

Biodegradable Plastic: A Sustainable and Lasting Solution to Plastic Waste Management in Nigeria

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Abstract

Biodegradable plastics offer a promising pathway to mitigate Nigeria's mounting plastic pollution by substituting persistent, fossil-based polymers with materials derived from renewable feedstocks that can be mineralised under appropriate conditions. This review assesses the viability of biodegradable plastics as a sustainable and lasting solution to Nigeria's plastic waste management challenge. It synthesises evidence on common biopolymers (PLA, PHA, starch blends, and cellulose derivatives), production routes, biodegradation mechanisms, and major application sectors, including packaging, agriculture, biomedicine, and consumer goods. The analysis highlights environmental benefits such as reduced persistent waste, potential soil health improvements, and lower lifecycle greenhouse gas emissions when locally sourced feedstocks are used. The economic opportunities identified include job creation across agriculture and manufacturing, cost savings in waste management where composting infrastructure exists, and value retention through local feedstock utilisation. However, the review emphasises critical barriers: high production costs, limited industrial composting and sorting infrastructure, weak regulatory standards and labels for compostability, low technical capacity for local polymer development, and public confusion over disposal pathways. Comparative policy lessons from Kenya, Rwanda, and South Africa demonstrate that strong regulation, investment in composting infrastructure, public sensibilization, and industry engagement are key enablers for scaling biodegradable solutions. To realise benefits in Nigeria, the paper recommends creating clear standards and certification schemes, targeting subsidies or tax incentives to lower cost barriers, investing in industrial composting and digital sorting technologies, and providing formal support for informal waste collectors. The review provides a practical implementation roadmap and research priorities to guide policymakers, industry and researchers towards scalable, context-specific solutions that align with Nigeria's National Policy on Plastic Waste Management and international sustainability commitments. In conclusion, biodegradable plastics can contribute substantially to a circular plastics economy in Nigeria if implemented within an integrated framework that combines policy reform, infrastructure development, technological innovation, and sustained public education.

Keywords: Biodegradable Plastic, Waste Management, Circular economy, Sustainability, Digital Technology.

Introduction

Plastics have become an indispensable material in modern society, widely used across diverse sectors including packaging, construction, medicine, and technology. Their unique combination of durability, versatility, light weight, and resistance to degradation has made them a material of choice for manufacturers and consumers alike. However, these same properties that make plastics useful also contribute to one of the most pressing environmental challenges of our time — plastic pollution. As plastics resist natural degradation, their accumulation in the environment has led to serious ecological, economic, and public health problems across the globe (Akinlabi and Oladapo, 2024).

Globally, plastic production and consumption have increased at an exponential rate, driven by industrial expansion, urbanisation, and population growth. China, North America, and Europe dominate global plastic manufacturing, with China accounting for about a third of total output (Liu and Liu, 2023; Ramaswamy et al., 2024; Issifu et al., 2025). This rapid growth in production has resulted in a parallel rise in plastic waste generation, with hundreds of millions of tonnes produced annually and an increasing share ending up in oceans, landfills, and informal dumpsites. The persistence of plastic waste in terrestrial and marine ecosystems, its fragmentation into microplastics, and its potential to enter food chains have made effective waste management an urgent global concern.

In Nigeria, the plastic industry is both a source of economic growth and environmental distress. The nation produces and imports large volumes of polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET), with annual consumption exceeding 1.25 million tonnes as of 2022 (World Bank, 2020). The packaging sector alone accounts for more than half of total plastic use, while other significant consumers include the construction and automotive industries (GMI Research, 2024). However, waste management systems have not kept pace with this rapid consumption growth. Only about 12 per cent of plastic waste generated in Nigeria is recycled, while the vast majority ends up in landfills, open dumps, or waterways (Animashaun et al., 2024). The informal waste sector, comprising thousands of waste pickers, plays a crucial role in collection and recycling but operates without adequate institutional support, safety regulations, or access to technology (Wirnkor et al., 2019).

The challenges of plastic waste management in Nigeria mirror global trends: insufficient infrastructure, poor sorting and collection systems, weak enforcement of environmental regulations, low public awareness, and limited investment in waste recycling and valorisation (Gidigbi et al., 2020). Open burning of waste and indiscriminate dumping remains prevalent, contributing to air and soil pollution, greenhouse gas emissions, and health hazards for nearby communities. Furthermore, the absence of large-scale industrial composting facilities and standardised recycling systems has impeded the country's ability to transition toward sustainable waste practices (Animashaun et al., 2024).

Addressing these challenges requires the adoption of sustainable and innovative solutions that reduce reliance on non-degradable, fossil-based plastics. One promising approach is

the introduction of biodegradable plastics — materials derived from renewable resources such as starch, cellulose, and microbial fermentation products that can naturally decompose into non-toxic residues like carbon dioxide, water, and biomass (Wilson, 2023). These biodegradable alternatives have shown significant potential to replace conventional plastics in various applications, including packaging, agriculture, and biomedicine. Nevertheless, their successful implementation in Nigeria depends on overcoming several barriers, including high production costs, lack of technical capacity, inadequate regulatory frameworks, and limited public awareness about their benefits and proper disposal (Onyekachi and Chukwuemeka, 2022).

The urgent need for sustainable solutions to Nigeria's plastic pollution problem calls for an integrated approach that combines policy reform, infrastructure investment, scientific research, and public-private collaboration. Transitioning from the current linear model of "take-make-dispose" to a circular economy focused on reduction, reuse, and recycling is vital (Onaji-Benson and Agada Ali, 2023). The promotion of biodegradable plastics, alongside strong environmental governance, could provide a pathway toward reducing plastic pollution, conserving natural resources, and safeguarding the environment for future generations. This study therefore seeks to evaluate the viability of biodegradable plastics as a sustainable and lasting solution to Nigeria's plastic waste management crisis.

Methodology

This study adopts a systematic literature-review approach designed to locate, appraise and synthesise the best available evidence on biodegradable plastics as a sustainable solution to Nigeria's plastic-waste problem. The review concentrates on three outcome domains emphasised in the topic—biodegradation performance (timeframes and mechanisms), economic factors (production and retail costs), and policy/infrastructure readiness—and intentionally combines international literature with Nigeria-specific and African regional sources so that global trends can be meaningfully compared with local realities. The rationale for this blended scope follows the paper's emphasis on both technical material properties and the policy-infrastructure constraints that determine real-world benefits in Nigeria.

To create a reproducible and defensible evidence base, searches were run across multidisciplinary academic databases and Nigeria- and Africa-focused repositories. Core academic searches include Scopus, Web of Science, PubMed/Medline (for environmental/biological degradation studies), ScienceDirect and Google Scholar for breadth. To capture Nigerian and regional knowledge that is often absent from mainstream databases, African Journals Online (AJOL), university institutional repositories (e.g., major Nigerian universities), and the websites or report libraries of national.

Searches were constructed from three core keyword groups (polymer/product terms, terms, and outcome terms; geography/context terms) and combined with Boolean

operators to balance sensitivity and precision. The polymer/product group will include terms such as “biodegradable plastic,” “bioplastic,” “polylactic acid,” “PLA,” “polyhydroxyalkanoate,” “PHA,” “starch” and “cellulose acetate”. Outcome terms will cover biodegradation concepts and methods (e.g., “biodegrad*”, “compost*”, “mineralis*”, “anaerobic digestion”, “soil degrad*”), economic metrics (e.g., “cost”, “price”, “production cost”), and life-cycle and climate metrics (e.g., “life cycle”, “LCA”, “greenhouse gas*”, “GHG”, “carbon footprint”, “emission*”). Geography/context terms will include “Nigeria”, “West Africa”, “Africa”, and “global” to allow both focused local searches and comparative retrieval.

All search operations were logged in a search record that records database name, full search string, date executed, filters applied (language, year range), and number of hits exported. The preferred temporal window was contemporary (approximately 2019–present) to capture technological and policy developments. The English language was the primary filter.

Biodegradable Plastics as a Solution

Biodegradable plastics have also gained great popularity in recent years because they are considered future-oriented alternatives to conventional plastics derived from petroleum. The materials are designed to decompose under specific environmental situations through the intervention of naturally available microorganisms, thereby addressing the current problem of plastic pollution (Kim *et al.*, 2023). Biodegradable plastics are derived from various sources, such as renewable sources and fossil-based sources with biodegradable additives blended into conventional plastics (Ciardelli *et al.*, 2019). Biopolymers from plants, like polysaccharides and proteins, are often used to make biodegradable plastics (Jethani and Hebbar, 2021).

