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Signature: Supervisor
(Dept. of Chemical Engineering)
Indian Institute of Technology
Banaras Hindu University

Co-Supervisor
(School of Biochemical Engineering)
Indian Institute of Technology
Banaras Hindu University

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Supervisor
(Dept. of Chemical Engineering)
Indian Institute of Technology
Banaras Hindu University

Co-Supervisor
(School of Biochemical Engineering)
Indian Institute of Technology
Banaras Hindu University

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October, 2020 K Rohit Srivastava

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List of Abbreviations

BCNC	Bacterial Cellulose Nanocrystals
BHKP	Bleached Hard Kraft Pulp
BPF	Banana Pseudo Stem Fiber
CA	Citric acid
CMMT	Citric acid modified montmorillonite
CPCB	Central Pollution Control Board
CS	Chitosan
DLS	Dynamic Light Scattering
EB	Elongation at Break
FTIR	Fourier Transform Infrared Spectroscopy
HDPE	High-Density Polyethylene
HNTs	Halloysite Nanotubes
LCNF	Lignocellulosic Nanofibers
LCNWs	Lignocellulosic Nanowhiskers
LDPE	Low-Density Polyethylene
MA	Maleic Anhydride
MA	Maleic Acid
MAPP	Maleic Anhydride Grafted Poly Propylene
MCC	Micro Crystalline Cellulose
MMT	Montmorillonite
MPa	Mega Pascals
NCFs CNF	Nanocellulose Fibrils
NFC	Nanofibrillated Cellulose
PBS	Poly Butylenes Succinate
PCL	Poly Caprolactone
PET or PETE	Polyethylene Terephthalate
PHA	Poly Hydroxyl Alkanoate
PHB	Poly Hydroxyl Butyrate
PHBV	Poly Hydroxyl Butyrate Co-Valerate
PLA	Poly Lactic Acid
PP	Polypropylene

PS	Polystyrene
PVA	Poly Vinyl Alcohol
PVC	Polyvinyl Chloride
RH	Relative Humidity
RSM	Response Surface Methodology
SEM	Scanning Electron Microscopy
TEMPO	[(2,2,6,6-Tetramethylpiperidin-1-Yl) Oxidanyl]
TONC	TEMPO-Oxidized Nanocellulose
TS	Tensile Strength
WST	Water Swelling Test
WVP	Water Vapour Permeability
WVTR	Water Vapour Transmission Rate
XRD	X-Ray Diffraction

Preface

Plastic is a major solid waste globally and its indestructible nature is leading to pollution of land and sea both. The major problem is caused by single use plastics like those used in packaging comprising mainly of polyethylene and polypropylene. These packaging wastes contribute up to 80% of plastic waste generated and are a cause of serious concern. The ease of manufacturing such materials along with low cost and desired properties like weather resistance, transparency and strength has made plastics almost indispensible.

Various attempts have been made for finding substitutes to plastic packaging and although some biodegradable polymers like poly lactic acid, starch, poly hydroxy alkanoates, poly vinyl alcohol have been developed over the years, these are yet to enter the main stream owing to economical aspects of manufacturing of these polymers. Efforts have also been made to prepare composite materials that can be used for packaging. Composites have been prepared with starch – polyvinyl alcohol, starch – poly lactic acid, starch – chitosan, poly vinyl alcohol – chitosan etc. However, lignocellulosic biomass from agricultural residues is a potential underutilised resource which can be used as fillers in composite materials thereby making the composites more economical. The use of such lignocellulosic fibres can enhance mechanical properties of composites as well as reduce their cost.

One such agricultural residue is banana pseudo stem. Banana is cultivated all over the Indian subcontinent and its pseudo stem contributes to a large amount of agricultural waste since a banana plant gives fruit only once and then its stem, called pseudo stem, is cut and left to rot near the fields. Banana pseudo stem fibers are rich in cellulose and have lower lignin content. Since lignin is of recalcitrant nature and therefore hinders with interface interactions between fiber and polymer matrix, banana pseudo stem fibers have an advantage over other agri-residues like rice and wheat stalks to be used as filler in composite film preparation.

The present work aims at solving two problems at once, by using the agricultural waste in making biodegradable composite films that can reduce the consumption of plastic by partially substituting them.

In this work, PVA, which is a water soluble and biodegradable polymer, and banana pseudo stem fibre have been used to prepare composite films with different ratio of banana pseudo stem fibre to PVA. Further different plasticizer, cross linkers and nano fillers like nano cellulose and nano clay (Montmorillonite – Sodium and Citric acid modified Montmorillonite) have been tested for their impact on film's properties. Banana pseudo stem fibers have been chemically treated with acid and alkali and the effect of such treatment has also been evaluated. Different size ranges and loading of banana pseudo stem fibre along with different plasticizers (glycerol, Sorbitol and fructose to improve the elasticity) and cross linkers (glutaraldehyde, citric acid and maleic acid -- for strength and moisture barrier) at various concentrations have been tested for best results of mechanical and water barrier properties since the films have been prepared for the purpose of packaging.

To further improve the water barrier and mechanical properties nano fillers have been utilized. Three nanofillers, nanocellulose, Montmorillonite nano clay and citric acid modified nanoclay have been incorporated in the composite films.

The composite films have been characterized for their mechanical properties like tensile strength and % elongation at break, and water barrier properties viz., water vapour permeability, swelling in water and water contact angle. The films have also been tested for their biodegradability by estimating the weight loss upon burial under soil for three months.

Chapter 1 provides a general introduction to the reader about the drawbacks of greater than ever production, consumption and later generation of plastic waste which is typically indestructible for hundreds of years while explaining the basic terminology and alternate solutions to the plastic problem, mainly in the form of using renewable and biodegradable materials derived from biomass. An outline of available biopolymers and their advantages and disadvantages in brief has been described and composite films synthesized using polyvinyl alcohol and lignocellulosic biomass have been briefly discussed.

Chapter 2 is a review of current literature regarding the use of bioplastics, polyvinyl alcohol in particular. Composite films prepared by PVA and reinforced with lignocellulosic polymers, nanocomposites of PVA and nano fillers like nano cellulose and nano silica, pretreatments of lignocellulosic biomass for film preparation have been reviewed.

Chapter 3 describes the materials and methods used for the experimental work. It describes in detail the materials used and methods involved in film preparation and characterization.

Chapter 4 provides the results obtained after preparing different kinds of films and carrying out their characterization tests along with a discussion of the possible cause of findings and their correlation with findings of other workers.

Chapter 5 concludes the thesis work done and summarizes the important findings. It also makes some useful recommendations for further work in this area.