.com/ojs/index.php/es/article/view/2080/4356.

LIMA, A. M. F., et al. Influência Da Adição de Plastificante Do Processo de Reticulação Na Morphologia, Absorção de Aguá e Propriedades Mecânicas de Filmes de Alginate de Sodium. Chemistry Nova, vol. 30, no. 4, Aug. 2007, doi:10.1590/S0100-40422007000400014.

LÓPEZ G., V. A.. Diffusion and Multiplication of Purple Grape Cluster Maize in the Provinces of Chimborazo, Imbabura and Cotopaxi. Quito, EC: INIAP, Santa Catalina Experimental Station, Núcleo de Desarrollo Tecnológico/Unidad de Desarrollo Tecnológico Cotopaxi, 2016, 2016, pp. 1–14.

LÓPEZ, O. V., et al. Physicochemical Characterization of Chemically Modified Corn Starches Related to Rheological Behavior, Retrogradation and Film Forming Capacity. Journal of Food Engineering, vol. 100, no. 1, Sept. 2010, pp. 160–68, doi:10.1016/j.jfoodeng.2010.03.041.

MALI, S., et al. Barrier, Mechanical and Optical Properties of Plasticized Yam Starch Films. Carbohydrate Polymers, vol. 56, no. 2, June 2004, pp. 129–35, doi:10.1016/j.carbpol.2004.01.004.

MANO, J. F., et al. Thermal Properties of Thermoplastic Starch/Synthetic Polymer Blends with Potential Biomedical Applicability. Journal of Materials Science: Materials in Medicine, vol. 14, 2003, pp. 127–35.

MANZANO N., P. A. Extraction of Anthocyanins from Purple Corn Crown (Zea Mays L.) For the Use of Agricultural Residues. [online], UNIVERSIDAD TÉCNICA DE AMBATO, 2016, Available at: https://repositorio.uta.edu.ec/bitstream/123456789/24479/1/BQ 105.pdf.

MARK, A. M., and MEHLTRETTER, C. L. Facile Preparation of Starch Triacetates. Starch–Stärke, 1972, pp. 73–76.

MATIGNON, A., and TECANTE, A. Starch Retrogradation: From Starch Components to Cereal Products. Food Hydrocolloids, 2017, pp. 43–50.

MAZA, J. E., et al. Obtaining Chulpi Corn Starch (Zea Mays Amylosaccharata). Technical and Applied Sciences, vol. 7, no. 3, 2021, pp. 943–58, doi:10.23857/dc.v7i3.2032.

MEDINA V., O. J., et al. MODIFIED ARRACACHA STARCH FILMS CHARACTERIZATION AND ITS POTENTIAL UTILIZATION AS FOOD PACKAGING. [online], JOURNAL OF THE FACULTY OF PHARMACEUTICAL CHEMISTRY, vol. 19, no. 2, 2012, pp. 186–96, Available at: http://www.scielo.org.co/pdf/vitae/v19n2/v19n2a5.pdf.

MELO, V., and CUAMATZI, O. BIOCHEMISTRY OF METABOLIC PROCESSES. 2019.

METTLER, T. Moisture Determination Method for Starch (Corn) with the HR83 Halogen Moisture Analyzer. [online], 2020, Available at: https://www.mt.com/mt_ext_files/Editorial/Generic/6/Starch_Editorial-Generic_1112878454980_files/Applikationsdatenblatt_StaerkeMais-d_ES.pdf.

MILADINOV, V. D., and HANNA, M. A. Starch Esterification by Reactive Extrusion. Industrial Crops and Products, 2000, pp. 51–56.

MIRMOGHTADAIE, L., et al. Effects of Cross-Linking and Acetylation on Oat Starch Properties. Food Chemistry, vol. 116, no. 3, Oct. 2009, pp. 709–13, doi:10.1016/j.foodchem.2009.03.019.

NOLAZCO C., D., and ARAUJO V. M. OBTAINING A PURPLE CORN FILTER (Zea Mays L.), EVALUATION OF COLOR LOSS AND ANTHOCYANIN DEGRADATION IN STORAGE. Scientific Annals, vol. 76, no. 2, Dec. 2016, p. 350, doi:10.21704/ac.v76i2.801.

NTE, INEN, and 2051:1995. Grains and Cereals. Ground corn, grits, flour, critz. Requirements.

PEDRESCHI, R., and CISNEROS, Z. L. Phenolic Profiles of Andean Purple Corn (Zea Mays L.). Food Chemistry, vol. 100, no. 3, Jan. 2007, pp. 956–63, doi:10.1016/j.foodchem.2005.11.004.

PEINADO D., M. STUDY OF THE BIODEGRADABILITY AND DISINTEGRATION OF STARCH AND PVA-BASED FILMS INCORPORATING DIFFERENT ANTIMICROBIAL SUBSTANCES. [online], UNIVERSITAT POLITÈCNICA DE VALÈNCIA, 2015, Available in: https://riunet.upv.es/bitstream/handle/10251/56383/ COMBING STUDY OF THE BIODEGRADABILITY AND DEGREE OF DISINTEGRATION OF STARCH-BASED FILMS AND P.... pdf?sequence=1.