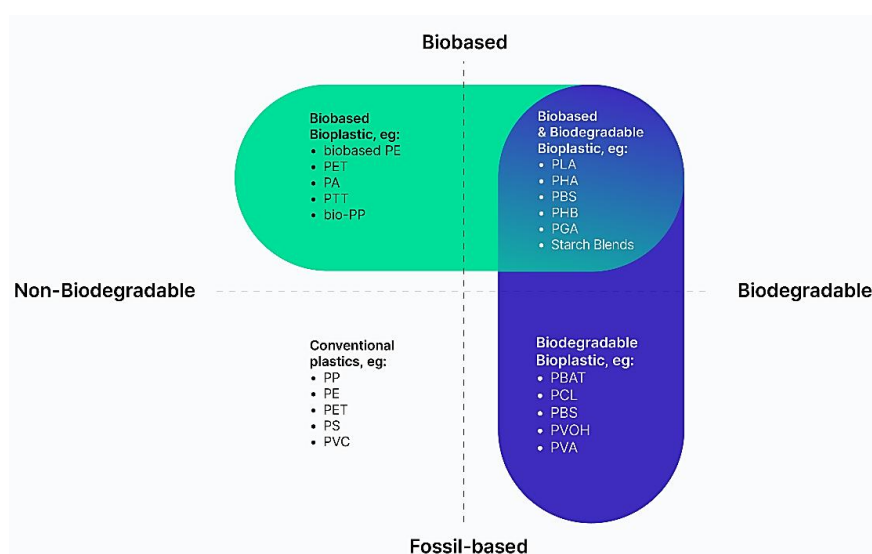


Figure 1: Bioplastics: Types and Biodegradability (Source: Circularise, 2025)

Polysaccharides, including cellulose and starch, are abundantly distributed across the globe and are currently being investigated for their potential to generate environmentally friendly plastics (Jethani & Hebbar, 2021; Aleksanyan, 2023). Starch-based plastics are increasingly recognised due to their cost-effectiveness, widespread availability, and ease of decomposition under typical environmental conditions (Jiang et al., 2020). Another notable biodegradable plastic is polylactic acid (PLA), synthesised from renewable raw materials like corn starch and sugarcane (Raj et al., 2022; Taib et al., 2023). As a member of the polyester family, PLA can be produced through multiple techniques, yielding variations in molecular weight and material characteristics (Taib et al., 2023). It exhibits excellent mechanical strength, optical clarity, and biodegradability, making it a viable replacement for traditional plastics in applications such as packaging (Subramaniam et al., 2019).

Table 1: Overview of Common Biodegradable Polymers

Polymer Type	Typical Feedstock Source	Bio-based?	Bio-degradable?	Common Degradation Environments (Variability Noted)	Key Properties/Trade-offs
PLA (Polylactic Acid)	Corn Starch, Sugarcane, Sugar Beet, Tapioca	Yes	Yes	Industrial Compost; Slow in Soil, Marine, Home Compost, Anaerobic Digestion	Rigid, Transparent, Good Mechanical Strength, Processable; Brittle, Low Heat Resistance ⁵
PHA/PHB (Polyhydroxyalkanoates/-butyrate)	Microbial Fermentation (Sugars, Lipids, Waste Streams)	Yes	Yes	Industrial & Home Compost, Soil, Marine, Anaerobic Digestion (Variable Rates)	Versatile (Rigid to Elastomeric), Good Barrier Properties; Can be Brittle, Costly ¹
Starch Blends	Plant Starch (Corn, Potato, Cassava) blended w/ others	Yes (Partially)	Yes	Industrial & Home Compost, Soil (Rate depends on blend)	Low Cost, Renewable; Often Brittle, Moisture Sensitive, Properties vary w/ blend ¹
Cellulose-based	Wood Pulp, Cotton, Bacteria	Yes	Yes	Compost, Soil (Modified forms vary)	Rigid, Strong (Native); Modified forms used for Films, Fibers, Hydrogels ¹
PBS (Polybutylene Succinate)	Fossil and/or Bio-based (Starch, Sugar)	Yes/Partially	Yes	Industrial Compost, Soil	Flexible, Heat Resistant, Processable, Good Blend Component ²⁰
PCL (Polycaprolactone)	Fossil-based	No	Yes	Compost, Soil (Slow degradation)	Processable, Biocompatible; Flexible, Slow Degradation Rate ⁷

PBAT (Polybutylene Adipate Terephthalate)	Fossil-based (potentially partly bio-based)	No (or Partial)	Yes	Industrial & Home Compost, Soil	Flexible, Tough, Processable; Often blended with PLA or Starch ²¹
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Note: Degradation rates and effectiveness are highly dependent on specific formulations, product dimensions, and environmental conditions (microbial populations, temperature, moisture, oxygen). ²

Additionally, abundant agro-wastes such as fruit peels, rice husks, wheat straws, and oil palm fibres serve as renewable feedstocks for producing plant-based biopolymers like polyhydroxyalkanoates (PHA) through microbial fermentation. These biopolymers exhibit promising biodegradability and mechanical properties, making them suitable for applications in food packaging, construction, and agriculture. For a comprehensive overview, Table 2 summarizes previous studies that have utilized various agricultural wastes for biopolymer production.

Table 2: Summary of Previous Studies on Agricultural Waste-Based Biodegradable Polymers

Agro-Source	Production Method	Biodegradability	References
Banana peel	Blending banana peel with glycerol	Completely biodegradable	Yaradoddi <i>et al.</i> (2016)
Banana peel	Extracting starch from banana peel	Degrades faster than conventional plastic in soil burial test	Manimaran <i>et al.</i> (2016)
Orange peel	Simple laboratory techniques using orange peel and glycerol as plasticizers	Disintegrates in soil, confirms biodegradability.	Yaradoddi <i>et al.</i> (2022)
Fruit and vegetable wastes	Different formulations using powdered peels, polyvinyl alcohol, glycerin, soya oil, acetic acid	Formulation with 100g powdered peels had considerable biodegradation	Orenia <i>et al.</i> (2018)
Banana peel starch (BPP) and composite of BPP, cornstarch, rice starch	Using potato peel powder, wood dust as fillers; glycerol and sorbitol as plasticizers	All samples showed biodegradation	Shafqat <i>et al.</i> (2021)
Amorphophallus paeonifolius and Manihot esculenta	Using glycerol and agar-agar as plasticizers	Biodegradable, characterized by UV-Vis, FTIR, SEM	Princey <i>et al.</i> (2020)
Yam and potato peels	Using hydrochloric and acetic acids on extracted starch	Biodegradable, promising alternative to synthetic plastics	Bello <i>et al.</i> (2024)
Food waste like banana peels, cornstarch	Simple laboratory methods	Synthesized bioplastic does not cause environmental pollution, unlike petroleum-based plastic.	Mukhopadhyay <i>et al.</i> (2017)
Potato starch	Well-designed processes to improve physicochemical properties	Biodegradable, could be an alternative to regular non-biodegradable plastics	Momotaz <i>et al.</i> (2022)

Agro-Source	Production Method	Biodegradability	References
Dent corn starch	Casting method using starch, water, glycerol	Biodegradability influenced by glycerol content	Iheanacho <i>et al.</i> (2024)
Caladium bicolor, Icacinia trichantha, Dioscorea villosa, oyster mushroom	Analyzing amylose/amylopectin ratio, gel characteristics of extracted starches	Starches from these non-edible sources can synthesize bioplastics to replace plastics in landfills	Alobi <i>et al.</i> (2017)
Microbes - extremophilic Archaea, chemoheterotrophic eubacteria, phototrophic cyanobacteria	Various fermentation schemes - batch, fed-batch, continuous processes	Biodegradable microbial biopolyesters	Koller (2018)
Tomato agricultural waste (stems)	Fused Filament Fabrication (FFF) 3D printing using filaments with tomato stem powder	Potential for biodegradability, greener waste management	Pemas <i>et al.</i> (2024)
Oil palm cellulose	Biodegradation tested in plantation soil	Total degradation estimated at 254 days based on CO ₂ release	Rahman & Syamsu (2018)

The biodegradation rates of these agricultural waste-based polymers vary considerably but generally demonstrate significant advantages over conventional plastics. For instance, oil palm cellulose-based bioplastics exhibited complete degradation within 254 days based on CO₂ release measurements, while starch-based alternatives degraded within 207 days (Rahman & Syamsu, 2018). These timeframes represent a dramatic improvement over conventional plastics that may persist for centuries. Apart from plant-derived sources, biodegradable plastics can also originate from fossil-based materials when supplemented with specific additives that facilitate degradation (Havstad, 2020). These additives enable plastic decomposition under particular environmental factors, including microbial activity, humidity, and optimal temperature conditions (Kane *et al.*, 2022). The rate and extent of biodegradation are strongly influenced by polymer composition, surrounding environmental parameters, and the presence of appropriate microorganisms (Havstad, 2020; Moshood *et al.*, 2022).

