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Bioplastic Production from Banana Peels: Unlocking the Power of Nature

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Abstract

Addressing plastic pollution is crucial for environmental and human well-being. Exploring and adopting sustainable alternatives to traditional plastic can significantly contribute to mitigating these harmful effects. Research and innovation in eco-friendly materials are essential for a more sustainable future. Bioplastic indeed showcase innovation by utilizing various biodegradable sources like banana peels, orange peel, corn starch,organic waste. They provide a sustainable alternative to traditional plastics and contribute to reducing environmental impact. The diverse range of materials, including biomass and renewable sources like cellulose and vegetable oil, highlights the versatility of bioplastics in addressing environmental concerns. Bioplastics can be of various types, which is based on the source that it has been derived from, such as Cellulose-based, Starch based, Protein based and Aliphatic polyesters bioplastics. Various scientists describe the production of a bioplastic film from banana paste. This approach aligns with the utilization of natural resources for sustainable material development. Bioplastic from banana peels can be used in industry for various applications such as molding, packaging and making carry bags. There's a big demand for bioplastic packaging and it is the largest segment of the European bioplastic market – estimated (44% of 2.05 million tones in 2017). At the same time rescuing the environment from potential harm by synthetic plastics. That's a significant growth projection for India's bioplastics market, indicating a shift towards more sustainable alternatives. Globally market is projected to grow at a CAGR of 24.36% to reach US$1,420.870 million by 2027, up from US$308.942 million in 2020.Environmental awareness and regulations contribute to this expansion.So, this review includes production of bioplastic from banana peels and improving environmental health.

Keywords: Bioplastic; Banana Peel; Carboxymethyl Starch; Plastic Pollution; Food Packaging Material.

INTRODUCTION

Environmental pollution is a huge global issue that affects both industrialized and developing countries. The plastic industry, while important in many sectors such as packaging and construction, is a major contributor to this problem due to the extensive usage of polymer materials, also known

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as plastic. Addressing the environmental impact of plastic manufacture and use is critical for sustainable and environmentally friendly operations. Bioplastics derived from renewable sources offer a possible alternative, with classifications including starch-based, cellulose-based, and protein-based bioplastics(Awoyera *et al.,* 2020)

Bioplastics' versatility is demonstrated by their wide range of uses, including disposable goods, structural materials, and even electroactive variations.Absolutely using banana peels and corn starch to make biodegradable plastic is a laudable step toward more sustainable options. The rigorous examination, which included solubility, biodegradability, rip strength, and tensile strength testing, demonstrates a dedication to assuring the practical feasibility and environmental sustainability of these materials. Success in these attempts could play an important role in lowering the environmental impact of traditional plastics.

Plastic comes in various shapes, including sheets, panels, and film, and can be flexible to meet specific application needs. Excessive plastic consumption can have significant negative consequences. It takes around 500 years to decay and becomes hazardous once decomposed. The goal of this study is to create biodegradable plastic from banana peels as a substitute for conventional plastic. The study also aims to demonstrate that the starch in banana peels can be used to generate biodegradable plastic. The biodegradable film's strength was measured using the elongation test, compared to a control film and a synthetic plastic. In the soil burial degradation test, biodegradable film decomposed faster than control film, but synthetic plastic did not disintegrate(Dimassi *et al.,* 2022)Banana peel bioplastic is suitable for packaging and carrying bags.Glycerol is applied as a plasticizer, increasing flexibility(Chandarana *et al.,* 2021)

