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Production of bioplastic using Jackfruit perianth

A Mohamed Muthaszeer[2], MV Ramanan[2], Ritty K Cherian[1], Parvathy Biji[1] & Elsa Cherian[1]*

[1]Saintgits College of Engineering, Kottayam, Kerala–686532, India
[2]St. Joseph's College of Engineering, OMR, Chennai-600 119, Tamil Nadu, India

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Overuse of plastics around the world has made them one of the key environmental concerns today. Disposal of plastic waste in landfills has serious environmental impacts due to its non-biodegradable nature. Agricultural waste, particularly plant materials containing starch gains attraction for its role in the production of alternative biodegradable materials with good tensile strength and other mechanical properties. The present work focuses on production of biodegradable bioplastic using perianth of Jackfruit [*Artocarpus heterophyllus* Lam. (Moraceae)], which otherwise goes as agro waste. Certain plasticizers are also used to improve the raw materials properties and it was subjected to various tests, to study its mechanical and chemical properties. The sample was characterized using Fourier transform Infrared spectroscopy (FTIR) and tensile strength was also checked. It was subjected to various resistance tests such as water resistance, alcohol resistance, flammability, alkali and acid resistance and it was confirmed that the bioplastic produced from Jack fruit perianth is a good option to normal plastics.

Keywords: Agro waste, *Artocarpus heterophyllus*, Biodegradability, Waste management

Plastics are widely used all over the world for various applications, and it generates large amount of waste each year all over the world[1]. These wastes can be recycled using incineration, pyrolysis, hydrogenation, gasification, etc. The disposal of plastic waste in landfills has greater environmental impacts due to its non-biodegradable nature. In this context, agricultural waste has gained attention as the source of interested in producing biodegradable plastics[2]**.** The bioplastic industry is the fastest growing industry with 25% growth rate every year and strong market demand in near future. Now-a-days natural fibers are used as emerging raw materials in plastic production due to its abundant availability, low cost and ease of biodegradability[3]

Animal waste proteins such as fish scales are also used to manufacture bioplastics. Fish scales contain large amount of keratin, and that serves as the raw material for production of bioplastics. Even various plasticizers can be used along with natural proteins for fabrication of bioplastic[4]. Similarly, more than billion pounds of chicken feather go waste from poultry industry. These feathers contain over 90% keratin that is resistant to digestion by animals and enzymes such as microbial protease. Hence, it can be used as a basic protein source for bioplastic production[5].

*Correspondence:
E-Mail: elsa.c@saintgits.org

Various thermoplastic materials are also being produced from agricultural products such as corn starch which contain 20-30% amylose and 70-80% amylopectin[5]. Nearly, 50% of the starch produced from agricultural products has a good film forming property and its tensile strength is proven. A starch with water content higher than 5% can be pasted under high pressure and temperature[6]. Agricultural waste containing starch is an economical source for biodegradable materials. In order to get a biodegradable plastic with good tensile strength and other mechanical properties, and these plant materials can be directly used[7].

Here, in this study, we focused on production of biodegradable bioplastic using a part of Jackfruit [*Artocarpus heterophyllus* Lam. (Moraceae)] perianth. The produced bioplastic was then subjected to various tests, to study about its mechanical and chemical properties.

Materials and Methods

Chemicals

All the chemicals used were of analytical grade.

Preparation of bioplastic

Perianth from the jackfruit was taken and cleaned properly. It was soaked in 0.2 M $NaHCO_3$ solution for 45 min and was further boiled at 100°C in distilled water. After decanting the water, it was dried in a gauge pad for 30 min andmadeto paste. About 25 mL of paste was mixed with 3 mL 0.5 N HCl and stirred using a glass rod. It was followed by the addition of appropriate amount of glycerol and cellulose mentioned in Table 1 and mixed thoroughly. Then 3 mL of 0.5 N NaOH was added to neutralize the pH. It was made to a homogenous paste and poured on a glass plate. It was baked in an oven at 100°C for an hour[7].

Optimisation of bioplastic composition

The composition of the bioplastic material was optimized on the basis of Table 1. The different samples of above compositions were prepared and it was baked at 100°C for an hour and the tensile strength, flammability, water absorption were tested for all the optimized batches. The best among the optimized batch is taken and was further characterized.

Testing of bioplastic

The bioplastic material produced was subjected to various test in order to understand its characters. A standard size (2 × 6 cm) of bioplastic material was cut and it subjected to various tests such as flammability test, water absorption test, acid resistance test, salt resistance test, biodegradability test, tensile strength test and drying test. Before testing, the samples were weighed, its initial weight was noted and the above tests were done by immersing the standard size of plastic material into various solutions as follows.

Chemical resistance of sample

Effect of strong acid and base on bioplastic was studied by immersing the strips in 0.5 M HCL - 0.5 M NaOH for one week and change in appearance was noted. The salt resistance of the synthesized material was studied by immersing in sodium chloride for one week.

Flammability test

To test the flammability of the produced bioplastics, strips with same dimensions were burnt using Bunsen burners and burning time was recorded.