The ability to biodegrade in plastics depends essentially on the chemical structure and the environmental condition, and less so on the source of the feedstock. Plastics from petroleum, and also from biological sources, could exhibit biodegradable character if they are in the required molecular structure. Major factors that influence biodegradation include the presence of hydrolysable bonds, crystallinity, molecular size, and surface structure (Kim *et al.*, 2023). Furthermore, environmental parameters, including temperature, pH, moisture, and microbial community, significantly influence the rate of degradation

(Lambert and Wagner, 2017; Kim *et al.*, 2023). It is necessary to distinguish between biodegradable plastics and other types, including oxo-degradable and hydro-degradable plastics. Oxo-degradable plastics use pro-oxidant additives to enhance oxidative breakdown, and the breakdown, while possible, may not ensure total biodegradation and could end up producing long-lived microplastics (Filiciotto & Rothenberg, 2021). Likewise, hydro-degradable plastics use the mechanism of hydrolysis to initiate breakdown, and they may not achieve total mineralisation through biological mechanisms (Aisbl and Deconinck, 2013).

The development of biodegradable plastics calls for a detailed investigation into the balance between usability and the ability to decompose at disposal. Even if the addition of hydrophilicity and the use of enzymatic-susceptible bondings enhance the biodegradability, the same functionalities could also impair the mechanical properties and durability required in some applications (Kim *et al.*, 2023; Lambert and Wagner, 2017).

Biodegradation Mechanisms and Timeframes

Recent studies have revealed that the biodegradation of polymers involves complex interactions between abiotic and biotic factors, occurring through multiple stages including biodeterioration, biofragmentation, bioassimilation, and mineralisation (Glaser, 2019). The primary mechanisms involve enzymatic hydrolysis by extracellular enzymes secreted by microorganisms, which break down polymer chains into smaller fragments that can be assimilated and mineralised into CO₂ and water under aerobic conditions (Roohi *et al.*, 2017).

The biodegradation timeframes vary significantly depending on polymer structure and environmental conditions. For instance, natural polymers like starch typically degrade within days to weeks, while modified biopolymers like thermoplastic starch (TPS) show comparable degradation rates but may require several months for complete mineralisation (Gamage *et al.*, 2022). More complex structures like cellulose acetate demonstrate extended degradation periods, particularly when the degree of substitution exceeds 1.8, requiring initial abiotic degradation before biological processes can proceed effectively (Polman *et al.*, 2021; Erdal and Hakkarainen, 2022). Environmental factors come into play when estimating actual biodegradation rates. Temperature, moisture, pH, and microbial community composition significantly influence the process efficiency (Yuan *et al.*, 2020). Laboratory studies often report accelerated degradation rates compared to field conditions due to optimised parameters, highlighting the importance of considering real-world environmental variables when assessing biodegradation potential (Briassolis, 2007; Barragán *et al.*, 2016; Polman *et al.*, 2021).

Recent research has identified that structural modifications during bioplastic production can substantially impact biodegradation mechanisms. Chemical modifications, such as acetylation in cellulose acetate, may require additional enzymatic pathways compared to the original biopolymer, while physical modifications like those in TPS generally maintain

similar degradation pathways (Kim *et al.*, 2023; Kaur and Chauhan, 2024). This understanding is important when creating new biodegradable materials with predictable environmental persistence.

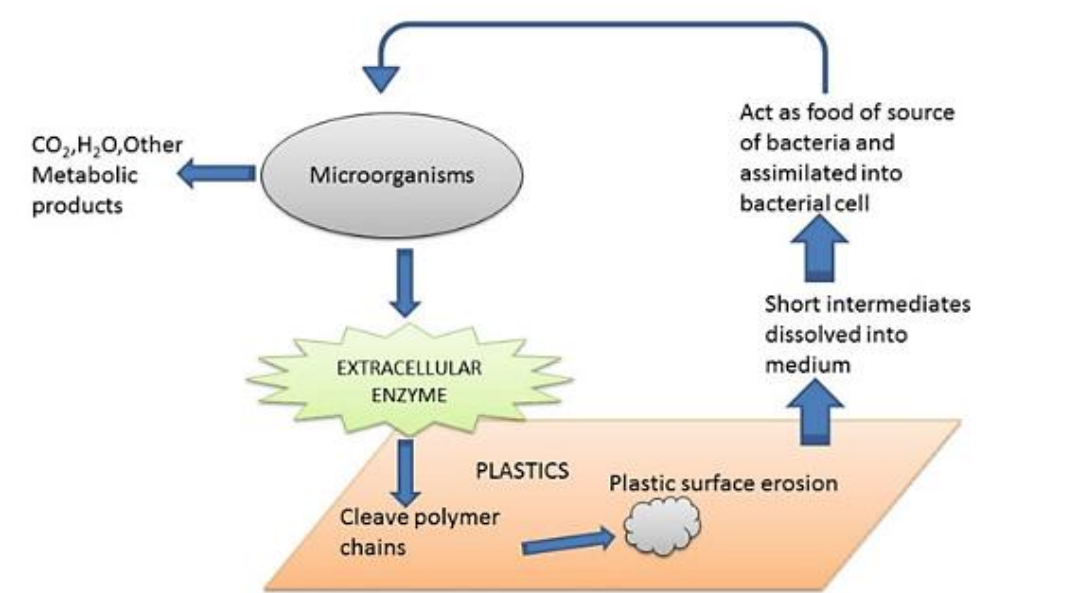


Figure 2: Plastic biodegradation mechanism under aerobic condition (Source: Gaur *et al.*, 2020)

The complexity of biodegradation mechanisms necessitates standardised testing methods and longer-term field studies to accurately assess environmental fate. Current research gaps include a limited understanding of synergistic effects between different degradation mechanisms and the impact of environmental variables on degradation rates in natural settings (Silva *et al.*, 2023).

Table 3: Comparative data summary Nigeria versus Global trends (Biodegradation timeframes, costs, emission saving)

Metric	Nigeria	Global trends
Common biodegradable materials	PLA, PHB/PHAs, thermoplastic starch (TPS), PBAT blends (small-scale/local trials). Local research & pilot production reported.	Polylactic Acid (PLA), Polyhydroxyalkanoates (PHB/PHAs), Thermoplastic Starch (TPS), Polybutylene Adipate Terephthalate (PBAT), Polybutylene Succinate (PBS) are the main commercial bioplastics used worldwide.
Biodegradation industrial composting	If industrial composting existed, many PLA/TPS/PBAT products would reach ~80–90% biodegradation in 2–6 months —	Typical requirement: many “compostable” bioplastics reach ~90% mineralization in 1–6 months under

	but industrial facilities are scarce in Nigeria , so real-world composting rarely occurs.	controlled industrial composting (55–60°C). Field performance varies.
Biodegradation home/soil/open environment	Rapid degradation not guaranteed — in Nigerian soils / waterways many compostable items show much slower breakdown (months → years); open-environment decomposition is inconsistent. Local studies show slow or limited degradation outside controlled conditions.	In natural soils, freshwater or marine environments, many “compostable” plastics degrade very slowly (months to years); some show negligible mass loss in water. Degradation highly environment-dependent.
Landfill behaviour	Landfill conditions in Nigeria are mostly anaerobic and variable; biodegradable plastics may persist for long periods and produce methane if anaerobic digestion occurs uncontrolled. Limited methane-capture infrastructure.	In anaerobic landfill conditions, biodegradable plastics can persist and generate methane over long timescales unless methane is captured; LCA assumptions vary by region.
Typical biodegradation timeframe (practical, real world)	Practical: many items still intact after months when dumped in open environment; expect months → years depending on polymer & local conditions. (Few operational industrial composting sites to meet lab conditions.)	Lab/industrial: 1–6 months (industrial compost). Home / open: highly variable — from months to many years.
Retail / production cost (unit)	Bioplastics estimated ~2–3× cost of petrochemical plastics in Nigeria (higher due to lack of economies of scale, import/tech costs). Small local producers increase prices further. UNIDO and recent Nigerian studies note higher cost as major barrier.	Globally, bioplastic costs are generally higher than conventional plastics — ranges depend on feedstock & scale. Many LCAs report higher production costs but potential cost reductions with scale and feedstock optimization.
Emission / GHG savings (life-cycle)	Potential GHG savings in Nigeria are conditional : if bioplastics are produced from waste biomass and processed with low-carbon energy, they can reduce net GHGs — but current small scale and fossil-energy supply chains often limit realized savings. Local LCA data are sparse.	Global LCAs show a wide range : some bioplastics (PLA, PHB) can reduce cradle-to-grave GHGs vs fossil plastics by ~10% up to >50% depending on feedstock, energy mix, land-use change and end-of-life scenario. Recent harmonized LCAs explore net-negative pathways under specific conditions.

Net practical climate benefit	Uncertain at scale in Nigeria now — depends on feedstock sourcing (residue vs dedicated crops), energy used in manufacture, and whether proper end-of-life (industrial composting, anaerobic digestion with methane capture) is available.	When produced and managed optimally (waste feedstock, renewable energy, controlled composting), certain bioplastics can deliver meaningful net GHG reductions; poor management can erase benefits.
Policy & market drivers	Nigeria: moves toward single-use plastics bans and policy interest (phased bans announced 2024). Policy could accelerate adoption but implementation, affordability and infrastructure remain barriers.	Several jurisdictions support bioplastics via procurement, landfill/composting infrastructure or standards — but global uptake limited by cost and performance uncertainties.