STATEMENT OF PROBLEM/HARMFUL EFFECT OF PLASTIC

Traditional plastic materials face environmental issues since they are non-biodegradable, resulting in pollution and waste. The use of banana peels and CMS in bioplastic compositions provides a sustainable alternative (Cruz *et al.,* 2022). Banana peel is a by product that helps to reduce waste, while CMS treatment increases starch characteristics for bioplastic applications. These biodegradable materials are consistent with the global trend toward sustainable and environmentally friendly plastic alternatives (Liu, 2006). Bioplastics, as opposed to ordinary plastics, have immense potential to provide environmental solutions. Bioplastics are a sustainable alternative made from renewable resources such plant starches, agricultural waste, and microbial fermentation (Agarwal *et al.,* 2022). Bioplastics are frequently biodegradable, which minimizes their long-term environmental impact when compared to traditional plastics (Alias *et al.,* 2022). Their production is often distinguished by lower carbon emissions, which contribute to a smaller environmental impact (Marsi *et al.* 2019). Bioplastics' adaptability and potential are developing as crucial components in the construction of a greener, more environmentally friendly future as a result of global attempts to create eco-conscious materials (Shaikh *et al.,* 2021).

KEY FEATURES OF BIOPLASTIC PRODUCTION

These bioplastics are defined by their unique characteristics, resulting in a highly functional spherical form. Interstellar polymers differ from linear polymers in that they exhibit less entanglement in solid phases, increased solubility in various solvents, lower melt viscosity, and faster molecular mobility (Oo *et al.,* 2019). Tensile strength is a commonly used structural measure for determining material strength, indicating the lowest amount of stress that an object can withstand before failing. These mechanical qualities are critical for ensuring the integrity of food packaging (Shaikh *et al.,* 2021). Bioplastics have lower water permeability than thermoplastic polymers, making them acceptable for the preservation of dry items (Marsi *et al.*). Oxygen permeability coefficients (OPC) are the amount of oxygen that can travel through a material per unit area and time under pressure [kg mm-2 s-1 Pa-1]. The low OPC prevents oxidation, increasing the product's shelf life (Jain *et al.,* 2019). Elongation at break is defined as the ratio of length change to beginning length, which demonstrates that the material may be stretched or extended without breaking. These numbers indicate the resilience of polymers, allowing them to create a variety of shapes (Shaikh *et al.,* 2021). Bioplastics are often manufactured using renewable energy sources such as maize starch, potatoes, tapioca, sugar cane bagasse, and algae (Yaradoddi *et al.,* 2022).Other advantages include low cost, light weight, remarkable flexibility, heat sealing, and durability (Fadzil & Othman, 2021b). In the face of rising environmental and health concerns, the food industry has showed a strong interest in biodegradable packaging manufactured from bioplastics. These sustainable alternatives, generated from natural organic components, provide environmental benefits and allow for an informed choice between synthetic petroleum-based plastics (Sharma *et al.*, 2021; Singh & Sharma, 2016; Kumar *et al.*, 2020). According to Domínguez-Soberanes and Berger (2022), biodegradable polymers promote sustainability, biocompatibility, and nontoxicity while also safeguarding the environment and human health.

Role of banana peel in bioplastic production

Banana (Musa spp., Musaceae family) is one of the main fruit crops cultivated for its edible fruits in tropical and subtropical regions It has been shown that banana peel contains many nutrients and minerals. The starch content of bananas has been reported to change from approximately 21 g/100g in unripe fruit to approximately 1 g/100g in fully ripe fruit . During ripening there is a decrease in enzyme-resistant starch and an increase in water-soluble pectin. Emaga *et al.*, 2008, Mohapatra *et al.*, 2010 found crude proteins in the amount of 1.95±0.14%, crude fat 5.93±0.13%, and 11.82±2.17% carbohydrate in the banana peel. The mineral composition of banana peel was phosphorus, iron, calcium, magnesium, and sodium. Zinc, copper, potassium, and manganese were found in very low concentrations as mg/100 g. The polymer produced using the banana peel blended with glycerol could help in the formation of plastic having the characteristic features of liability, user friendliness and strength.

