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PRODUCTION OF BIOPLASTIC FROM WASTE MAIZE COB

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Abstract

This research focused on the development of bioplastics from waste maize cob, which can be used as a natural binder, and, processed maize, serving as the primary starch source. The motivation behind this study was to provide an eco-friendly alternative to conventional petroleum-based plastics, which significantly contribute to environmental pollution. The method used was a factorial experiment. Different amounts of starch and maize cob binder were tested to determine their effects on the bioplastic properties. Starch was extracted from the processed maize using a wet milling process. The required amounts of starch, maize cob powder, and glycerol were weighed using an analytical balance. The starch-binder-plasticizer mixture was heated at 90°C in an electric heater for 11 to 15 minutes. The results indicated that the bioplastic produced from maize starch and corn cob exhibited superior mechanical performance compared with bioplastics made from non-fermented starch sources, such as potato and cassava. The material showed significant elasticity ranging from 0.60 ± 1.02, 3.00 ± 1.02, 0.50 ± 1.02, 1.00 ± 1.02, 0.50 ± 1.02, 1.00 ± 1.02, and 2.50 ± 1.02 (amongst sample A to G respectively) and tensile strength (6.50 ± 1.31, 6.50 ± 1.31, 3.50 ± 1.31, 5.50 ± 1.31, 3.50 ± 1.31, 4.50 ± 1.31, and 6.00 ± 1.31(among group A to G respectively). Groups B and G showed a reduced water absorption rate, making it a viable option for packaging applications. The findings indicate that combining waste maize cob and fermented maize starch can produce a high-performance bioplastic with potential applications in industries that require environmentally friendly and biodegradable materials, particularly packaging.

INTRODUCTION

The global demand for plastics has seen an excellent increase over the last few decades, as a result of their versatility, durability, and wide range of applications (Geyer *et al.*, 2020). Traditional plastics, which are mostly derived from petroleum-based sources, have contributed to significant environmental problems, including long degradation times and plastic waste accumulation in natural ecosystems, thereby disrupting ecosystems. This has

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led to a growing interest in developing sustainable alternatives, such as bioplastics, which are produced from renewable resources.

One promising and suitable source of raw material for bioplastic production is agricultural waste, particularly maize cobs. Maize (*Zea mays*) is one of the most cultivated crops globally, with its production generating large quantities of waste by-products, including cobs, husks, and stalks (Adhikari *et al*., 2022). Traditionally, maize cobs have been either left at the farm, burned, or used as animal feed, with low economic value. However, recent advancements in biopolymer technology have highlighted the importance of maize cobs as a valuable by-product for the production of bioplastics.

The components of maize cobs, including cellulose, hemicellulose, and lignin, make them suitable for conversion into biodegradable polymers. These polymers can be used to produce various bioplastic materials, offering a better alternative to conventional plastics. The use of waste maize cobs for bioplastic production not only provides a solution to agricultural waste management but also falls in line with global efforts to reduce reliance on fossil fuels and mitigate environmental pollution (Maharana *et al*., 2020).

The need for sustainable waste management practices and the development of eco-friendly materials is ever more pressing, given the current environmental crisis. The production of bioplastics from waste maize cobs addresses multiple sustainability challenges, including waste valorization, the reduction of greenhouse gas emissions, and the depletion of non-renewable resources. As a major agricultural residue, maize cobs represent an underutilized resource with significant potential for contributing to the circular economy.

Bioplastics derived from maize cobs give plenty of advantages over conventional plastics. They are biodegradable, reducing the environmental burden of plastic waste, and their production is less energy-intensive than petroleum-based plastics. Moreover, the use of agricultural waste as a raw material for bioplastic production can improve the economic value of maize farming, particularly in regions where maize is a basic crop (Gupta and Kumar, 2022). This study is particularly relevant in the context of developing countries where agricultural waste management remains a significant challenge and where there is a need for affordable and sustainable materials.

Recent studies have demonstrated the feasibility of producing bioplastics from various lignocelluloses; however, there is still a gap in research specifically focused on maize cobs (Jiang *et al.*, 2020). The study contributes to this emerging field by providing insights into the potential of maize cobs as feedstock for bioplastic production and by exploring the scalability of these processes for industrial applications.