Sources: Ali *et al.*, 2023; Bolaji *et al.*, 2024; Qasim *et al.*, 2022; Cruz *et al.*, 2022

Production Processes of Selected Biodegradable Plastics

Polyhydroxyalkanoates (PHAs)

PHAs are a family of microbially produced polyesters that can be synthesised from various biomass feedstocks. The most common production route is via bacterial fermentation, where select microorganisms accumulate PHAs intracellularly under nutrient-limited conditions with excess carbon (Koller, 2018). Key factors influencing the PHA yield, molecular weight, and properties include the specific bacterial strain, carbon source, fermentation conditions, and downstream processing (Girdhar *et al.*, 2013; Favaro *et al.*, 2019). While this biological process enables the production of a range of PHA homopolymers and copolymers, it is generally costly due to the sterile cultivation requirements and expensive feedstocks (Koller, 2018).

Alternative PHA production methods include enzymatic synthesis using PHA synthases and chemical synthesis via ring-opening polymerisation of β -lactones (Winnacker, 2019; Muneer *et al.*, 2020; Shakaroun, 2021). In vitro, enzymatic PHA production allows tighter control over polymer properties but is limited by the high cost and complexity of synthesising the required CoA-functionalized monomers (Meereboer *et al.*, 2020; Turco *et al.*, 2021). Chemical synthesis, while enabling the production of high-purity PHAs with defined structures, relies on pure lactone monomers that are challenging to produce with both high yield and enantiopurity (Shakaroun, 2021).

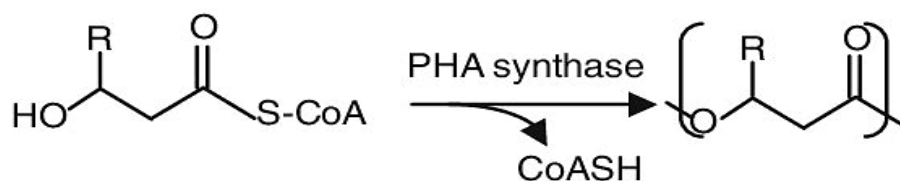


Figure 3: Polyester syntheses by polyhydroxyalkanoate (PHA) synthase (Source: Matsumoto and Taguchi, 2010)

Therefore, while PHAs hold enormous promise as biodegradable plastics, their production processes need further optimisation to achieve cost competitiveness. Utilisation of waste feedstocks, metabolic engineering of PHA-producing strains, and improved bioreactor designs represent some key strategies being explored (Blunt et al., 2018; Lim et al., 2023).

Poly(lactic Acid) (PLA)

PLA is typically produced via ring-opening polymerisation of lactide, the cyclic diester of lactic acid (Mehrpouya *et al.*, 2021). The monomer lactic acid is commercially manufactured by bacterial fermentation of sugars, with sugarcane, corn starch, tapioca starch, and whey as common feedstocks (Tan *et al.*, 2018; Rawoof et al., 2021). To obtain high molecular weight PLA, the fermentation-derived lactic acid is converted to lactide, purified, and then polymerised using metal catalysts (Mehrpouya *et al.*, 2021). Direct condensation polymerisation of lactic acid is also possible, but it tends to yield lower molecular weights (Hu *et al.*, 2016).

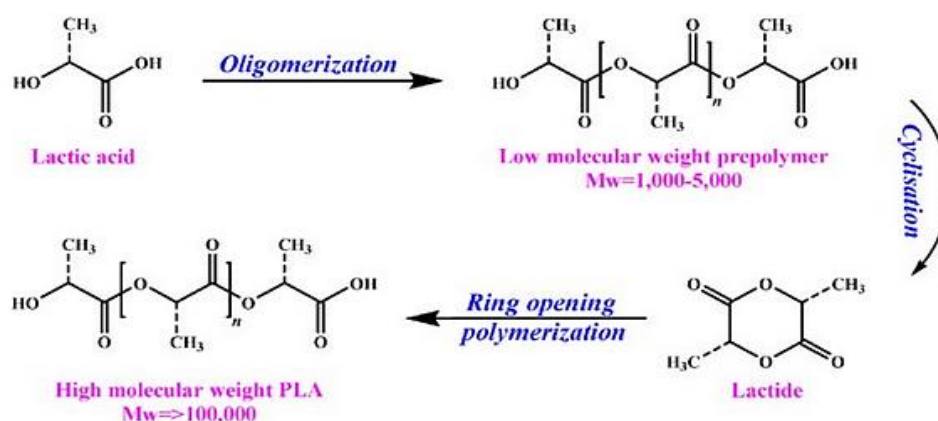


Figure 4: Ring-Opening Polymerization (ROP) of lactide to produce PLA (Source: Mehrpouya *et al.*, 2021)

The properties of PLA are highly dependent on the stereochemistry (L:D ratio) and sequencing of the lactic acid monomers (Inkinen et al., 2011; Yin et al., 2018). Controlling these structural parameters during synthesis is thus critical to tailoring the thermal,

Major Application Sectors

Applications in Packaging

As the dominant market sector for biodegradable plastics, packaging applications are diverse, aiming to replace conventional plastics across various formats, particularly for single-use items (Barone *et al.*, 2025). Biodegradable polymers like PLA, PHA, starch blends, PBS, and PBAT are formulated into numerous packaging forms:

Films: These are extensively used for food wrapping, carrier bags, compostable waste bags, agricultural produce bags, and as sealing layers for trays containing products like meat or vegetables. Advanced applications include "active" or "smart" films incorporating antimicrobial or antioxidant agents (e.g., thymol) designed to inhibit spoilage and extend the shelf life of perishable foods such as pasta, sausages, or fresh produce. This represents a move beyond simple substitution, leveraging material properties for enhanced functionality (Barone *et al.*, 2025).

Rigid Containers & Trays: Applications include packaging for cosmetics, food trays for fresh fruits, salads, and vegetables (often designed for modified atmosphere packaging to maintain quality), and clamshell containers. PLA is frequently used for its rigidity in these applications. While beverage bottles are mentioned, these often utilise bio-PET, which is biobased but typically not biodegradable (Moshood *et al.*, 2021).

Bags: This category includes retail shopping bags, bags for collecting organic waste for composting, and packaging for produce.

Coatings: Biodegradable polymers, particularly starch and gelatine, are used to create thin, often edible, coatings applied directly to foods like fruits and vegetables to reduce moisture loss, control gas exchange, and prolong shelf life. Non-edible coatings are also employed to enhance the barrier properties (e.g., against fats, gases, and water vapour) of other biodegradable packaging materials, like PLA films or starch foams.

Foamed Products: Starch-based foams are common for loose-fill packaging materials (similar to conventional packing peanuts) and moulded items like trays and clamshells.

Cutlery & Tableware: Single-use items such as cups, plates, bowls, cutlery (forks, knives, spoons), straws, and lids are frequently made from biodegradable plastics like PLA or starch blends, replacing conventional polystyrene or polyolefin products.

Role in Reducing Persistent Plastic Waste

The fundamental rationale for employing biodegradable plastics in packaging, especially for items with short use phases, is their potential to mitigate the problem of persistent plastic waste accumulation. Unlike conventional plastics that can persist for hundreds of years, biodegradable materials are designed to break down through microbial action after disposal.

Compostable packaging offers a specific end-of-life advantage through organic recycling. When processed in industrial composting facilities or anaerobic digesters, these materials can be converted into valuable soil amendments (compost) or renewable energy (biogas),

effectively closing the loop and diverting waste from landfills. This pathway is particularly relevant for food-contaminated packaging, which often poses challenges for traditional mechanical recycling processes. By facilitating the collection of food scraps along with the packaging, compostable materials can potentially increase the capture rates and quality of organic waste streams. Furthermore, the use of renewable feedstocks for bio-based biodegradable packaging contributes to reducing reliance on finite fossil resources.

However, recognising these benefits is contingent on several factors. The packaging must indeed biodegrade effectively under the specific disposal conditions it encounters, and the appropriate collection and processing infrastructure (e.g., widespread access to industrial composting) must be available and utilised correctly by consumers. A potential conflict also exists between the need for packaging to provide adequate protection and barrier properties during its functional lifetime and its inherent design for degradation, often necessitating complex material formulations involving blends, coatings, or nanocomposites to balance stability and end-of-life breakdown.

Applications in Agriculture

Biodegradable plastics offer potential solutions to specific challenges in agriculture, primarily related to plastic waste management and the efficient delivery of agrochemicals. Several key applications have emerged:

Mulch Films: This is a prominent application where biodegradable films (often made from materials like PBAT, PLA, or starch blends) serve as an alternative to conventional polyethylene (PE) mulching. These films provide similar agronomic benefits, such as suppressing weed growth, conserving soil moisture, regulating soil temperature, and potentially increasing crop yields. The principal advantage advertised is the possibility of tilling the film directly into the soil after the growing season, thereby eliminating the labour-intensive and costly process of removing and disposing of used PE films, which are often heavily contaminated with soil.