Table 1: Composition of Banana Peel

Component	Amount (in 100g)
Protein	0.9
Crude Lipid	1.7
Carbohydrate	59
Crude Fibre	31.7
Minerals	**Amount (in mg/g)**
Potassium	78.1
Calcium	19.2
Sodium	24.3
Iron	0.61
Manganese	76.2
Bromine	0.04
Rubium	0.21
Strontium	0.03
Zirconium	0.02
Niobium	0.02

The significance of CMS in bioplastics

The study of starch-based biodegradable film is a major research topic in starch usage in pharmaceuticals (Onyeaka *et al.*, 2022b). Chemical and physical alterations to starch structures have overcome the intrinsic constraints of native starch, such as water insolubility and limited flow capability (Shah *et al.*, 2022). These alterations have resulted in the expanded use of starch from traditional pharmaceutical excipients in more advanced applications such as emulsifiers, drug carriers, and film starters (Onyeaka *et al.*, 2022b). Carboxymethyl starch (CMS), an anionic, etherified modified starch obtained by replacing certain starch OH groups with carboxymethyl moieties, has emerged as a well-studied and widely used modified starch in the food and pharmaceutical industries (Kittipongpatana and Kittipongpatana, 2016). Despite its superior flexibility and strength when compared to native starch film, carboxymethyl starch (CMS) experienced issues as a film-forming material due to its hygroscopic character, resulting in film instability during prolonged storage (Onyeaka *et al.*, 2022b; Shah *et al.*, 2022). Several research have investigated methods for increasing CMS hydrophobicity, including the addition of hydroxypropyl groups, fatty acid esters, and conjugation with zein. Another reported method involves esterifying starch by replacing -OH groups with ester groups, and using short-chain anhydrides such as propionic and butyric anhydrides to improve hydrophobicity and give "bioplastic" qualities (Onyeaka *et al.*, 2022b). The modified starch has been demonstrated to have increased water and oil-holding capacity, as well as decreased crystallinity, solubility, and solubleness (Shah *et al.*, 2022). The carboxymethyl starch (CMS) film had a homogeneous look, a slightly loose layer, and enhanced flexibility due to water solubility and reduced hydrogen bonding effects from carboxymethylation. Similarly, a smooth uniform surface and good flexibility were seen in the film formed by butyrylation of carboxymethyl starch (CMSB) (Kittipongpatana&Kittipongpatana, 2016). However, the addition of the butyryl group to the starch molecule increased its hydrophobic characteristics, resulting in a decrease in CMSB solubility. Interestingly, carboxy methylation reversed this effect, transforming CMSB into a suitably hydrophilic form with 100% solubility at room temperature (Shah *et al.*, 2022; Kittipongpatana & Kittipongpatana, 2016). The butyrylation alteration resulted in a modest increase in reflection signal strength, indicating more granule crystallization. On the contrary, carboxymethylation-induced alteration resulted in a decrease in signal intensity, which corresponded to a decrease in granule crystallinity (Kittipongpatana & Kittipongpatana, 2016).

APPLICATION OF BIOPLASTIC

Bioplastics are widely used in various industries, including packaging, food, automotive, textiles, pharmaceuticals, and cosmetics.

Packaging

Today, bio-packaging is available in many European supermarkets. Sainsbury, a UK retailer, was a pioneer in recognizing the benefits of compostable plastic packaging.

Several supermarket chains, like Delhaize (Belgium), Iper (Carrefour group, Italy), Albert Heijn (Netherlands), and Migros (Switzerland), are embracing bio-packaging. Last year, Wal-Mart, the world's largest store, debuted its first product collectionin corn-based PLA packaging in the United States. Composting unsold expired food products with their packaging saves supermarkets a significant amount of money compared to separating the contents from the packaging. Food residues make no difference to the recycling process. The same goes for compostable service packs such trays, plates, cups, and silverware (Ghasemlou *et al.*,2024)

Using banana peel bioplastic as food packaging material offers numerous advantages, making it a promising alternative to conventional plastic. Bioplastics derived from banana peels are sustainable, biodegradable, and renewable, addressing environmental concerns associated with traditional plastics. This bioplastic also exhibits desirable properties such as flexibility, durability, and barrier capabilities, ensuring adequate protection for various food products.

