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Investigating the Biopolymer Properties of Neem Leaf Extract for Food Packaging Applications

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Abstract
Azadirachta indica, commonly known as Neem, belongs to the Meliaceae family and is a well-known traditional medicine in Africa, particularly in Nigeria. Neem tree's various parts have been employed in the development of a range of products, including antifungal, anthelmintic, anti-diabetic, antiviral, antibacterial, sedative, contraceptive, and other applications. The current study aims to unveil the biopolymer properties of Neem leaf extract and its tensile properties for potential use in food packaging applications.
In this investigation, Neem leaves were collected, and a crude extract of Neem was obtained by pouring them into boiling water and cooling and reconciling the extract for 24 hours. Constituents, such as glycerol, glucose, agar, and gelatin, were added to the extract, and it was then heated for approximately 20 minutes at a temperature of 65°C. The biopolymer-based plastic film was observed after 48 hours of incubation at room temperature. Micro tensile tests were conducted to assess the developed polymeric film's strength, which was found to be relatively weaker than bioplastic material, but it required significantly less energy for its development. Further intensive research work is necessary to enhance the strength properties of the developed biopolymer to make it a suitable packaging material. The biopolymer obtained from Neem leaf extract holds immense potential to replace conventional plastic as a biomaterial.
***Keywords**: Neem tree, swelling, solubility, tensile, packaging*

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I. INTRODUCTION

Azadirachta indica, commonly known as Neem, is a versatile tree with religious, medicinal, and social significance. It belongs to the Meliaceae family and is found worldwide, with a higher concentration in Western Africa and Nigeria. Neem is classified as a 25-meter-tall tree with a semi-straight trunk that starts fruiting after three to five years of growth. The leaves are approximately 30 cm in length and consist of 10-12 saw-toothed leaflets. Neem extracts are used in treating various diseases, including cancer, skin diseases, digestive disorders, and AIDS, due to the presence of active chemical compounds such as glycosides, dihydrochalcone, coumarin, tannins, zadirachtin, nimbin, nimbidine, diterpenoids, triterpenoids, and proteins (Ali *et al*., 2021).

Bioplastics, are either biodegradable, biobased, or possess both properties. Biodegradable plastics are degraded by microorganisms in nature, resulting in the conversion of bioplastics into water, carbon dioxide, and biomass. Biobased bioplastics are made from biomass instead of oil. The use of natural polymers in the environment is feasible and reduces pollution, making neem a promising candidate for the production of bioplastics (Oyekanmi *et al*.,2021).

The demand for food-packaging materials has increased significantly, and consumers now demand that packaging be environmentally friendly in addition to keeping food healthy, fresh, and aesthetically pleasing. Traditional synthetic polymers used for food packaging cause significant environmental damage and are non-biodegradable, necessitating more comprehensive action and energy for recycling (Bilo *et al*.,2018). The development of packaging that inhibits moisture gain or loss, prevents microbial contamination, and acts as a barrier against permeation of water vapor, oxygen, carbon dioxide, and other volatile compounds has created a market for innovative packaging materials, such as biodegradable films made from raw materials generated from renewable sources (biopolymers). Polysaccharide-based biopolymers are the most widely studied materials for the synthesis of edible bio-films. Therefore, the synthesis of biofilms has become a promising solution for maintaining and/or improving the quality of packaged items while reducing waste packaging. (Mathew *et al*.,2019).

Elena Stoleru *et al*., 2021, examined the use of bioplastics, specifically those derived from biological sources, as a potential solution to the environmental and health issues associated with conventional plastics used in food packaging. Bioplastics can be classified as either biodegradable or non-biodegradable, and have been found to be effective in extending shelf-life and enhancing food quality and safety. The study focuses on active food packaging and reviews the latest developments and challenges in the field, highlighting the advantages and limitations of bio-derived plastics compared to traditional plastics. The study also provides an overview of recent advancements in active food packaging applications.