Planting Pots and Containers: Biodegradable pots used for raising seedlings allow for direct planting into the field or garden without removing the pot, reducing transplant shock and simplifying handling for both commercial growers and hobby gardeners.

Controlled-Release Systems for Fertilisers and Pesticides: Biodegradable polymers (including PLA, PCL, PHAs, starch, chitosan, and alginate) are employed as coating materials or matrix binders for fertilisers and pesticides. These formulations are designed to release active ingredients gradually over time, aiming to synchronise nutrient or pesticide availability with plant requirements. This approach promises several benefits: improved nutrient use efficiency (NUE), reduced losses of fertilisers through leaching or volatilisation, minimised environmental pollution (e.g., water contamination), decreased frequency of application, and potentially lower overall usage of agrochemicals. Processing techniques like melt extrusion are utilised to create these composites.

Other Niche Applications: Biodegradable plastics are also used for protective films for specific crops, like bananas, fastening clips or ties, slow-releasing fertiliser rods, pheromone traps for insect control, seed coatings to enhance germination or deliver treatments, greenhouse coverings, agricultural nets, non-woven fabrics, and superabsorbent polymers designed to improve water retention in soils.

Benefits for Soil Health and Waste Reduction

The adoption of biodegradable plastics in agriculture is primarily motivated by the desire to reduce persistent plastic waste and potentially improve soil conditions:

Waste Reduction: Biodegradable mulch films directly address the significant challenge of disposing of conventional PE mulch. By being designed for soil incorporation, they eliminate the need for collection, cleaning, and landfilling or incineration of large volumes of contaminated plastic film, saving farmers labour and disposal costs.

Reduced Microplastic Accumulation: The intention is to prevent the long-term buildup of persistent plastic fragments in agricultural soils, a known consequence of incomplete removal and degradation of PE mulch. However, concerns remain, as incomplete or slow biodegradation of the biodegradable alternatives could still lead to the accumulation of micro(bio)plastic residues.

Potential Soil Health Improvements: Some research suggests that the incorporation of biodegradable mulch materials may have positive effects on soil properties compared to bare soil or PE mulch. These potential benefits include enhanced soil microbial activity and enzymatic functions, improved soil structure (e.g., reduced bulk density), increased soil organic matter content, and better nutrient availability or cycling (e.g., nitrogen use efficiency). Controlled-release fertilisers using biodegradable coatings also contribute to better soil fertility management by minimising nutrient losses to the environment. Nevertheless, the long-term impacts of incorporating potentially large quantities of biodegradable polymer fragments and associated additives into soil ecosystems require further investigation.

The economic viability of biodegradable mulch films often depends on a trade-off: their typically higher purchase price must be offset by the savings realised from avoided removal and disposal costs associated with PE mulch. This economic balance can be sensitive to variations in film performance, the reliability and rate of biodegradation under local field conditions, and regional regulations governing plastic waste disposal. Similarly, while controlled-release agrochemicals offer environmental advantages, their broader adoption is often constrained by higher manufacturing costs compared to conventional products and the technical challenge of precisely tailoring release kinetics to diverse agricultural scenarios.

Applications in Biomedicine

The biomedical field represents a significant area for the application of biodegradable polymers, where their ability to degrade and be absorbed or eliminated by the body after fulfilling a temporary function offers distinct advantages over permanent implants. Biodegradable polymers are utilised in a wide array of medical devices and therapeutic systems:

Surgical Sutures: Absorbable sutures, made from materials like polyglycolic acid (PGA), polylactic acid (PLA), and their copolymers (PLGA), were among the earliest successful clinical applications. They provide temporary wound closure and eliminate the need for suture removal.

Drug Delivery Systems (DDS): A major application involves using biodegradable polymers (e.g., PLA, PLGA, PCL, PHA, polyanhydrides, and polyorthoesters) to fabricate implants, microparticles, nanoparticles, or hydrogels for the controlled and targeted release of therapeutic agents, including drugs, proteins, vaccines, or genes. These systems aim to maintain drug concentrations within a therapeutic window for extended periods, reduce dosing frequency, minimise side effects, and deliver drugs specifically to target sites (e.g., tumours).

Tissue Engineering Scaffolds: Biodegradable polymers serve as temporary three-dimensional frameworks designed to support cell adhesion, growth, and differentiation, guiding the regeneration of damaged or diseased tissues such as bone, cartilage, skin, nerves, or tendons. Common materials include PLA, PGA, PCL, PLGA, PHA, natural polymers like chitosan and alginate, and composites incorporating materials like hydroxyapatite (HA). Advanced fabrication techniques like 3D printing are increasingly used to create complex scaffold architectures.

Orthopaedic Implants: Biodegradable materials, including polymers (PLA, PGA, PCL, PLDLA) and sometimes metals (magnesium or zinc alloys), are used to manufacture temporary fixation devices like screws, plates, pins, suture anchors, and interference screws for treating fractures or repairing ligaments and tendons. These implants provide stability during healing and then gradually degrade, potentially promoting bone remodelling and avoiding stress-shielding effects associated with permanent metal implants.

Wound Healing Products: Biodegradable films, membranes, hydrogels (e.g., based on cellulose, chitosan, and alginate), and patches are developed as advanced wound dressings that can protect the wound, manage exudate, deliver antimicrobial or growth factors, and promote tissue repair.

Other Specialised Applications: Biodegradable polymers are also investigated or used in cardiovascular applications (stents, patches, valves), adhesion barriers to prevent post-surgical scarring, dental implants or fillers, and even in biophotonics for implantable optical fibres or waveguides.

Applications in Consumer Goods

Beyond packaging and specialised industrial uses, biodegradable plastics are increasingly finding their way into everyday consumer products, driven by market demand for more sustainable options. Applications in this sector often target disposable or short-lifespan items where plastic waste is a significant concern

Disposable Tableware and Cutlery: This includes single-use plates, cups, bowls, forks, spoons, knives, straws, and container lids, frequently made from PLA or starch-based materials as alternatives to conventional polystyrene or polyolefin products.

Textiles and fibres: Biodegradable polymers, notably PLA, are processed into fibres used in various textile applications, such as clothing (especially sportswear), nappies, sanitary products, non-woven wipes (e.g., baby wipes), and home furnishings like drapes and carpets. Regenerated cellulose fibres also fall in this category.

Other Consumer Goods: The range extends to items like toys, protective casings for electronics (e.g., phones, laptops), egg cartons, kitchen utensils, bathroom fixtures, clothes pegs, hooks, knobs, cosmetic packaging and applicators, and components in paints, adhesives, foams, and waxes.

Rationale

The adoption of biodegradable plastics in consumer goods is largely propelled by growing consumer awareness and preference for environmentally friendly products. Companies may leverage these materials to enhance their brand image, by signalling a commitment to sustainability and potentially differentiating themselves from competitors. The desire to reduce reliance on fossil fuels and minimise the contribution of products with short lifecycles to persistent plastic waste are also key drivers. Additionally, potential advantages like improved food safety due to lower risk of chemical leaching compared to some conventional plastics and the prospect of future cost reductions or regulatory benefits further motivate their use. However, the application in textiles presents unique end-of-life considerations. While biodegradability is promoted, clothing and wipes are typically laundered, a process known to release microfibres into wastewater systems. Wastewater treatment plants are generally not designed to ensure the complete biodegradation of these fibres. Consequently, even biodegradable microfibres could potentially enter aquatic environments, where degradation conditions may be unfavourable, mirroring the pollution concerns associated with conventional synthetic microfibres, at least in the short- to medium- term.

Table 4: Summary of Advantages and Limitations by Application Sector

Application Sector	Key Advantages	Key Limitations/Challenges
Packaging	Reduced waste persistence; Organic recycling potential (compostables); Fossil fuel reduction (bio-based); Facilitates food waste collection; Potential shelf-life extension (active pkg.)	Higher cost; Performance gaps (barrier, strength); Specific degradation needs (often industrial compost); Lack of composting infrastructure; Recycling stream contamination
Agriculture	Avoids mulch removal cost/labor; Reduces PE film waste/residue; Potential soil health benefits; Controlled release of agrochemicals (efficiency, reduced pollution)	Higher initial cost (mulch, CRF); Variable/slow degradation in soil; Potential microplastic risk; Performance issues (mulch durability); Feedstock concerns; Complexity of CRF tuning
Medicine	Biocompatibility; Biodegradation avoids removal surgery; Controlled drug release; Temporary support for tissue regeneration; Tunable properties	Stringent biocompatibility requirements (incl. byproducts); Need for precise degradation control; Potential inflammatory response (e.g., acidic byproducts); Complex material-tissue interactions; High development/regulatory cost
Consumer Goods	Reduced waste persistence; Fossil fuel reduction (bio-based); Consumer appeal/Brand image; Potential food safety benefits (tableware)	Higher cost; Performance limitations; Specific degradation needs vs. disposal reality; Lack of infrastructure; Recycling contamination; Microfiber release (textiles); Consumer confusion

Furthermore, while consumer acceptance is crucial, it may often be based on an incomplete understanding of the nuances of biodegradability. Widespread confusion regarding terminology and the specific conditions required for degradation can lead to improper disposal by well-intentioned consumers. If products requiring industrial composting are littered, placed in conventional recycling bins (causing contamination), or put in unsuitable home compost systems, their potential environmental benefits are lost, demonstrating the urgent need for clear communication and accurate labelling alongside product availability.