Moreover, utilizing banana peel bioplastics promotes circular economy principles by valorizing waste streams and contributing to the reduction of plastic pollution. As society seeks more eco-friendly solutions, exploring banana peel bioplastics as food packaging material holds significant potential in mitigating environmental impact while maintaining packaging integrity and safety.

Bags: bags are one of the fastest expanding industries for bioplastics in the early 21st century, driven by concerns about litter, perceived waste, and biowaste handling. Bioplastics are suitable substitutes for traditional oil-based polymers in this area.

Excellent performance features, strength, contact clarity, and demonstrated high-speed output. Bioplastics can be transformed into waterproof and fat-resistant film, offering eco-friendly wrapping and packing choices. A great natural feel and proper barrier technologies allow products such as cheese to breathe on their way to the consumer. Flexible materials having paper-like deadfold properties extend their application range.

Electronics and Autos

In 2009, NEC, a Japanese multinational, successfully developed and deployed a flame-retardant bioplastic suitable for use in electronic devices (Bozó *et al.,* 2012)

The novel bioplastic contains over 75% biomass components and may be produced with halved CO2 emissions compared to traditional petroleum-based flame-retardant plastics (PC/ABS). NEC's innovative bio plastic is one of the most environmentally friendly flame-retardant materials utilized for electronic gadget casing. Ford Motor Corp. was the first automaker in the world to use bio plastics in the manufacture of auto parts way back in the 1920s. Recently, Toyota motor corp. employed them in the cover for the spare tire in the Raum, a new model that went on sale this May. The bio plastic used here is polybasic acid (PLA) is made from plants, such as sweet potatoes and sugarcane.

Agriculture and Horticulture

The intrinsic trait of biodegradability has unique benefits in agriculture and horticulture.

Mulch film: Bioplastics can be transformed into opaque or semi-transparent films that provide optimal growing conditions and can be ploughed into the ground at the conclusion of the development cycle to supply soil nutrition for future seasons. Using less pesticides to produce pure meals is a strong selling point for organic or vegetable production. Using mulching films instead of collecting them from the field, cleaning them, and recycling them enhances the operation's efficiency and profitability (Jiménez-Rosado *et al.*, 2021).

Tree Supporter and Plant Supporter/ Stakes:Bioplastics are being developed to protect young trees from forest waste and promote healthy growth. Early in the developing cycle, vermin and adverse environments are protected. However, the substance will Bio-disintegrate as the tree matures. Litter is removed from managed woodland, reducing collection expenses. Horticulturists use bioplastics to create plant holders that are durable, water-resistant, available in a variety of colors, and decay naturally into biomass.

BENEFITS OF BIOPLASTICS

1. ***Eco-Friendly:*** Traditional plastics rely on fossil fuels, making them unsustainable. Obtaining fossil fuels also causes significant harm to the natural environment. Bioplastics are created from biomass, including trees, vegetables, and trash, and are fully biodegradable. Bioplastics are created from fully renewable sources. Plastic manufacturing can lead to pollution, including the discharge of dioxins, which are carcinogens that can accumulate in humans and wildlife and cause reproductive and immune system diseases (Sarkingobir *et al.*, 2021)
2. ***Require less time to degrade:*** Traditional plastics take thousands of years to dissolve, while these plastics remain in the environment, causing significant damage on the ocean floor over time. These polymers inhibit growth and destroy natural habitats. Bio plastics on the other hand, biodegradation takes significantly less time. Some bioplastics can be degraded at home, while others require specialized conditions and take less time to totally decompose. This alleviates significant pressure on existing landfills.
3. ***Toxicity:*** Some plastics breakdown quickly in the ocean, producing hazardous compounds that affect animals, plants, and humans via the food chain. Biodegradable plastics are fully harmless and contain no chemicals or poisons. This plastic harmlessly breaks down and is absorbed by the earth. The benefits of bioplastics are crucial since the world's hazardous plastic load continues to rise, posing significant challenges for future generations.
4. ***Lower energy consumption:*** While bioplastics are still manufactured using fossil fuels, many of them require far less fuel. Polylactic acid synthesis uses less energy compared to other polymers.

