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Synthesis and Characterization of Biodegradable Starch-Based Bioplastic Using *Plectranthus Rotundifolius*

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ABSTRACT

Plastics are highly toxic, can cause various health issues, and affect the ecosystem severely. Most widely used plastics cannot be easily decomposed in the soil and finally it results in environmental hazards and pollution. In recent years, plastic became an integral part of human modern life. Due to this reason, an effective waste management is necessary to prevent the pollution of our environmental resources, human health issues and damage of the ecosystem. The bio-plastic may replace the conventional plastic produced from petroleum and other sources. The bio-plastic can be produced from natural raw materials such as biomass and starch rich food materials. Starch-based bio-plastic will easily degrade by exposure of environmental conditions such as sunlight, moisture content and certain micro-organisms like fungi, bacteria or algae. Plectranthus rotundifolius is commonly known as Chinese potato in India, it contains about 20% of starch in it. Due its starchy property it is selected for the study. The biodegradability characteristics of these plastics create a positive impact and awareness in the society.

Keywords: Bioplastic, starch, *Plectranthus rotundifolius,* Biodegradable

1 INTRODUCTION

Plastics are a group of artificial or natural organic materials that can be mold and hardened. Plastics are very common and useful nowadays and are used in almost every places to meet basic needs such as food packages, baggage, cell phones, electronics, pharmaceutical and automobiles industries [1]. The plastics industry is a new industry and it is one of the fastest growing industries in the world. Since the mid-nineteenth century, it began with the introduction of nitrocellulose and camphor mixture. Polyethylene has an excellent low-temperature resistance, outstanding power insulation, a great chemical resistance, a marvelous radiation resistance, and a good pressure resistance. Polyethylene is composed only of carbon and hydrogen, there is no polar element present hence it comes with good water resistance [2]. The plastics cause emission of carbon and many other toxic gases during its production results in environmental and health issues. The plastic might take several hundreds of years to decay within the environment. Hence, efforts are taken to reduce the use of synthetic plastics and to promote bio-plastic [3]. Biodegradable plastics are plastics produced from natural materials that are mostly organic materials such as corn, potato, cassava starch, banana peel and other cellulose based materials etc. Biodegradable plastic is a potential alternative to petroleum-based plastics. It helps in the reduction of oil consumption and promoting a greener environment. Around 50% of the market of bio-plastic is starch-based plastics. Plastics are slow to degrade and the pollution can unfavorably affect lands, waterways and oceans. Living organisms, particularly marine organisms can also be affected through entanglement, direct assimilation of plastic waste, contact with chemicals within the plastics and cause interruptions in bio-functions of the living organisms. These bio-polymers evince the characteristic features of highly functionalized spherical nature, interstellar polymers exhibit different properties from those of their linear counterparts, such as less entanglement in the solid state, high solubility in numerous solvents, low melt viscosity and fast molecular motion [4]. These are of two types: one is plastic materials which will be decomposed in natural aerobic process and another is decomposed in anaerobic environments. Degradation occurs when the soil microbial consortia start consuming these polymers and eventual release of monomers to the environment certainly has less hazardous effects on the landscape. These polymers are either composed of bio-plastic (PHA or PHB) or plastics which are derived from renewable raw materials or petroleum based a plastic which contains additives. Nowadays, bio-plastics are made by corn starch, potatoes starch or banana starch, cassava starch, cellulose etc. Micro-organisms like Fungi and bacteria found in soil get to work breaking down PLA into its basic parts. Under the proper aerobic conditions, with heat and moisture, PLA will compost like any other organic material. The microorganisms found in compost consume the bio-plastic and break it down into humus, a nutrient-packed, soil-like substance that acts as natural plant food. The final waste products are water and carbon dioxide [5]. Starch is a naturally occurring soluble carbohydrate that can be obtained from various raw materials like corn, rice, potato, yam, cassava, banana peels and sweet potato. Starch manifests some similar properties as polymers when exposed to hydrolysis. Due to its large availability, low cost, renewability and biodegradability, starches are commonly used in the production of bio-plastic. Starch can act like a thermoplastic in the presence of plasticizer, with application of heat and mechanical treatment. As native starch-based films are limited to high water affinity and brittleness; other natural biopolymers are often added as fillers to modify and improve films properties [6]. PLA is a plastic substitute made from fermented plant starch typically from corn or sugarcane which is quickly becoming a popular alternative to traditional petroleum-based plastics [7]. Plants are considered to be a profitable option for production of bio-plastic mainly due to the capability as solar driven bio-factories with the potential for being renewable, sustainable and natural polymer production, such as starch and cellulose. Among those naturally produced plant polymers, starch is considered as a promising candidate for developing sustainable materials which mainly due to complete biodegradability of starch, low cost and renewability. However, starch-based materials have some drawbacks including long term stability caused by water absorption, aging caused by retro gradation and poor mechanical properties. To overcome these limitations, plasticizer such as glycerin has been added to improve shelf-life and elasticity of the product [8].