Advantages Over Conventional Plastics

Biodegradable plastics have garnered significant attention as potential alternatives to conventional plastics, primarily due to their perceived environmental benefits.

Environmental Impact

One of the primary advantages of biodegradable plastics is their potential to reduce environmental pollution. Traditional plastics, derived from fossil fuels, contribute significantly to environmental degradation, persisting for hundreds of years and leading to issues such as microplastic accumulation and harm to wildlife. In contrast, biodegradable plastics can be decomposed into natural elements like carbon dioxide, methane, and biomass through microbial activity, potentially minimising long-term pollution. However, the rate and completeness of this degradation depend on environmental conditions and the specific plastic composition.

Moreover, the production of bio-based biodegradable plastics often results in a lower carbon footprint compared to conventional plastics. By utilising renewable resources, such as plant-based materials, these plastics can reduce greenhouse gas emissions associated with their life cycles. Nonetheless, it's important to consider the entire life cycle, including factors like land use and agricultural impacts, to fully assess their environmental benefits.

Waste Management

Biodegradable plastics offer potential advantages in waste management, particularly through composting. They can be broken down in industrial composting facilities, contributing to organic waste streams and reducing landfill usage. However, effective composting requires appropriate infrastructure and conditions, which may not be universally available. Additionally, the presence of biodegradable plastics in recycling streams can pose challenges, as they may contaminate batches of conventional plastics.

Sustainability and Resource Use

The shift towards biodegradable plastics aligns with the principles of a circular economy by promoting the use of renewable resources and enhancing the biodegradability of materials. This transition can lead to a reduction in dependence on finite fossil fuels and encourage more sustainable production practices. However, considerations such as competition with food production for feedstock and the environmental impact of agricultural practices must be addressed to ensure overall sustainability.

Challenges and Considerations

While biodegradable plastics present several advantages, they also face challenges. Higher production costs compared to conventional plastics can hinder widespread adoption. Additionally, the varying degrees of biodegradability under different environmental conditions raise concerns about their effectiveness in reducing pollution. Furthermore, the potential formation of microplastics during degradation and their impact on ecosystems necessitate further research.

The Implementation Framework for Nigeria

Review of Current National and Sub-National Policies

Nigeria has made major progress towards recognising and addressing the challenges posed by plastic waste through the establishment of the National Policy on Plastic Waste Management (NPPWM) in 2021. This policy aims to promote the sustainable use of plastic as a resource throughout its lifecycle, with key objectives including improving waste management practices, reducing greenhouse gas emissions from plastic production and disposal, limiting the use of single-use plastics (SUPs), and encouraging a circular economy within the plastic value chain (Fofana, 2025). The NPPWM, initially prepared and published in January 2020, aligns with international commitments such as the Basel Convention, the MARPOL Convention, the Sustainable Development Goals (SDGs), and the UN Climate Change Convention (Federal Ministry of Environment, 2024). It emphasises principles like the circular plastic economy, the polluter pays principle, the precautionary principle, and the pollution prevention pay principle (Fofana, 2025)..

To operationalise the NPPWM, the Federal Government, in collaboration with the United Nations Industrial Development Organization (UNIDO) and with funding from the Government of Japan, developed Implementation Guidelines between March 2023 and November 2024 (Fofana, 2025). These guidelines provide actionable strategies for government agencies, private sector stakeholders, non-governmental organisations, and local communities, focusing on three key areas where state and local governments play a crucial role: improved collection of plastic waste and diversion from dumpsites and landfills; enhanced recycling of plastic waste; and the elimination, reduction, and circulation of SUPs (Federal Ministry of Environment, 2024).

At the sub-national level, some states have initiated their efforts to tackle plastic pollution. Lagos State, being a commercial centre and a major contributor to plastic waste, has attempted to address the issue through the Lagos State Environmental Protection Agency (LASEPA). LASEPA formulated a policy aimed at banning single-use plastics, including PET bottles. However, the effective implementation and enforcement of this policy have faced limitations due to various factors (Onaji-Benson & Agada Ali, 2023). Lagos State recently said that it would ban polystyrene foam plastics and SUPs starting in January 2024 (WKAI Global, 2024). The state government has also engaged with the Food and Beverages Recyclers Alliance (FBRA) to discuss the modalities for enforcing the ban on SUPs, indicating a commitment to move forward with these measures (LASMEWR, 2025). LASEPA has also undertaken initiatives such as partnering with waste management companies to promote sustainable practices, including the management of used cooking oil, drawing parallels with plastic waste management efforts (LASG, 2024). Additionally, LASEPA has explored incentives for plastic waste collection by offering healthcare provisions in exchange for large quantities of plastic waste in certain communities (Eminton, 2022).

While the current policy framework in Nigeria demonstrates a growing commitment to addressing plastic waste, its primary focus appears to be on managing the challenges associated with conventional plastics. There might be a need to explicitly integrate provisions and incentives specifically designed to promote the adoption and effective management of biodegradable alternatives within this existing framework.

Policy Analysis of Other Selected African Countries

Kenya

Kenya demonstrates a strong commitment to reducing plastic pollution primarily through restricting conventional single-use plastics rather than comprehensive policies for biodegradable plastics (Griffin and Karasik, 2022). The landmark 2017 ban on plastic carrier bags, one of the strictest globally, includes significant fines and potential imprisonment for non-compliance. This ban document recommends alternatives, including "100% biodegradable bags", implicitly recognising biodegradable options as part of the transition away from conventional plastics (Luzze, 2023). In 2020, Kenya extended its ban on all single-use plastics in protected areas, such as national parks, beaches, and forests, recognising the vulnerability of ecologically sensitive zones (Global Plastic Action Partnership, 2025). The Kenya Plastics Pact, a voluntary industry-led initiative, aims to foster a circular economy for plastics by 2030, bringing together stakeholders across the plastics value chain with ambitious recyclability targets (Luzze, 2023).

In 2024, Kenya's National Environment Management Authority (NEMA) mandated the use of 100% biodegradable bin liners for organic waste collection in specific areas, representing the most direct policy action specifically promoting biodegradable plastics. This sector-specific mandate demonstrates where biodegradable options offer clear environmental advantages (Ngida, 2024). Further legislation in November 2024 effectively banned the manufacturing, importation, and use of all plastic bags, tightening previous bans (Nduati-Mutero and Macharia, 2025). Currently, Kenya provides tax exemptions and corporate tax reductions for investments in plastic recycling plants, but no specific incentives directly promote biodegradable plastics adoption or production (ANDE, 2025). The 2017 plastic bag ban achieved 80% effectiveness in reducing targeted bags, though challenges persist from smuggling banned plastics from neighbouring countries. Consumer behaviour shows positive shifts, with increased environmental awareness and tripled reusable bag ownership. The ban has spurred innovations like eco-friendly sanitary towels using bioplastic materials (Amir-ud-Din et al., 2024).

Rwanda

Rwanda established itself as a leader in tackling plastic pollution through a comprehensive ban on non-biodegradable plastic bags implemented in 2008 (Chen and Redkar-Palepu, 2023). This initial ban has expanded to include other single-use plastics, reflecting sustained commitment to reducing plastic waste. Rwanda explicitly permits only paper and

biodegradable packaging, clearly signalling a preference for environmentally friendlier alternatives. Specifically, carrier bags made from home compostable plastics are allowed, while oxo-degradable plastics that fragment into microplastics are banned, demonstrating a discerning approach based on scientific evidence (Xie and Martin, 2022). The Rwandan government actively invests in establishing compostable plastic packaging factories, showcasing a proactive commitment to building the infrastructure necessary for the widespread adoption of biodegradable alternatives (Nkurunziza, 2024). Rwanda implements a total ban on non-biodegradable plastics with strict enforcement and hefty fines for violations. Public sensitisation campaigns ensure awareness and compliance, while strict border control prevents banned plastic inflows (Ogututu et al., 2023).

Rwanda's policy provides strong indirect incentives for biodegradable plastics adoption by permitting only paper and biodegradable packaging. The government encourages companies to adopt sustainable packaging solutions and directly invests in biodegradable plastic packaging manufacturing (Ogututu et al., 2023). Enforcement relies on significant fines, with the Rwanda Environment Management Authority (REMA) conducting public education and undercover inspections. The policy has been remarkably effective, contributing to Rwanda's reputation as one of Africa's cleanest nations. It has significantly reduced plastic waste, improved public health, and fostered a thriving eco-friendly alternative packaging industry (REMA, 2025). Reports indicate reduced animal deaths from plastic ingestion and decrease in soil erosion, flooding, and potentially malaria. Rwanda has set an ambitious target to eliminate plastic waste from landfills by 2030 (Xie and Martin, 2022).