Aim of the study

The study aimed to investigate the potential of waste maize cobs as feedstock for the production of bioplastics.

Objectives of the study

The objectives of this study were to:

- Determine the elasticity of bioplastics produced from waste maize cob.
- Determine the tensile strength of bioplastics produced from waste maize cob.
- Determine the bioplastic permeability of waste maize cob.

MATERIALS AND METHODS

Study area

The research was conducted at the Applied Biology and Biotechnology department laboratory, Enugu State University of Science and Technology, Agbani, Enugu state, Nigeria. Agbani is a town located in the Nkanu West Local Government Area in Enugu State (Plate 1). It is situated in the southern part of Enugu State, approximately 20 kilometers south of Enugu City, latitude 6.1333° north and longitude 7, 4667° east. The laboratory is equipped with the necessary facilities for biochemical analysis and material testing, ensuring that the experimental procedures adhere to standard protocols. The ambient temperature of the laboratory and humidity level were maintained, providing optimal conditions for the bioplastic production process.

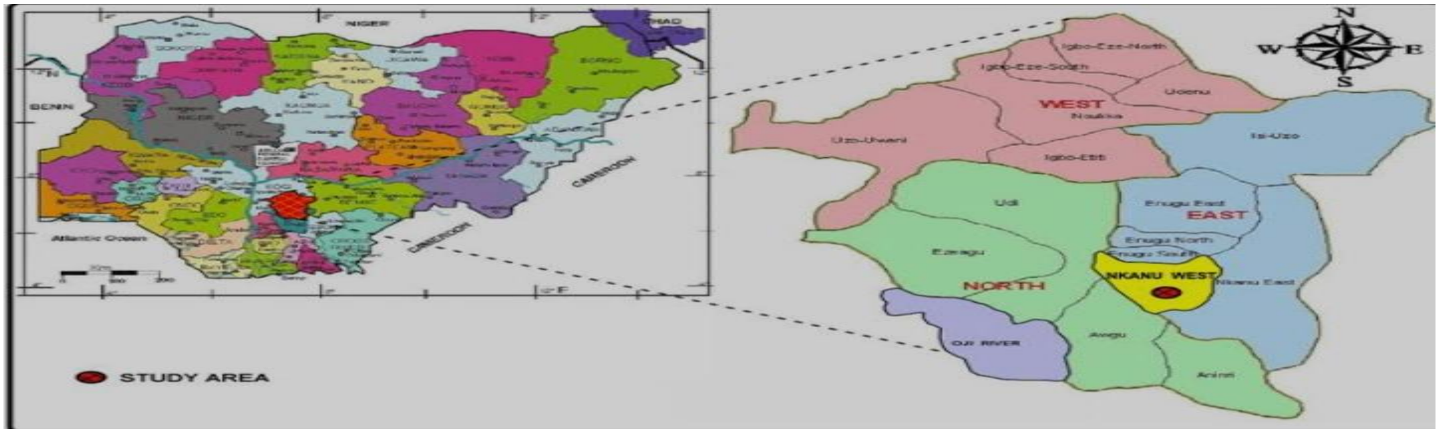

Plate 1: Geographical (map) description of Agbani.
Source: Google map.

Reagents

All reagents used in this study were of analytical grade and were sourced from reputable suppliers to ensure their purity and consistency. The key reagents were acetic acid, glycerol, sorbitol, and distilled water. The plasticizer glycerol was used to enhance the flexibility of the bioplastic. Each reagent's concentration and volume were carefully measured using calibrated instruments to ensure precision in the experimental procedures.

Source of starch

The starch used in this study was extracted from maize. Processed maize was sourced from local vendors in the Agbani community in Nkanu West LGA, Enugu state, ensuring that the maize used was of a consistent variety. The maize cobs used as the binder were also collected from the same sources to maintain uniformity of the raw materials. The choice of maize cob and processed maize as sources was based on availability, low cost, and the high starch content of processed maize, which is essential for bioplastic production.