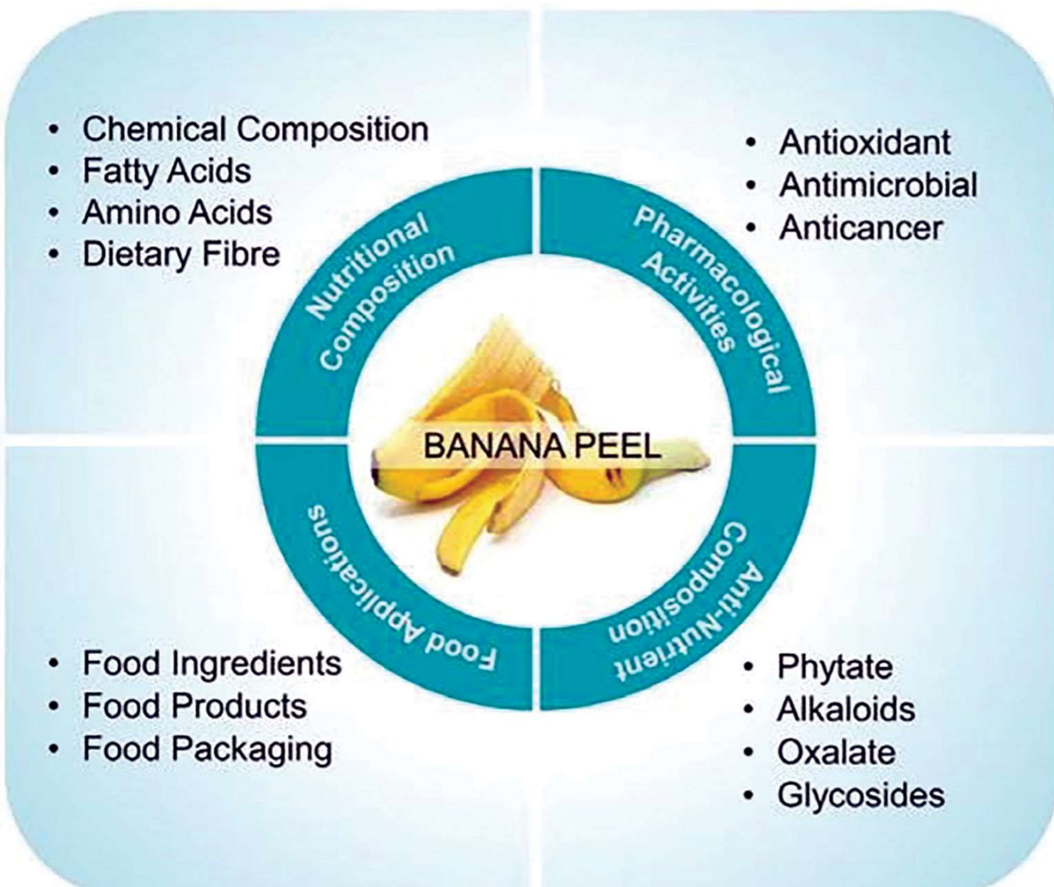

Fig. 2: Various benefits of banana peel

CONCLUSION

Finally, the review demonstrates that utilizing banana peels and Carboxy Methyl Starch (CMS) to create bioplastics as sustainable alternatives to regular plastics has revolutionary potential. Banana peels' particular qualities, which are high in natural polymers such as pectin, make them a useful source of waste reduction and eco-friendly bioplastic production. Meanwhile, to solve problems associated with traditional plastics, CMS is included into bioplastics to improve their mechanical qualities. This unique technique not only helps to safeguard the environment, but it also represents the global trend toward sustainable materials. Bioplastic synthesis from agricultural waste and modified starch has potential applications in active and modified atmosphere packaging, contributing to food packaging sustainability and lowering the environmental impact of plastic waste.

Conflict of Interest

There are no conflicts to declare

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