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RESEARCH ARTICLE

Production of Degradable Bio Plastics from Invasive Alien Plants in Anamalais, the Western Ghats

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ABSTRACT

The work of the invention embraces to create ecofriendly bio plastics from the exotic plants species such as *Cylindropuntia ramosissima* (Engelm.) F.M. Knuth, *Parthenium hysterophorus* L., *Lantana camara* L. and *Leucaena leucocephala* (Lam.) de Wit. These plants are frequently available biomass and nonnative species, also most threat to our native plants and environment. The present work has entirely new report to produce bioplastics from exotic plants extract combinations; no work has been published for the selected study plants up to the product level. These plant samples were extracted by boiling method. The extracted samples were produce the formulations A, B and C. With the combination of these plants materials at different ratio with suitable non-hazardous chemical substances resulted in quality bioplastics production. Since the combination of various exotics yielded good quality bioplastics when compared with the individual plant. These bioplastics were tried to make different commercial products like sheets, pen stand, cup, plate, food packaging container, photo frame, pencil, glassware's packing materials, and mulching sheets for agriculture etc.

Keywords: bio plastics, environment, exotic plants, formulations, commercial products

INTRODUCTION

Plastics are one of the worst full materials in the world, its everywhere, every part of our society. The problem is the plastics are not natural substance, it containing harmful chemicals like polyethylene terephthalate (PET). Plastics are made from synthetic polymers such as polypropylene and polyethylene are known to cause environmental concerns due to their non-biodegradable nature, because of long chain carbon molecules that are probably made from polymers of petroleum product [1]. It will create pollution and health issues. The enormous use of petroleum-based plastic compounds emphasized a need for sustainable alternatives derived from renewable resources [2]. One strategy to overcome this is the use of biobased polymers, which are derived from renewable materials, leading to the development of 'green or eco-composite materials' that can be easily degraded or bio assimilated [3]. These materials are expected to be one of the important materials to realize and maintain a sustainable productive society [4].Therefore, this is a time to replace petroleum-based plastics as eco-friendly and eco-tolerable alternatives. Main goal of this project is to make the plastics from biodegradable plant materials. Plant materials are generally containing rich amount of starch, cellulose and lignin. It will replace the usage of the petroleum-based synthetic polymers. These degradable bio plastics are totally ecofriendly, safe and do not have any harmful chemicals and toxic substances. The main advantage of this bio plastic is that they degrade quickly in the environment without producing any pollution. Plastic from plant materials can be used for making bio plastic plates, bags etc. due to its flexibility and durability. Beyond deadly plastics, one more threat to our environment is the invasive alien or exotic plant species which destroys the indigenous plants and change the ecosystem. The eradication of these exotic species is unavoidable. Instead, the exotic plant species can be converted to biodegradable plastics without harming the environment. The exotic plant is available abundantly and throughout the year at all seasons in Tamil Nadu. Hence the present work has been designed to create ecofriendly bio plastics from the exotic plants species such as *Cylindropuntia ramosissima* (Engelm.) F.M. Knuth (Cactaceae), *Parthenium hysterophorus* L. (Compositae), *Lantana camara* L. (Verbenaceae) and *Leucaena leucocephala* (Lam.) de Wit. (Leguminosae).

MATERIALS AND METHODS

Collection and preparation of Plant Materials
The plant materials of the selected exotic species were collected from various regions of Anamalai, Western Ghats and plains of Pollachi, Tamil Nadu. The collected plant materials was washed and cleaned to remove the dust particles and converted into small pieces. The weighed 200 g of plant samples were grounded using distilled water 1000 ml and boiled for 30 minutes. These solutions was filtered and kept for further use.

Production of degradable bio plastics [5, 6]
The extracted solutions were mixed at different ratios and makeup into 100 ml. With this solution 1 M sodium bicarbonate were added as disinfectant. Further 6 ml of (0.25 N) HCl, 4 ml acetic acid, 3 gram starch and 2 ml Glycerol was added to this mixture, 0.5 N NaOH is added according to pH desired. Followed by the small amount of natural colours will be added for producing different colours of bioplastics. The solutions were boiled in distilled water for about 30 minutes. Further the samples are dried, placed in a beaker and using a hand blender, the samples are pureed until a uniform paste is formed. The paste was poured into a metal tray and put in the oven at 130°C about one hour. The metal tray was allowed to cool and the film is scraped off the surface. This process was continued with triplicates for rectifying complications.