2 MATERIALS AND METHODS

The Chinese potatoes *(Plectranthus rotundifolius)* were collected from a local market in Kerala. The chemicals used in this study are Hydrochloric acid (HCL), Sodium hydroxide (NaOH), Glycerin, H_2SO_4, Ethanol, Methanol, Acetone and chloroform.

A). Preparation of the Chinese potato sample

There were a few procedures followed before the extraction of the starch from the Chinese potato. These included the: 1. Weighing 2. Washing 3. Peeling 4. Dicing.

The selected sample was first weighed. This step was done to obtain an initial mass of the tuber. Potato tubers with a total weight of approximately 1 kilogram were used in the extraction. The selected sample was then washed with water to remove the contaminants such as dirt, soil, small roots and other unwanted plant materials. The washed sample was again weighed to obtain the difference in the weighing before and after washing. The sample was then hand peeled using a knife. The peeled potato was then carefully hand diced to small regular cubes of similar size. The blending and slurring procedure of the sample was done in double distilled water by using a blender. For water slurring of the sample of diced Chinese potato, the ratio of the tuber to water (double distilled water) added was 500ml. The filtration procedure was done by passing the slurry obtained through double-layered cheesecloth. The filtration procedure was done to separate the starch granules extract from the residue of the potato sample. The starch was washed into the filtrate by adding double distilled water from a wash bottle onto the residue. The starch sediment was washed twice to get pure starch. After washing steps, dried the sample for about 2 days under sunlight or room temperature. Collect the starch power in a container after complete drying.

B). Production of starch based bioplastic

7gm of dried Chinese potato starch was diluted with 70ml distilled water. The beaker containing the starch solution was brought on a heater plate including a magnetic stirrer.

Fig 1. Steps involved in bioplastic production

A magnetic stick was added in the beaker and let stirring at 170-180 RPM. Then 10ml of 0.1 M HCl was pipette in the mixture and the same amount of 0.1M NaOH was added for neutralization. Add 4ml of 1% glycerol into the mixture. Then the heater was switched to 100^{0}C and the mixture was allowed to heat for about 15mins and the stirrer was brought to 230 RPM as the mixture was hardening. The mixture took about 1 hour to form an opaque gel. The gel was spread on a mold made with an aluminum foil. The sample was allowed to dry for about 2 days at room temperature.

3 CHARACTERIZATION

A). FTIR Spectroscopy

FTIR analysis was carried out to characterize the functional groups that present in the sample.

APPLICATION STUDIES

A). Solubility Test

The film sample was cut into six square sections of 2.0 cm, and the dry film mass was weighed accurately and recorded. The samples remained immersed in solutions and water taken in beaker for 6hrs. The solutions are: 1).Con. HCL 2).Con.H_2SO_4 3).Chloroform 4).Methanol 5).Acetone 6).Ethanol 7).water.