PORRAS N., D. P., and ARANA, N. B. EVALUATION OF PHYSICAL PROPERTIES OF THERMOPRESSING BIOPLASTICS MADE FROM CASSAVA FLOUR. [online], Biotechnology in the Agricultural and Agroindustrial Sector, vol. 12, no. 2, 2014, pp. 40–48, available at: http://www.scielo.org.co/pdf/bsaa/v12n2/v12n2a05.pdf.

PRIETO M, J., et al. Acetylation and Characterization of Barley Starch. [online], Latin American Journal of Natural Resources, vol. 6, 2010, p. 33, Available at: http://200.23.187.21/index.php/rlrn/article/view/181/117.

RACHED, L. B., et al. Evaluation of the Physicochemical and Functional Properties of White and Purple Mapuey Starches (Dioscorea Trifida L.) Modified by Acetylation and Oxidation. Journal of the Faculty of Pharmacy, vol. 76, no. 1, 2014, pp. 84–95.

RINCÓN, A. M., et al. Effect of Acetylation and Oxidation on Some Properties of Starch from Breadfruit Seeds (Artocarpus Altilis). Latin American Archives of Nutrition, 2007, pp. 287–94.

RINCÓN, A. M., et al. Effect of Acetylation and Oxidation on Some Properties of Starch from Breadfruit Seeds (Artocarpus Altilis). [online], RINCON, vol. 57, no. 3, 2007, pp. 287–94, Available at: http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0004-06222007000300012.

SALINAS M., Y., et al. Physicochemical changes of starch during maize nixtamalization in varieties with different grain hardness. [online], SCIELO, vol. 53, no. 2, 2003, pp. 188–93, Available at: http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0004-06222003000200011.

SÁNCHEZ T., et al. Technical Guide for Cassava Starch Production and Analysis. [online], FAO AGRICULTURAL SERVICES BULLETIN, 2007, pp. 66–76, Available at: https://www.fao.org/3/a1028s/a1028s.pdf.

SINGH, J., et al. Factors Influencing the Physico-Chemical, Morphological, Thermal and Rheological Properties of Some Chemically Modified Starches for Food Applications—A Review. Food Hydrocolloids, vol. 21, no. 1, Jan. 2007, pp. 1–22, doi:10.1016/j.foodhyd.2006.02.006.

SINGH, N., et al. Structural, Thermal and Viscoelastic Characteristics of Starches Separated from Normal, Sugary and Waxy Maize. Food Hydrocolloids, vol. 20, no. 6, Aug. 2006, pp. 923–35, doi:10.1016/j.foodhyd.2005.09.009.

SÍVOLI, L., and PÉREZ, E. Physicochemical and Functional Characteristics of Chemically Modified Corn Starch. Cross-Linking Formation. [online], Tecnol. Food. (Mex), vol. 31, no. 1, 2014, pp. 5–9, Available at: https://www.researchgate.net/publication/230802490_Caracteristicas_Fisicoquimicas_y_Funcionales_del_Almidon_de_Maiz_Modificado_Quimicamente_Formacion_de_Enlaces_Cruzados.

SODHI, N. S., and SINGH, N. "Characteristics of Acetylated Starches Prepared Using Starches Separated from Different Rice Cultivars." Journal of Food Engineering, vol. 70, no. 1, Sept. 2005, pp. 117–27, doi:10.1016/j.jfoodeng.2004.09.018.

SONG, J. H., et al. Biodegradable and Compostable Alternatives to Conventional Plastics. Philosophical Transactions of the Royal Society B: Biological Sciences, vol. 364, no. 1526, July 2009, pp. 2127–39, doi:10.1098/rstb.2008.0289.

SOTO, D., and OLIVA, H. METHODS FOR PREPARING STARCH-BASED CHEMICAL AND PHYSICAL HYDROGELS: A REVIEW. [online], Rev. LatinAm. Metal. Mat, 2011, pp. 154–55, Dsiponoble in: https://www.researchgate.net/profile/Haydee-Oliva/publication/262478738_Metodos_para_preparar_hidrogeles_quimicos_y_fisicos_basados_en_almidon_Una_revision/links/5c1ac584a6fdccfc705ac795/Metodos-para-preparar-hidrogeles-quimicos-y-fisicos-basados-en-almid.

SULBARÁN, A., et al. Acetylation of Millet Starch (Pennisetum Glaucum) and Evaluation of Its Application as a Possible Excipient. Colombian Journal of Chemical-Pharmaceutical Sciences, vol. 47, no. 2, May 2018, pp. 255–76, doi:10.15446/rcciquifa.v47n2.73969.

SULBARAN R., A. E. Acetylation of Millet Starch and Evaluation of its Application as a Possible Pharmaceutical Auxiliary. [online], Universidad Nacional de Colombia, 2013, Available at: https://repositorio.unal.edu.co/bitstream/handle/unal/20459/192577.20131216.pdf?sequence=1&isAllowed=y.