South Africa

South Africa focuses more on managing conventional plastic waste through recycling initiatives and Extended Producer Responsibility (EPR) regulations, adopting a cautious stance toward biodegradable plastics (Uche, 2023). Since 2003, South Africa has implemented plastic bag regulations mandating thicker bags to improve recyclability (Ali et al., 2023). The 2021 EPR regulations place responsibility for end-of-life management of packaging materials on producers, potentially encouraging more recyclable or compostable materials (International Energy Agency, 2025). South Africa established a voluntary standard, SANS 1728, for labelling degradable plastics, including guidelines for biodegradable, compostable, and oxo-biodegradable plastics (Bolaji et al., 2024). A proposed standard for compostability, SANS 17088, based on international standards, was under consideration. The South African Plastics Pact set a target for 100% of plastic packaging to be reusable, recyclable, or compostable by 2025 (Plastics SA, 2020).

Despite growing interest in biodegradable plastics, industry bodies like Plastics SA and the South African Bureau of Standards (SABS) have issued warnings about unverified biodegradability claims and potential negative impacts on recycling streams and consumer

behaviour. Oxo-biodegradable plastics remain contentious, with some advocating for their use while others raise concerns about microplastic fragmentation (Ali et al., 2023). South Africa has achieved relatively high plastic recycling rates compared to other African nations. The market for biodegradable plastic additives is growing, suggesting increasing interest in biodegradable plastics. However, concerns persist regarding their overall environmental impact, including potential recycling stream contamination and limited industrial composting infrastructure (Dennison *et al.*, 2025).

Lessons Learnt for Nigeria

Nigeria can glean several valuable lessons from the experiences of Kenya, Rwanda, and South Africa in developing and implementing policies related to biodegradable plastics and broader plastic waste management. Rwanda's remarkable success in significantly reducing plastic pollution underscores the effectiveness of strong government will and the implementation of comprehensive and consistently enforced bans on problematic plastics (Agbeko, 2025). Nigeria could consider adopting a similar approach by implementing phased bans on specific single-use plastics where viable and environmentally sound biodegradable alternatives are readily available. Rwanda's policy also highlights the necessity of a nuanced approach to biodegradable plastics, as evidenced by its ban on oxo-degradable plastics and its explicit allowance for home compostable options based on their distinct environmental impacts (Omondi, 2024). Nigeria should prioritise establishing clear definitions and stringent standards for biodegradable and compostable plastics to ensure that only truly beneficial alternatives are promoted.

The experiences of both Kenya, through the Kenya Plastics Pact, and South Africa, with the South African Plastics Pact, demonstrate that industry engagement and the establishment of voluntary initiatives can play a crucial role in complementing government regulations and driving progress towards sustainability (Kenya Plastics Pact, 2025). Nigeria should work closely with its plastics industry to look into the possibility of similar partnerships and set voluntary goals for the use of biodegradable and compostable packaging. Rwanda's proactive investment in compostable plastic manufacturing emphasises the importance of supporting the development of the necessary infrastructure to facilitate a transition to biodegradable alternatives (Nkurunziza, 2024). Nigeria needs to thoroughly assess its existing composting and overall waste management infrastructure and consider strategic investments to effectively handle biodegradable plastics and ensure their proper disposal. The success of Rwanda's plastic ban was significantly supported by extensive public sensitisation campaigns, and Kenya also utilised public awareness efforts to promote compliance. Nigeria must invest in comprehensive public education initiatives to inform consumers about the benefits of biodegradable plastics, how to correctly identify them, and the importance of proper disposal methods to maximise their environmental benefits. Rwanda's stringent enforcement of its plastic ban was a critical factor in its effectiveness, and Kenya also relies on strong penalties to ensure compliance (Rosen, 2024). Nigeria needs

to strengthen its enforcement mechanisms at all levels of governance to ensure that any new policies related to biodegradable plastics are effectively implemented and adhered to. Kenya's experience with job losses in the plastic manufacturing sector following its ban serves as an example for considering the potential economic impacts of plastic regulations (Plastics Engineering, 2024). Nigeria should conduct thorough impact assessments before implementing significant policy changes and consider providing support for businesses and workers to transition to the production and utilisation of sustainable alternatives, including biodegradable materials. Finally, the experiences of Kenya, Rwanda, and South Africa collectively provide valuable lessons for Nigeria. Continuous monitoring and learning from the successes and challenges encountered by its regional neighbours in addressing plastic waste will be crucial for Nigeria as it develops its own effective and context-specific policies.

Benefits of Implementing in Nigeria

Environmental Benefits

Reduction of Plastic Pollution: Nigeria generates over 2.5 million tonnes of plastic waste annually, much of which accumulates in landfills and coastal areas, harming aquatic life and clogging drainage systems. Biodegradable plastics decompose through natural microbial action into water, carbon dioxide, and biomass, preventing long-term accumulation in the environment. Studies indicate that compostable plastics can reduce visible plastic debris in surface waters by up to 80% when proper collection and composting systems are in place.

Enhanced Soil Health: When biodegradable plastics break down, they can improve soil structure by increasing organic matter content and promoting microbial diversity. Research on starch-based blends shows that residual nutrients from degradation boost soil fertility and water retention, supporting crop growth. Unlike petroleum-based plastics, which fragment into microplastics and persist indefinitely, biopolymers reduce the risk of soil contamination and the resultant threat to food chains.

Lower Greenhouse Gas Emissions: Lifecycle assessments reveal that bioplastics derived from agricultural feedstocks can achieve up to 40% lower greenhouse gas emissions compared to traditional plastics due to carbon sequestration during biomass growth. Although transportation and processing increase emissions, optimised local production in Nigeria could further minimise the carbon footprint of biodegradable plastics, contributing to national climate action goals.

Economic Benefits

Job Creation and Economic Growth: The expansion of biodegradable plastics production in Nigeria can catalyse new employment opportunities across agriculture, manufacturing, and waste management. In East Africa, similar initiatives created over 5,000 direct jobs in bioplastic fabrication and composting facilities within five years. A thriving bioplastics sector can thus alleviate unemployment and diversify Nigeria's industrial base.

Cost Savings in Waste Management: Traditional plastic waste management in Nigerian cities incurs high collection and landfill costs. A cost-benefit analysis in Delta State showed that integrating compostable plastic streams with organic waste segregation programs yielded a net present value of ₦112.5 million and a benefit-cost ratio of 1.50, outperforming conventional recycling alone. By diverting biodegradable plastics to composting facilities instead of landfills, municipalities can reduce tipping fees and extend landfill lifespans.

Boost to Local Industries: Local production of feedstocks such as cassava and maize for biopolymer synthesis can invigorate agricultural value chains. Nigeria, as the world's largest cassava producer, has the raw materials to support a domestic bioplastics industry, reducing reliance on imported petrochemical feedstocks and keeping value within the national economy. Integrating farmers into bioplastic supply chains also offers diversified income streams and rural development benefits.

Social and Health Benefits

Improved Public Health: Plastic pollution contributes to waterborne diseases and respiratory issues through microplastic inhalation and leachate in water supplies. By replacing conventional plastics, biodegradable alternatives can decrease environmental reservoirs of harmful chemicals such as phthalates and bisphenol A, leading to lower incidence of endocrine disorders and gastrointestinal illnesses in affected communities.

Community Awareness and Behavioural Change: Introducing biodegradable plastics often coincides with public education campaigns on waste segregation and sustainable consumption. Such initiatives in Lagos State increased household participation in composting programs by 30% within a year, demonstrating that material shifts can drive broader behavioural change toward environmental stewardship.

Policy and Regulatory Advantages

Alignment with National Plastic Waste Policy: Nigeria's National Policy on Plastic Waste Management (NPPWM), launched in 2021, mandates reduction of non-recyclable plastics and encourages sustainable alternatives. Biodegradable plastics fulfil key NPPWM objectives by ensuring end-of-life management through composting and reducing landfill volumes, helping the government achieve targeted plastic reduction goals by 2025.

Support for International Commitments: Nigeria has ratified global agreements, including the UN Environment Programme's resolutions on plastic pollution and Sustainable Development Goal 12 on responsible consumption and production. Adopting biodegradable plastics demonstrates compliance with international environmental standards, enhancing Nigeria's reputation and attracting green financing.

Technological and Innovation Opportunities

Research and Development Growth: Fostering a biodegradable plastics industry spurs R&D in polymer science and process engineering within Nigerian universities and startups.

Collaborative projects with international institutions, such as EU-Nigeria partnerships under Eunomia's implementation guidelines, have already begun evaluating scalable bioplastic materials tailored to local conditions.

Technology Transfer and Local Adaptation: Successful models from countries like Thailand and Brazil show that technology transfer agreements can accelerate domestic capacity building. By adapting best practices and customising feedstock blends for Nigeria's climate, industry players can optimise performance and cost, ensuring that biodegradable plastics meet regional quality and durability requirements.