Experimental procedure

The experiment was designed as a factorial experiment with two main factors: the type of starch source (maize-derived starch) and the type of binder (maize cob powder). Different amounts of starch (10ml, 15ml, 20ml, etc.) and corn cob binder (0.1g, 0.2g, 0.6g etc.) were used. The experiment was replicated thrice, and data on the physical properties of the bioplastics, such as tensile strength, elasticity, and permeability, were collected.

Experimental groups

Sample A was gotten by mixture of 0.3g of binder (grounded maize cob), 10ml of the source of starch and 1.25ml each of the reagents and heated for 7.5 minutes followed by 48 hours of incubation, sample B was gotten by mixing 0.4g of the binder, 15ml of the source of starch, and 1.88ml each of the reagents and was heated for 11.3 minutes followed by 48 hours of incubation, sample C was achieved by mixing 0.6g of binder, 20ml of source of starch, 2.5ml each of the reagents and was heated for 15.00 minutes followed by 48 hours of incubation, sample D was achieved by mixing 0.9g of binder, 30ml of source of starch, 3.75ml of each reagents and heated for 22.5 minutes followed by 48 hours of incubation, sample E was gotten by mixing 1.2g of binder, 40ml of source of starch, 5ml each of the reagents, and was heated for about 30 minutes followed by 48 hours of incubation sample F was achieved by the mixture of 0.1g of binder, 20ml of source of starch, 2.5ml each of the reagents and was heated for 5 minutes followed by 48 hours of incubation, and finally, sample G was the mixture of 0.2g of binder, 20ml of source of starch, 2.7ml each of the reagent and was heated for 6.5 minutes followed by 48 hours of incubation

Extraction of starch

Starch was extracted from the processed maize using a wet milling process. The starch was first diluted with an equal volume of distilled water, after which a few volumes of water were removed to obtain the actual starch.

Measuring and addition of reagents, plasticizer, and binder

The required amounts of starch, maize cob powder, and glycerol were weighed using an analytical balance (table 1). For each formulation, the starch was first mixed with distilled water to form a slurry. Maize cob powder was then gradually added to the starch slurry while stirring continuously to ensure a uniform mixture. Acetic acid was then added together with sorbitol (1g dissolved in 100ml of distilled water) and then mixed uniformly. Glycerol, as a plasticizer, was added last to the mixture to ensure that the final formulation exhibited homogenous consistency. The mixture was then subjected to heat treatment to initiate the gelatinization of the starch and the binding action of the maize cob powder.

Table 1: Biosource and plasticizer measurement

Sample	Binder	Source of starch	Acetic acid	Sorbitol	Glycerol
A	0.3 g	10 ml	1.25ml	1.25 ml	1.25 ml
B	0.4 g	15ml	1.88ml	1.88ml	1.88ml
C	0.6 g	20ml	2.5ml	2.5ml	2.5ml
D	0.9g	30ml	3.75ml	3.75ml	3.75ml
E	1.2g	40ml	5ml	5.0ml	5ml
F	0.1g	22ml	2.5ml	2.5ml	2.5ml
G	0.2g	20ml	2.7ml	2.7ml	2.7ml

Heat Treatment and Incubation Period

The starch-binder-plasticizer mixture was heated at 90°C in an electric heater for 11, 15, 30 minutes (depending on the samples) (table 2). This heat treatment facilitated gelatinization of the starch, which is critical for the formation of a cohesive bioplastic matrix. During this process, the mixture was continuously stirred to prevent lump formation and to ensure an even heat distribution. After heating, the mixture was poured into molds and allowed to cool at room temperature for 24 hours.

The molded bioplastic samples were incubated at room temperature (25°C) for 48 hours to allow complete drying and curing. This incubation period is crucial for the stabilization of the bioplastic's physical properties, ensuring that the samples reach their final form before testing. The incubation was carried out in a controlled environment to prevent contamination and to ensure uniformity among all samples.