Observations
Tensile strength
The strength of the plastics was determined by applying a pulling force on the plastic from the opposite sides and determines whether or not the plastic breaks. For the tensile strength calculations, the following formula was used:

$$\text{Tensile strength} = \frac{\text{Force (N)}}{\text{Cross sectional area (mm}^2\text{)}}$$

Where, Force (N) = Weight of the sample (gm) X 10^{-3} X 9.81
The cross sectional area was measured by using Vernier caliper. The thickness and length of the bioplastic sample are converted to cross sectional area using the following equation [7]. Cross sectional area (mm^2) = thickness x length

Shelf-life Test:
The shelf life of the bio plastics was assessed by visual inspection on a daily basis (The darkening of the plastic suggested decay).

Biodegradation tests by composting [6, 9]
Known weight (1g) of the samples of the produced bio plastics was buried into the municipal solid waste mixture. The mixture consisted of leaves, paper waste, cow manure, food waste, composting seeds, urea, wood waste and water [8]. The mixture was kept in an oven at 55°C, at which the maximum growth of thermophilic microorganisms occurred. Then, they were examined for possible biodegradation. The samples were weighed every three days in order to determine the percentage of weight loss.

Effect of acids
The produced bio plastic samples were put into sulfuric acid solution and acidic soil with the concentrations of 10%, 20% and 30%. The samples were dried and weighed periodically for in order to determine the weight changes after each time period. The test was compared between the produced bio plastics and the other known types of plastics.

Effect of alkalis
Samples of the bio plastics were put into alkali solution and alkali soil (sodium hydroxide) with different concentrations (10%, 20%, 30% and 40%). The percentage of weight loss was calculated daily.

Effect of salts
Bio plastic samples were mixed with solid salts like ferrous sulfate, sodium chloride, tri-sodium orthophosphate and lead acetate and observed for its resistance to the action of salts in five days once.

Production of bio plastic by different molding method
The products of bio plastics were tried to make based on strength in different forms by molding method. The bio plastics products like photo frames, pen stands, plates, cups etc.

RESULTS AND DISCUSSION

Bio plastic production
The present study for the production of bioplastics the following exotic plants were selected *viz*., *Cylindropuntia ramosissima* (Engelm.) F.M. Knuth, *Parthenium hysterophorus* L., *Lantana camara* L. and *Leucaena leucocephala* (Lam.) de Wit. (Fig. 1). These plant materials were extracted by boiling method. The extracted samples were mixed together with different ratios to produce the formulations A, B and C. The weight of the final paste obtained, pH and weight of the bioplastic film produced were recorded and tabulated. (Table 1, 2, 3 & 4 and Fig. 2). The positive results are exhibited for all formulated (A, B and C) exotic plant sample extracts. The produced bioplastic films has good strength, stability and flexibility may better for alternative to chemical based synthetic plastics. Therefore, replacement of synthetic polymers with plant based polymers make the basis for a sustainable and ecofriendly plastic production [10]. Likewise so many authors have investigated widely for biopolymers from plants such as field grown crops of wheat, corn, potato, soy, and starch; sweet potato starch, cassava starch, cocoa pod husk and

jackfruit seed starch, banana peels [11, 12, 13, 14, 15]. Generally plant materials contain starch, cellulose, lignin, oils and proteins. In bioplastics these compounds are constructed of linked molecules that form long polymer chains (biopolymers) [16].