Implementation Challenges in Nigeria

Policy and Regulatory Framework Challenges

Nigeria's policy landscape for plastics is evolving but still lacks clear guidelines specific to biodegradable materials. Despite a January 2025 ban on single-use plastics, implementation has been staggered, with minimal public preparedness and enforcement mechanisms. The absence of national standards for defining and testing "biodegradable" or "compostable" plastics creates uncertainty among producers and importers about compliance requirements. Regulatory oversight is further weakened by limited capacity within environmental agencies, which have struggled to align fiscal policies with environmental goals, allowing industry influence to stall stronger measures. Without harmonised labelling and certification systems, consumers and waste managers cannot distinguish truly biodegradable products from conventional plastics marketed under greenwashing claims.

Infrastructure and Waste Management Systems

Effective biodegradation requires separate collection, sorting, and industrial composting facilities—elements largely missing in Nigeria. Municipal waste collection covers less than 50 per cent of urban areas, and recycling infrastructure remains under-resourced, particularly outside Lagos and Abuja. Most organic waste streams are co-disposed with general refuse, meaning that even certified compostable plastics end up in landfills or waterways, where conditions prevent proper degradation. The scarcity of anaerobic digestion or industrial composting plants means only a fraction of biodegradable materials can complete their decomposition cycle under controlled settings. Rural regions—where traditional practices once eschewed synthetic packaging—lack any formal systems for segregating or processing waste, leaving biodegradable plastics to mimic the environmental fate of conventional polymers.

Economic and Financial Constraint

Biodegradable plastics currently command a price premium of 300–500 per cent over petrochemical counterparts, making them unaffordable for most Nigerian businesses and

consumers. High production costs stem from small-scale operations, lack of economies of scale, and reliance on imported raw materials, inflating transportation and import duties. Limited access to green financing or subsidies means that start-ups and processors cannot compete on price with established petrochemical polymer manufacturers. Consumer purchasing power is constrained by macroeconomic challenges—such as inflation and exchange-rate volatility—further disincentivising investment in costlier biodegradable options.

Technological and Research Capacity

Nigeria's ability to create new bioplastic formulations is still in its early stages. There aren't many research institutions working on polymer science that is specific to local feedstocks. Existing studies emphasise the attractiveness of starch- and cellulose-based polymers but note that technical hurdles—such as poor mechanical strength and inconsistent degradation rates—limit commercial viability. Weak collaboration networks, scarce pilot-scale facilities, and limited funding for scale-up projects widen the gap between academic research and industrial application. Intellectual property constraints and inadequate local expertise hinder the transfer of technology from global bioplastic leaders, making it difficult to adapt processes to Nigeria's climatic and resource context.

Public Awareness and Cultural Attitudes

Although 80 per cent of Nigerians express concern about environmental issues, actual adoption of bioplastics remains low due to limited awareness of benefits and disposal protocols. Many consumers are unaware of biodegradable alternatives or doubt their performance compared to familiar plastics, leading to resistance—even when products are available. Cultural practices around reusing and repurposing packaging have declined, replaced by convenience-oriented, single-use behaviours that biodegradables alone cannot reverse without parallel educational campaigns. A successful transition will require sustained behaviour change interventions, leveraging traditional sustainable practices (e.g., banana leaf wrappers) alongside modern innovations.

Environmental and Climatic Considerations

Nigeria's tropical climate—with high humidity and temperature—can accelerate biodegradation but also promotes microbial growth that may unpredictably affect material properties before end-use. Seasonal flooding events can disperse biodegradable fragments into waterways, where reduced oxygen levels impede aerobic decomposition, potentially exacerbating microplastic formation. Soil composition variability across regions influences degradation kinetics, necessitating localised testing protocols to ensure materials meet performance and environmental safety standards.

Supply Chain and Raw Material Availability

Sourcing feedstocks—such as cassava starch, sugarcane bagasse, and agricultural residues—competes with food and feed needs, raising concerns about land-use trade-offs and sustainability. Fragmented agricultural value chains and post-harvest losses limit reliable supply volumes and quality consistency, deterring large-scale bioplastic manufacturers. Lack of integrated supply-chain logistics for collecting, preprocessing, and transporting biomass adds complexity and cost, requiring new infrastructure investments.

Market Dynamics and Industry Readiness

Large incumbents with entrenched supply chains and political influence dominate Nigeria's petrochemical plastics industry, capable of lobbying against policies that favour bioplastics. Market demand remains niche, focused on premium sectors (e.g., agro-packaging, medical disposables), while mass-market applications see little traction due to price and performance concerns. Small and medium enterprises (SMEs) in the packaging sector cite limited technical support and market uncertainty as reasons to avoid investing in biodegradable options.

Digital Technology Integration

Digital transformation is reshaping operations and value generation within organizations through the integration of technologies like artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and cloud computing (Goel et al., 2024). Specifically, in the domain of biodegradable plastics, this integration spans the entire lifecycle, from research and development to manufacturing, waste management, and recycling, promoting a connected ecosystem for optimized processes and decision-making (Rosário and Dias, 2022). It is crucial for these technologies to align with sustainability goals such as the Sustainable Development Goals (SDGs). AI and machine learning are streamlining the innovation of biodegradable materials, enabling quicker predictions of chemical structures and properties—an approach that reduces traditional development times and costs associated with laboratory experimentation (Ghasemlou, 2025).

For example, the polySCOUT AI model can generate suitable polymer structures based on user-defined properties almost instantaneously, aiding in the development of biodegradable synthetic textiles (Amos, 2024). IoT and sensor technologies further enhance manufacturing efficiency by collecting real-time data on key parameters, allowing for proactive issue identification and quality assurance (van der Meer, 2025). A notable example is the retrofit by Hargrove Controls & Automation in collaboration with Danimer Scientific, which incorporated advanced control systems for PHA plant operations, significantly improving resource efficiency and safety monitoring (Deidda, 2024). In the waste management sector, digital platforms and analytics are vital for promoting a circular

economy by optimizing the collection, sorting, and recycling of biodegradable plastics (Amos, 2024).

Companies utilize sensor-equipped platforms to track waste, while AI-driven sorting technologies increase accuracy in separating biodegradable materials, addressing contamination issues in recycling streams (Agbeko, 2025). Case studies illustrate successful integrations, such as AMP Robotics' AI systems for material sorting and blockchain technologies that enhance transparency in waste management practices (HEC, 2025). These advancements collectively demonstrate the critical role of digital technologies in improving efficiency, sustainability, and accountability within the biodegradable plastics industry.

Conclusion

In conclusion, the pervasive issue of conventional plastic waste, exacerbated by inadequate management practices globally and particularly in Nigeria, necessitates a shift towards sustainable alternatives. Biodegradable plastics, which come from a variety of sources and break down in ways that are different from those of long-lasting polymers, could be a solution for packaging, agriculture, and consumer goods. They could help reduce the amount of plastic that ends up in the environment and the need for fossil fuels. However, their successful implementation in Nigeria faces significant challenges, including the need for clear policies and standards, substantial investment in waste management infrastructure (especially composting facilities), overcoming high costs, boosting technological capacity, and fostering public awareness and proper disposal behaviours. Addressing these hurdles with an integrated approach involving policy reform, infrastructure development, stakeholder collaboration, and leveraging digital technologies will be crucial to realising the environmental and economic benefits of biodegradable plastics as part of Nigeria's circular economy strategy.

Recommendations

1. Promote the Transition to a Circular Economy: Shift from the linear "take-make-dispose" model to a circular model emphasising reduction, reuse, and recycling of plastics across all sectors.
2. Enhance Public Awareness Campaigns: Launch sustained education and awareness campaigns to inform the public about plastic pollution, biodegradable alternatives, and proper waste disposal methods.
3. Strengthen Waste Management Infrastructure: Invest significantly in waste collection, sorting, and recycling infrastructure, especially in urban centres like Lagos, to reduce environmental leakage.
4. Support the Informal Recycling Sector: Integrate and support informal waste collectors by formalising their roles, improving working conditions, and providing incentives to boost recycling rates.

5. Encourage the Use of Biodegradable Plastics: Provide subsidies or tax incentives for companies adopting biodegradable materials in packaging, agriculture, and consumer goods
6. Implement and Enforce Plastic Waste Regulations: Fully enforce existing national and sub-national policies such as the National Policy on Plastic Waste Management (NPPWM), and update them to include biodegradable plastics.
7. Ban or Restrict Single-Use Plastics (SUPs): Expand existing bans on SUPs like plastic bags and polystyrene to include more items and ensure effective enforcement.
8. Develop Industrial Composting Facilities: Establish widespread industrial composting infrastructure to support the proper degradation of compostable bioplastics.
9. Foster Public-Private Partnerships (PPPs): Encourage collaborations between governments, private sectors, NGOs, and academia to fund and implement waste management solutions.

Authorship Contribution Statement

M.U. Akalonu: Article reviewer, writing - original draft, and editing; **I.C. Nnorom:** supervision, correction of draft and original, **S.O. Eze:** supervision, correction.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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