Table 2: Samples heat and incubation period

Samples	Period of heat (minutes)	Time of incubation (hours)
A	7.50	48
B	11.30	48
C	15.00	48
D	22.50	48
E	30.00	48
F	5.00	48
G	6.50	48

RESULTS

Production of bioplastics from waste maize cobs

The results show different characteristics of the bioplastics, such as elasticity, tensile strength, and permeability (table 3). After the samples were analyzed, it showed that samples B and G had higher elasticity than the other samples due to variations in the amount of reagents/ plasticizers added to them as well as the amount of source of starch and binder. There was no much difference in the tensile strength of the bioplastic samples amongst the 7 samples (6.50 ± 1.31, 6.50 ± 1.31, 3.50 ± 1.31, 5.50 ± 1.31, 3.50 ± 1.31, 4.50 ± 1.31, and 6.00 ± 1.31 N/m^2), respectively. The permeability showed that samples B and G recorded little or no passage, meaning that the bioplastic of those samples showed resistance to water penetration unlike other samples, although samples A, D, and F showed mild resistant to permeability.

Table 3: Characteristics of bioplastics from waste maize cob.

Sample	Elasticity (N/m^2) ± SD	Tensile Strength (N/m^2) ± SD	Permeability
A	0.60 ± 1.02	6.50 ± 1.31	++
B	3.00 ± 1.02	6.50 ± 1.31	+++
C	0.50 ± 1.02	3.50 ± 1.31	+
D	1.00 ± 1.02	5.50 ± 1.31	++
E	0.50 ± 1.02	3.50 ± 1.31	+
F	1.00 ± 1.02	4.50 ± 1.31	++
G	2.50 ± 1.02	6.00 ± 1.31	+++

KEY

+ (high rate of water penetration/permeability)
++ (mild rate of water penetration/permeability)
+++ (Low rate of water penetration/permeability)

Result of pictorial bioplastic variation among different samples

The pictorial illustration showed several outcomes of different bioplastic samples (A to G) from waste maize cob (plate 2). The pictorial representation shows that sample G had a suitable bioplastic outcome compared with the other samples used in the study.

Plate 2: Pictorial representation of bioplastics produced from maize cob of different samples

DISCUSSIONS, CONCLUSIONS, AND RECOMMENDATIONS

Discussion

Bioplastic production has been an increasingly researched area, and various studies have explored using agricultural waste as raw material. In this study, we focused on using waste maize cob as a binder and processed maize (fermented corn starch) as a starch source. The present study is consistent with the work of Aboluwarin *et al*. (2020), who reported that bioplastics made from maize cob had strong tensile properties, which were attributed to the high cellulose content in the material. Similarly, Sharma *et al*. (2021) demonstrated that maize cob-based bioplastics showed enhanced tensile strength, making them suitable for applications requiring durability. The study also agreed with the findings of Zhang *et al*. (2019), who stated that bioplastics derived from maize cob waste were not only environmentally friendly but also had high-quality tensile strength, which improved their usability in packaging. Sharma *et al*. (2021) reported that maize cob-based bioplastics exhibit excellent elasticity due to the presence of natural polymers like lignin and hemicellulose, which enhance flexibility, which is in agreement with the present study. Similarly, this work agrees with Singh and Patel (2020), who showed that bioplastics derived from maize cob exhibit good elasticity, allowing them to maintain structural integrity under stress. This study supported the research by Zhang *et al.* (2019), who reported that bioplastics made from maize cob exhibited low water permeability due to the hydrophobic nature of lignin and other natural components in the cob. Similarly, Kumar *et al*. (2021) is consistent with this results. Their study highlighted that maize cob-based bioplastics exhibit minimal water absorption, which enhances their suitability for packaging and storage applications.

Conclusion

The production of bioplastics from waste maize cob demonstrates significant potential because of its excellent tensile strength, elasticity, and low permeability. These attributes make maize cob-based bioplastics suitable for various applications, including packaging and moisture-sensitive uses.

Recommendations

We recommend that bioplastics made from waste maize cob should be encouraged to mitigate the environmental pollution caused by petroleum-based plastics. The development of bioplastics from waste maize cob and maize starch can be further optimized by addressing issues such as process standardization, exploration of alternative plasticizers, scaling up production, optimization of binder concentration.

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