Tensile strength

The significant tensile strength for the bioplastic samples were observed for A, B and C formulations. The results of tensile strength reaches a maximum of 0.100534 N/mm^2 and 0.091343 N/mm^2 for sample B and A respectively. Followed by the minimum tensile strength exhibits at 0.086814 N/mm^2 for C formulations. (Table 5 and Fig. 3). These results are agreed with [7]; they were conducted the bioplastics film production from waste banana peels in different phases and parameters. It is revealed that the maximum tensile strength ranged at 0.343511, 0.274844, 0.264248 N/mm^2 and the minimum tensile strength were reached at 0.118252 and 0.094858 N/mm^2. From the above results the moderate tensile strength was observed all compositions of samples and it is confirmed as biopolymers due to the components like starch, cellulose, lignin present in the bioplastic film. Additionally the author [17] was clearly pointed out the good result of tensile strength could be comes by adding glycerol to improve mechanical strength in the film production.

Biodegradation tests by composting

The biodegradation tests by composting were noted that the weight loss of bioplastic films at three days ones for twenty one days after soil burial (Table 6 and Fig. 4). The remarkable degradation is observed and it is confirmed accordingly the weight chances of known weighed samples placed in soil. But there is no weight changes were observed for known types of synthetic plastics. Bio plastics have higher percentage of biodegradability than all other synthetic plastic [18, 19, 20]. A synthetic polythene plastic will require a couple of hundred years to degrade under normal environmental condition resulting in high volume of accumulation [21, 22]. Here it may conclude the produced bioplastic materials to be transformed in to compost that can be used as fertilizer for plants. According to the American Society for Testing and Materials (ASTM), biodegradable plastics by definition undergo degradation by naturally occurring soil microorganisms, for which the plastic polymers serve as an energy source [23, 24, 25].

Effect of acids, alkalis and salts

The degradability of bioplastic samples were tested on acidified soil and solutions (Table 7 & 8 and Fig. 8 to 14). The results of acidified soil treated bioplastic samples were measured their weight changes at different interval days. It is revealed that the bioplastics are degraded and decayed gradually at all the concentrations of acids. The initial weight of one gram of bioplastics samples for A, B and C are changed their weight at all the concentrations of sulphuric acid with soil. After the twenty fourth day the maximum weight loss were observed at 0.40g at 10% concentration, 0.44g at 20% concentration and 0.54g at 10% concentration for sample A, B and C respectively (Table 7 and Fig. 5). The degradability of samples in acidic solutions, the bioplastic films was treated in four days for all the concentrations. The result indicates the degradation rate of bioplastics is faster in acid solution than acidic soil (Table 8). Because the degradation ability in acid solution the bioplastic film was directly affect by hydrolysis process which leads to faster degradation. But in soil burial with acid solution the bioplastic sample degradation is depending on the availability of soil moisture, oxygen and concentration of the acidic nature. The bioplastic degradability was also tested with alkali condition for samples A, B and C. The bioplastic films were placed in salts like ferrous sulfate, sodium chloride, tri-sodium orthophosphate and lead acetate, alkali solutions and alkali soil at different concentrations and observed at different time intervals. The changes of weight for bioplastic films were recorded and tabulated (Table 9 to 14). The result showed that the weight of the film was interestingly increased subsequent days. The reason for weight increasing of bioplastic films after subsequent days is due to salt accumulation. Later it was slightly decreased; this result indicates the degradability of bioplastics is take place due to osmostic imbalance in alkali environment. This condition leads to water loss of the bioplastic films resulted by weight loss. This process was continued until the degradation end. The observed results were shown in the table 9 to 14.

Production of bio plastic products

Successfully produced bioplastics were tried to make different products such as multipurpose bioplastic sheets, pen stand, cup, plate, food packaging container, photo frame, pencil, glassware's packing materials, and mulching sheet are shown in figures 6 and 7. The highlight of this project is the produced bioplastic sheets can be suggested to use for mulching sheet in modern agricultural technology for covering the surface of the soil in order to increase the temperature, to retain moisture, to suppress the weeds, and to promote the germination of seeds. It can be ploughed into the ground at the end of the growth cycle, providing soil nutrition for future seasons. [26] Katherine and Douglas has pointed out the U.S. National Organic Program (NOP) maintains standards for the use of Biodegradable plastic mulches (BDMs) in certified organic agriculture. The Biodegradable Plastics Institute first petitioned for the use of BDMs to the National Organic Standards Board (NOSB) in 2012. In 2014, the petition was approved and BDMs were added to the National List (Organic Materials Review Institute) [27]. In forth coming years bio based mulching film technology can contribute towards purely organic and sustainable agriculture in Tamil nadu. It may enhance environment, productivity, economic sustainability and affordability.