The lasting portions of the film were filtered after 6 hours and then dried in a hot air oven at 110°C until an ultimate fixed weight was found. Glycerol has a good water solubility range from 18% to 25%. The percentage of total soluble matter (% solubility) was calculated as:

WS (%) = $[(W_0 - W_f)/W_0] \times 100$

WS= solubility in water

W_0 = beginning weight

W_f = final weight

B). Biodegradability test

The specimen was cut into pieces of 4.0 cm. Found near the roots of plants which are rich (having slight moisture content) was collected and stored in a beaker. One sample was buried inside the soil under the depth of 2 cm and another buried under the depth of 3 cm for 15 days under the conditions of the room. The weight of the specimen was measured before and after the testing. The biodegradability test was measured by Equation:

Weight Loss (%) = [(Wo−W)/Wo] _×100

Where,Wo and W are the weights of samples before and after the test.

C). Water uptake test

There are 2 samples were taken for water uptake test with different weights. The initial weight of the samples was recorded. The samples then placed into a beaker containing 60ml of water at room temperature for 24 hrs. The sample was then taken out from the water and wiped off. The amount of water uptake was calculated by using the following formula:

Water uptake = [Wet weight-Dry weight/Wet weight] × 100

4 RESULTS AND DISCUSSIONS

CHARACTERIZATION

Fourier Transform Infrared spectroscopy (FTIR)

Table. 1

Functional group	Wave number [cm^{-1}]
O-H	3221.48
C=O	1643.74
C-O	1112.54
C-O	1046.76
C-C	976.86

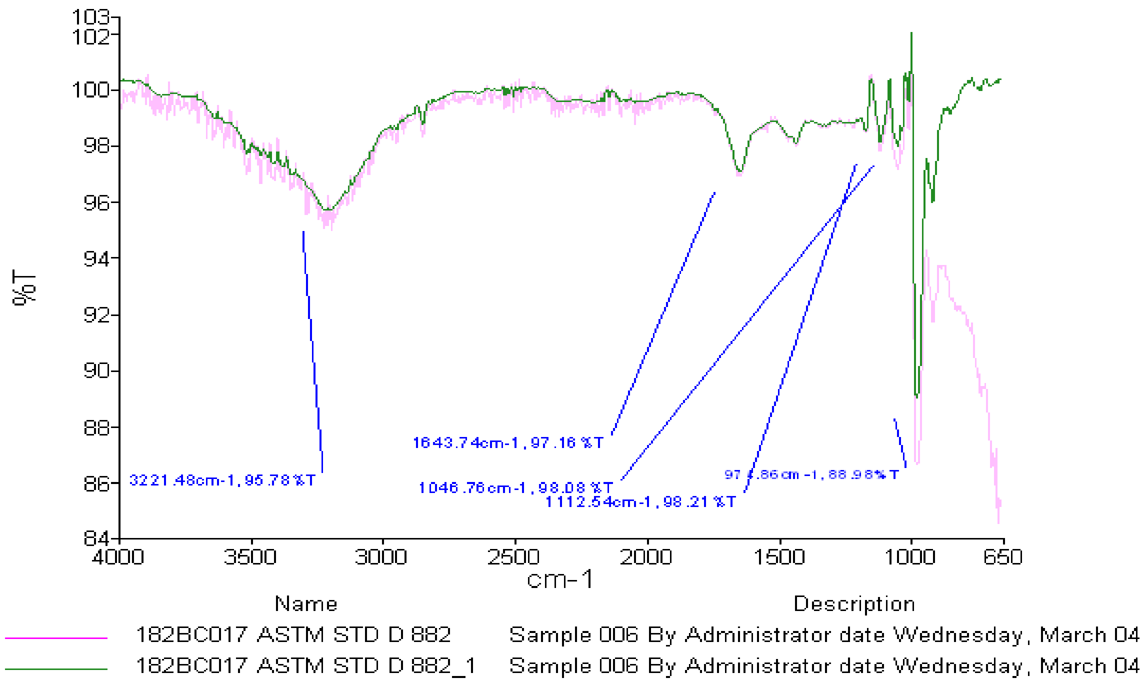

Fig 2. Fourier Transform Infrared spectroscopy (FTIR)

The FTIR spectra of bioplastic were done to detect the functional groups present in starch-based bioplastic. The spectra of bioplastic obtained from this study displayed the presence of four major absorption peaks which are O-H stretch (hydroxyl group), C=O stretch (carbonyl group), C-O stretch and C-C stretch.