Elena Butnaru *et al.,* 2021, discovered that in recent years, there has been a growing interest in biodegradable plastics due to the increasing demand for plastics and the need for safe disposal. Synthetic biodegradable plastics contain specific chemical bonds such as ester, amide, and urethane that can be broken down by microorganisms. The food industry has seen a trend towards natural alternatives for prolonging the shelf life of foods, leading to a review of synthetic biodegradable plastics in food packaging. This chapter specifically looks at the performance of poly (vinyl alcohol), poly(caprolactone), and other polymers in active food packaging, as well as the environmental impact of synthetic bioplastic-based food packages, including end-of-life options and biodegradation. Despite the promising properties of these biodegradable plastics, their commercialization and implementation still face challenges. discussed. Although at this moment these biodegradable synthetic plastics are still far from being an economical and feasible alternative to compete with conventional plastics in the near future there is a positive outlook if the research progress in this field is taken into account.

Natural polymers offer several benefits, including reducing environmental pollution, which makes them a viable option for regular use. Among natural polymers, Neem has various medicinal and other positive properties. Therefore, the objective of this research is to explore and study the properties of a Neem-Based bioplastics suitable for food packaging.

II. MATERIALS AND METHOD

2.1 Experimental Procedure

The experimental procedure was conducted according to Ashwini *et al*.,2018.

2.1.1. Sample Collection

The samples for this study were collected by plucking mature, dark green Azadirachta indica leaves. A botanist authenticated the leaves based on their morphological features to ensure the plant species' accuracy. For the extraction process, the leaves were carefully selected for similar size and shape.

2.1.2. Leaf Extract

5g of Neem (Azadirachta indica) leaves were washed and weighed in this study. Using a mortar and pestle, the leaves were crushed into a paste. The paste was mixed with 100ml of distilled water and boiled. The mixture was strained through a kitchen strainer after boiling to remove any debris. The resulting extract was kept at room temperature for 20-24 hours.

2.1.3. Neem Bioplastic Preparation

A 0.75g of glucose, 1.20g of Gelatin, 0.55g of agar, and 1.8ml of glycerol were added to the extracted Neem solution. All of the chemicals used were analytical reagent grade and obtained from the NCAM lab. A magnetic stirrer was used to stir the mixture for 2 hours at a temperature of 65°C.The mixture was then cast on a clean and dry acetate sheet and allowed to dry for 48 hours. The dried film was finally peeled away from the sheet.

2.2. Evaluating Parameters

2.2.1. Swelling and Solubility Analysis

A swelling test was performed to evaluate the bioplastic's sustainability and durability by immersing pre-weighed samples in various solvents, including water, chloroform, and methanol, for 2 hours. The weight disparity was then calculated. Furthermore, the bioplastic's solubility was investigated by immersing the samples in solvents such as chloroform, water, methanol, and ethanol, with solvents diluted to 30% and 60% for comparative analysis. The bioplastic samples were immersed in these solvents for a few hours, say 2-3 hours, and the results were recorded.

2.2.2. Tensile Strength Analysis.

The tensile properties of the bioplastic were also evaluated by characterizing and analysing their tensile strength. Rectangular specimens of the samples were tested using the NCAM Universal Testing Machine equipped with a 5kN load-cell. The ends of the specimens were vertically mounted on two mechanical gripping units of the tensile tester.

III. RESULT AND DISCUSSION

3.1 Swelling Test

The table below contains experimental data for three different samples (Samples 1, 2, and 3), where each sample was dissolved in a different solvent (Water, Chloroform, or Methanol) and a specific quantity (5) was used. Several measurements were taken during the experiment, including the initial weight, final weight, and weight difference for each sample, which are listed in the table.

Each sample's initial weight (column 4) represents the weight of the sample before it was dissolved in the solvent. This weight is necessary to calculate the concentration of the sample in the solvent, which is an important parameter in many chemical and biological applications.

Each sample's final weight (column 5) represents the weight of the sample after it has been dissolved in the solvent and the solvent has been removed, either by evaporation or filtration.

Because it takes into account the weight of both the sample and the solvent, this weight is also important in determining the concentration of the sample in the solvent.

The weight difference (column 6) represents the difference between the initial and final weights of each sample, which indicates how much sample was dissolved in the solvent.

If the weight difference is positive, the sample dissolved in the solvent; if it is negative, the sample did not dissolve or some of it was lost during the experiment.