CONCLUSION

In 2050 there will be more than nine billion people but only one earth we need more sustainable solution to conserve our planet from the harmful effects of synthetic plastics. To produce sustainable ecofriendly bioplastics is an only way to increase healthy environment. So this project may helpful to develop bio based polymers to replace the petroleum-based synthetic plastics. The results of our bio plastics are degraded quickly but the problem is the materials do not resist to over moisture level. So in future the upgraded bioplastics can be developed in to a complete bio polymers product.

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Table 1. Preparation of the exotic plants raw materials for bio plastic production

Sample name	Sample Weight (grams)	Weight of the final paste (grams)	Volume of the final paste obtained (ml)
Cylindropuntia ramosissima	200	110	135
Parthenium hysterophorus	200	220	250
Lantana camara	200	400	420
Leucaena leucocephala	200	220	250

Table 2. Preparation of Formulations A

Sample name	Proportions of the final paste obtained (ml)	pH	Weight of the bio plastic film (grams)	Color of the bio plastic film
Cylindropuntia ramosissima	50	Acidic	12.944	Dark Brown
Parthenium hysterophorus	30			
Lantana camara	10			
Leucaena leucocephala	10			

Table 3. Preparation of Formulations B

Sample name	Proportions of the final paste obtained (ml)	pH	Weight of the bio plastic film (grams)	Color of the bio plastic film
Cylindropuntia ramosissima	30	Acidic	10.866	Dark Brown
Parthenium hysterophorus	20			
Lantana camara	20			
Leucaena leucocephala	30			

Table 4. Preparation of Formulations C

Sample name	Proportions of the final paste obtained (ml)	pH	Weight of the bio plastic film (grams)	Color of the bio plastic film
Cylindropuntia ramosissima	50	Acidic	10.708	Dark Brown
Parthenium hysterophorus	50			
Lantana camara	50			
Leucaena leucocephala	50			

Table 5 Tensile strength for the produced bioplastic flims

Bioplastic sample	Weight of the bioplastic sample (gm)	Force (n) (Weight of the sample X 10^{-3} X 9.81)	Thickness of the sample (mm)	Length of the sample (cm)	Cross sectional area (mm²)	Tensile strength (N/ mm²)
A	12.944	0.126981	0.0562	24.8	1.39	0.091343
B	10.866	0.106566	0.0500	21.2	1.06	0.100534
C	10.708	0.105045	0.0495	24.5	1.21	0.086814

Table 6. Biodegradation tests by composting

Bioplastic sample	Weight of the samples in grams								
	Bioplastic film before soil burial	Synthetic plastics	3rd day	6th day	9th day	12th day	15th day	18th day	21st day	Synthetic plastics in 21st day
A	1	1	3.03	1.04	0.51	0.46	0.40	0.40	0.39	1
B	1	1	1.89	1.05	0.85	0.79	0.46	0.40	0.34	1
C	1	1	3.20	1.43	1.04	0.90	0.32	0.43	0.41	1

Table 7. Effect of acids solution with soil

Bioplastic sample	sulphuric acid concentrations (%)	Weight of the samples in grams									
		Bioplastic film before treatment	Synthetic plastics	After 1 day	4th day	8th day	12th day	16th day	20th day	24th day	Synthetic plastics in 24th day
A	10	1	1	1.94	1.26	1.46	0.88	0.85	0.41	0.40	1
	20	1	1	1.17	1.09	1.44	0.97	0.60	0.76	0.73	1
	30	1	1	1.39	1.95	1.52	1.03	0.91	0.85	0.71	1
B	10	1	1	1.69	1.20	1.01	0.96	0.67	0.60	0.60	1
	20	1	1	1.14	1.18	0.83	0.78	0.68	0.46	0.44	1
	30	1	1	1.29	1.58	2.02	1.14	0.89	0.91	0.89	1
C	10	1	1	1.74	1.05	1.14	0.75	0.67	0.77	0.54	1
	20	1	1	1.82	2.09	1.77	1.71	1.43	1.33	1.29	1
	30	1	1	1.53	1.91	1.11	1.10	1.00	0.98	0.86	1