5 APPLICATION STUDIES

Biodegradable properties

Table 2. Biodegradable properties

SR NO.	Sample burial depth(cm)	Initial weight(W_0)	Final weight(w)	Weight loss (%)
01	2	0.16	0.11	31
02	3	0.16	0.09	44

After 15 day period of soil burial test, the samples were weighed and the percentage weight loss was calculated. It was observed within 15days the percentage of weight loss of Chinese potato buried under 2cm was 31%. And the second sample buried under the depth of 3cm depth was 44%. These materials are degraded into the environment over comparatively short periods of time. According to the percentage of weight loss, Chinese potato starch-based bioplastic exhibited a higher degree of biodegradation.

SOLUBILITY TEST

Table 3. Solubility Test

Solvents	Initial weight (W_0)	Final weight (W_f)	Solubility (%)
HCl(conc.)	0.06	0.00	100
H_2SO_4(conc.)	0.06	0.00	100
Chloroform	0.05	0.02	60
Ethanol	0.04	0.04	0
Acetone	0.03	0.03	0
Methanol	0.05	0.05	0
Water	0.06	0.06	0

To evaluate the effect of different solvents solubility test was conducted on the synthesized bioplastic. The results of solubility test of starch based bioplastic revealed that the material has no solubility in water which makes it more eligible to be a bioplastic material. Potential applications require water insolubility to enhance product integrity and water resistance. It was also insoluble in Acetone (polar solvent), Methanol, and ethanol, partially soluble in chloroform (60%) and completely soluble in conc. Sulphuric acid and Hydrochloric acid (100%).

WATER ABSORPTION TEST (UPTAKE TEST)

Water absorption test is carried out to determine the water absorptivity of the material. The starch is mainly responsible for the water absorption due to its inherent hydrophilic nature. There are 2 samples were taken for water uptake test with 2 different weights. The dry weight of first sample is 0.13g and the wet weight is 0.28g.Then the second sample with a dry weight of 0.07g and the wet weight is 0.17g.The calculation results shows that the starch-based bioplastic exhibits a higher degree of water absorption.

Table 4.

SI.NO.	Initial weight(gm)	Final weight(gm)	Absorption (%)
01	0.13	0.28	54
02	0.07	0.17	59