The initial weight of Sample 1 was 0.058 grams, and the final weight was 0.070 grams, resulting in a weight difference of 0.012 grams. This indicates that Sample 1 was dissolved in the solvent water. The initial weight of Sample 2 was 0.062 grams, and the final weight was 0.060 grams, resulting in a weight difference of -0.002 grams. As a result, Sample 2 did not dissolve in the chloroform solvent. The initial weight of Sample 3 was 0.052 grams, and the final weight was 0.020 grams, resulting in a weight difference of -0.032 grams. As a result, Sample 3 did not dissolve in the methanol solvent.

Table 1: Swelling Analysis Carried Out for The Bioplastic in Different Solvent

Sample No	Solvent	Quantity	Initial Weight	Final Weight	Weight Difference
Sample 1	Water	5	0.058	0.070	0.012
Sample 2	chloroform	5	0.062	0.060	-0.002
Sample 3.	methanol	5	0.052	0.020	-0.032

3.2 Solubility Test

Table 1 contains information about three different samples, which are identified by their Sample Numbers. Each sample was tested for solubility in three different solvent concentrations: chloroform, ethanol, and methanol. The Solvent column shows which solvent was used in the test for each sample. Organic solvents such as chloroform, ethanol, and methanol are commonly used in scientific research.

Each table row represents a different sample, which is identified by a Sample Number.

The first sample, Sample 1, was tested with the solvent Chloroform. Chloroform was used in two concentrations: 30% and 60%. The sample was tested at both concentrations, as indicated by the Concentration column. The Observation column indicates that the sample was insoluble in both Chloroform concentrations. This means that the sample did not dissolve in the Chloroform but remained as a separate phase. This was true for both the 30% and 60% Chloroform concentrations.

The same procedure was used for Sample 2, but the solvent was Ethanol this time. Ethanol concentrations of 30% and 60% were used once more. According to the Observation column, the sample was insoluble in both Ethanol concentrations. This means that the sample, like Sample 1, did not dissolve in the Ethanol and instead remained as a separate phase.

Methanol was used as the solvent in the third sample, Sample 3. Methanol was used in two concentrations, as with the other samples: 30% and 60%. The Observation column indicates that the sample was insoluble in both Methanol concentrations. This indicates that the sample did not dissolve in Methanol and instead remained as a separate phase.

Table 2. Solubility Analysis Using Different Solvent

Sample No	Solvent	Concentration	Observation
Sample 1	Chloroform	30% / 60%	Insoluble / Insoluble
Sample 2	Ethanol	30% / 60%	Insoluble / Insoluble
Sample 3.	Methanol	30% / 60%	Insoluble / Insoluble

3.3 Tensile Strength

The tensile strength of the developed Neem-based bioplastic material was found to be 5.0 Mpa, which is significantly less than the ASTM D882 standard requirement. However, given the enormous potential of Neem leaves, particularly in medical products such as treatment for cancer, skin diseases, digestive disorders, and AIDS.

To find the best composite for Neem-based blend preparation and as a potential alternative to conventional plastic in packaging industries, extensive research must be conducted.

IV. CONCLUSION AND RECOMMENDATION

Based on the research presented above, we can conclude that Neem-based bioplastics can be used for a variety of applications in both medical and food packaging. Further applications can be investigated if tensile strength is improved.

However, the developed bioplastic has acceptable soluble, swelling, and degradation properties. According to the information provided, the tensile strength of the Neem-based bioplastic material developed did not meet the standard requirement of 5.0 Mpa.Given the potential benefits of Neem leaves in medical products, more research could be conducted to identify the best composite for preparing Neem-based blends.

Researchers should concentrate on developing and testing different composites to improve the mechanical properties of Neem-based bioplastics, such as incorporating natural fibers or changing the processing conditions.

Furthermore, to ensure that the material is a sustainable alternative to conventional plastics, it must be investigated for biodegradability and environmental impact. Overall, the development of Neem-based bioplastics is a promising area for the packaging industry, with the potential to provide a sustainable solution for reducing plastic waste and promoting eco-friendly practices with additional research and innovation.

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