Table 8. Effect of acids solution without soil

Bioplastic sample	Sulfuric acid concentration (%)	Weight of the samples in grams						
		Bioplastic film before treatment	Synthetic plastics	After 1 day	2nd day	3rd day	4th day	Synthetic plastics in 4th day
A	10	1	1	1.23	2.42	0.59	0.29	1
	20	1	1	2.23	2.43	0.53	0.11	1
	30	1	1	1.99	2.01	0.49	0.21	0.98
B	10	1	1	1.93	1.32	0.93	0.40	1
	20	1	1	1.31	2.26	0.81	0.17	1
	30	1	1	1.83	2.44	0.94	0.17	0.98
C	10	1	1	2.27	2.12	0.83	0.33	1
	20	1	1	2.08	2.23	0.84	0.19	1
	30	1	1	2.52	1.83	0.93	0.14	0.98

Table 9. Effect of alkalis solution with soil

Bioplastic sample	Sodium hydroxide concentrati-ons (%)	Weight of the samples in grams									
		Bioplastic film before treatment	Synthe-tic plastics	After 1 day	4th day	8th day	12th day	16th day	21st day	24th day	Synthetic plastics in 24th day
A	10	1	1	1.84	1.44	1.08	0.98	0.96	0.95	0.94	1
	20	1	1	2.14	2.25	2.08	1.88	1.82	1.58	1.42	1
	30	1	1	1.33	1.40	1.33	1.28	1.30	1.32	1.27	1
	40	1	1	2.44	2.62	2.46	2.37	2.53	1.20	1.84	1
B	10	1	1	1.59	1.35	1.02	0.98	0.98	0.94	0.94	1
	20	1	1	1.23	1.28	1.17	1.09	1.08	1.05	1.04	1
	30	1	1	1.14	1.23	1.16	1.12	1.14	1.13	1.11	1
	40	1	1	1.32	1.40	1.39	1.32	1.53	1.66	1.53	1
C	10	1	1	1.89	1.66	1.24	1.12	1.10	1.08	1.02	1
	20	1	1	1.44	1.46	1.27	1.15	1.15	1.10	1.07	1
	30	1	1	1.21	1.30	1.22	1.15	1.15	1.30	1.10	1
	40	1	1	1.56	1.69	1.67	1.65	1.75	1.84	1.65	1

Table 10. Effect of alkalis solution without soil

Bioplastic sample	Sodium hydroxide concent-rations (%)	Weight of the samples in grams					
		Bioplastic film before treatment	Synthetic plastics	After 1 day	2nd day	3rd day	4th day	Synthetic plastics in 4th day
A	10	1	1	1.93	1.51	0.53	0.13	1
	20	1	1	1.31	1.89	0.84	0.23	1
	30	1	1	1.83	1.02	0.31	0.11	1
	40	1	1	2.27	1.45	0.71	0.31	1
B	10	1	1	2.31	1.67	0.54	0.17	1
	20	1	1	2.29	1.72	0.74	0.26	1
	30	1	1	1.81	2.47	0.27	0.13	1
	40	1	1	1.83	2.47	0.89	0.34	1
C	10	1	1	1.62	1.41	0.58	0.19	1
	20	1	1	2.37	1.64	0.33	0.13	1
	30	1	1	2.71	2.49	0.12	0.02	1
	40	1	1	3.07	2.96	0.93	0.39	1

Table 11. Effect of solid salt ferrous sulfate

Bioplastic sample	Weight of the Bioplastic film before treatment (grams)	Weight of the Synthetic plastics (grams)	Weight of the samples in grams for one month						Weight of the Synthetic plastics after 1 month
			5th day	10th day	15th day	20th day	25th day	30th day	
A	1	1	1.04	0.99	0.99	0.99	1.00	1.01	1
B	1	1	1.06	1.02	1.01	1.01	1.05	1.03	1
C	1	1	1.02	0.98	0.99	0.99	1.00	0.99	1