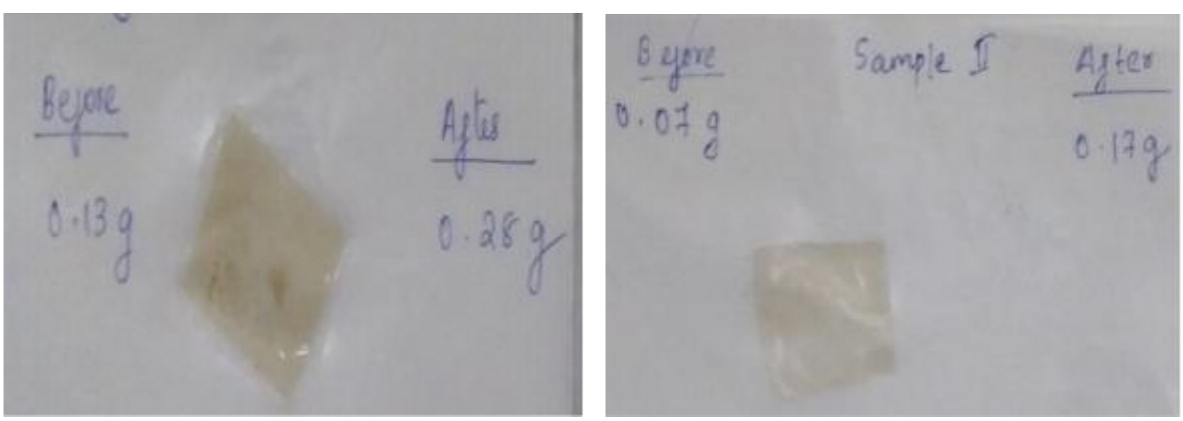

Fig 3. Water uptake test

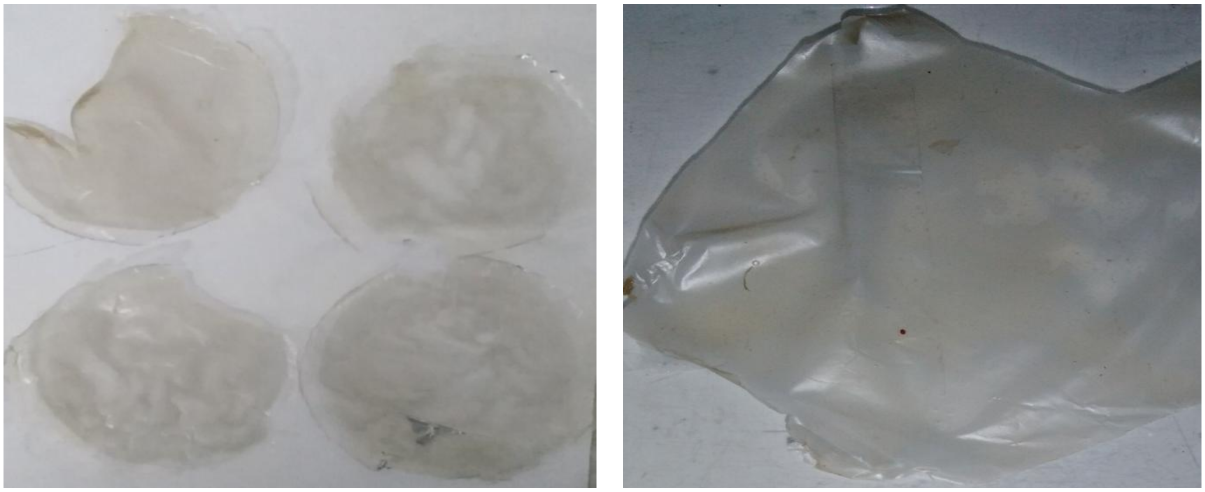

Fig 4. Bioplastic films

6 CONCLUSION

Starch-based bio-plastic was successfully produced from Chinese potato starch using glycerol as plasticizer (Fig 3). The plastic film produced from Chinese potato starch was found to be opaque, soft, non– sticky and flexible. The sample was tested for solubility in various solvents and water. It was observed that which is insoluble in common solvents and water and partially soluble in chloroform but completely soluble in concentrated acids like Sulphuric acid and hydrochloric acid. The bio-plastic films possess higher degree of water absorptivity on water uptake test. The starch-based bio-plastic films possess a higher degree of degradation within a short period of time. For characterization study, Fourier transform infrared spectroscopy (FTIR) was carried out, which detects the functional groups present in the synthesized bio-plastic film. Bio-plastics are a revolution in the green plastic world. Bio-plastics do not cause any environmental and health hazards and is completely ecofriendly. Plastics can be recycled and reused, but bio-plastics are even reversible. Degradable plastic was obtained in a span of 2-3 days. All the materials that were used could be found available in our household easily. Its production does not need any higher supervision and can make with the simplest and affordable facilities. It could be the next big thing that could actually help in a healthy cancer free and pollution-free environment. They would certainly not damage any marine life as they are composed of biomasses. It can be concluded that this article will helps to create awareness in our societies about the hazardous effects of plastic and its effective waste management. The bio-plastics from Chinese potato starch were a feasible solution as a substitute for petroleum based plastics.

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