Table 12. Effect of solid salt sodium chloride

Bioplastic sample	Weight of the Bioplastic film before treatment (grams)	Weight of the Synthetic plastics (grams)	Weight of the samples in grams for one month						Weight of the Synthetic plastics after one month
			5th day	10th day	15th day	20th day	25th day	30th day	
A	1	1	1.11	1.05	1.024	1.10	1.08	1.01	1
B	1	1	1.03	1.04	1.34	1.10	1.11	1.12	1
C	1	1	1.13	1.08	1.06	1.11	1.14	1.14	1

Table 13. Effect of solid salt tri-sodium orthophosphate

Bioplastic sample	Weight of the Bioplastic film before treatment (grams)	Weight of the Synthetic plastics (grams)	Weight of the samples in grams for one month						Weight of the Synthetic plastics after one month
			5th day	10th day	15th day	20th day	25th day	30th day	
A	1	1	1.04	1.03	1.04	1.07	1.08	1.11	1
B	1	1	1.03	1.06	1.04	1.08	1.05	1.12	1
C	1	1	1.06	1.07	1.08	1.10	1.14	1.14	1

Table 14. Effect of solid salt lead acetate

Bioplastic sample	Weight of the Bioplastic film before treatment (grams)	Weight of the Synthetic plastics (grams)	Weight of the samples in grams for one month						Weight of the Synthetic plastics after one month
			1st day	2nd day	3rd day	4th day	5th day	6th day	
A	1	1	1.05	1.01	0.96	0.96	1.02	1.00	1
B	1	1	1.02	0.99	0.96	1.01	0.99	0.90	1
C	1	1	1.16	1.11	1.04	1.08	1.16	1.10	1

Figure 1. Photographs of study plant species

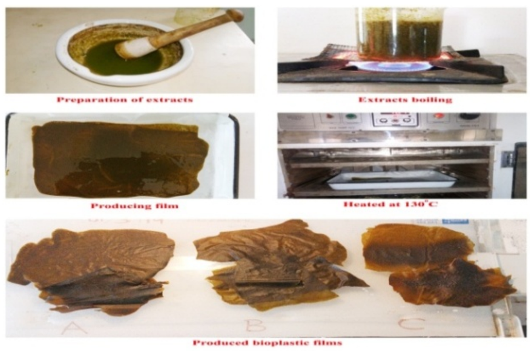

Figure 2. Showing the steps in bioplastic production

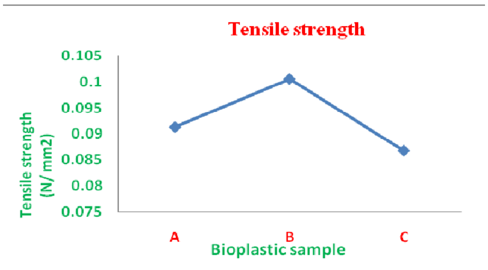

Figure 3 Tensile strength for the produced bioplastic flims

Figure 4. Biodegradation test by composting

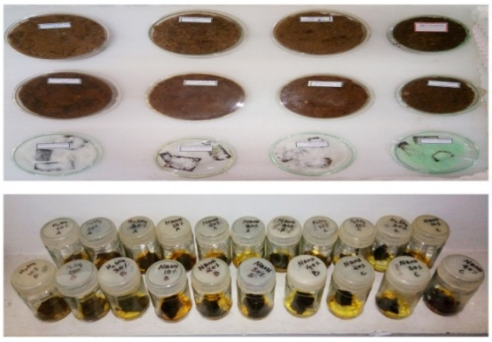

Figure 5. Effect of acids, alkalis and salts on bioplastic degradability

Figure 6. Multipurpose bioplastic film sheets produced in different colours and bioplastic products

Figure 7. Bioplastic films used as glassware's packing materials and used as mulching sheet