Table 1 — Different compositions of bioplastics

Jack fruit paste (mL)	Cellulose 2% (mL)	NaOH 0.5N (mL)	HCl 0.5N (mL)	Glycerol (mL)	Sample
25	2.5	3	3	2	A
				4	B
25	5	3	3	2	C
				4	D
25	7.5	3	3	2	E
				4	F
25	10	3	3	2	G
				4	H

Characterization of bioplastic material

Load test for Tensile strength

Strips of bioplastics was prepared with uniform area of cross section and then hanged on a retort stand placed 3.5 cm apart. Then a spring balance was connected to the middle of the strip and weight load was added, till the strip break apart. Replicas were done and an average value was taken and tensile strength was calculated using the following formula.[8]

$$Tensile\ strength = \frac{Weightload\ (N)}{Area\ of\ cross\ section\ of\ strip\ (m^2)}$$

The batch with most preferable attributes in all the above test has been selected for further characterization studies such as FT-IR, Biodegradability test and Drying test.

Biodegradability test

Biodegradation of the bioplastics was studied by both α-Amylase degradation method and natural degradation method. In the α-amylase degradation method, bioplastics produced was taken and dipped in 5% α-amylase solution and observation was carried out for every half-an-hour. To check the natural degradation of bioplastics, the optimized bioplastics was taken and buried in the garden soil taken in a beaker.

Results and Discussion

The bioplastic sheet prepared from jackfruit perianth appeared dark brown and less transparent. The synthesized bioplastic (Sample G) is shown in Fig. 1.

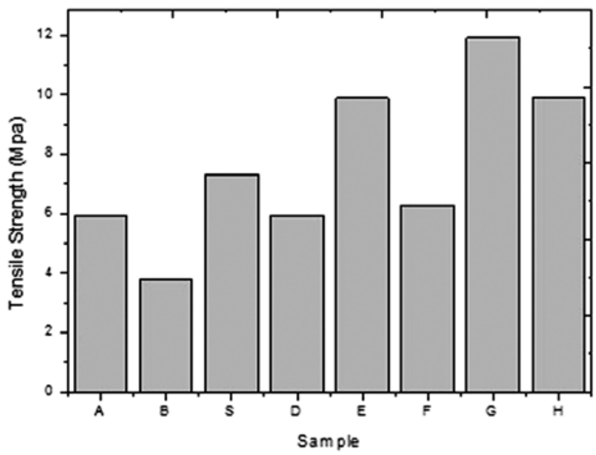

Fig. 1 — Bioplastic synthesized from Jackfruit perianth

Chemical resistance of the sample

The effect of different chemicals on bioplastics was studied using different chemicals such as HCl, NaOH and NaCl. The results are shown in Table 2. When the synthesized bioplastic was burned in flame, it got converted into ashes completely which could be put into some use without harming the environment.

One of the important properties of the bioplastics is the nature of water resistance. For this, water absorption was checked for the strips of almost uniform characteristic features by immersing in water for 24 h and the strip was weighed after the time period. Based on the water uptake data given in Table 2, sample G (glycerol 2 mL) showed more water resistance. Glycerol is a hydrophilic molecule which is used as the plasticizer, so it has the tendency to bind more amount of water[9]. From the result, it is observed in most of the cases, strips with more glycerol content absorbed more water which supports the above point.

Tensile strength analysis

The effect of cellulose and glycerol content of bioplastic on the tensile strength of bioplastics is shown in Fig. 2. It shows that increasing concentration of cellulose support the tensile strength of bioplastics. A maximum tensile strength of 11.92 MPa was provided by the bioplastics containing 10 mL of 2% cellulose and 2 mL glycerol (sample G). It can be due to grouping of the intermolecular hydrogen bonding that cause a molecular bond of cellulose more compact. Also, it is revealed that increase in the glycerol content decreased the tensile strength. Addition of glycerol resulted in competition for hydrogen bonding thereby affecting hydrogen bond formation within carbohydrates resulting in more freedom of motion and crystallization of plasticizer in the film[10,11].

Characterization of bioplastics using FTIR

Fig. 3 represents the FTIR spectra of synthesized bioplastics. The dominant absorption peaks around

Fig. 2 — Tensile strength analysis of synthesized bioplastic

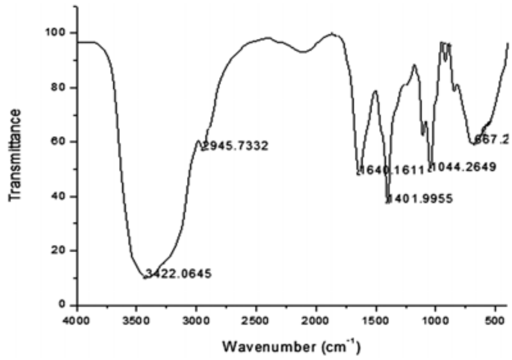

Fig. 3 — FTIR spectra of bioplastic from Jackfruit perianth

Table 2 — Effect of different chemicals and water on bioplastics

Sample	Water Absorption Test			Flammability Test	Resistance to chemicals		
	Initial wt (g)	Final wt (g)	Difference in wt (g)		HCl	NaOH	NaCl
A	1.15	1.58	0.43	37	Change in dimension	Change in dimension but slight water absorption	Slight water absorption
B	1.2	1.65	0.45	44	Change in dimension	Change in dimension but slight water absorption	Slight water absorption
C	1.15	1.55	0.4	33	No change in dimension	Water absorption	Water absorption
D	1.25	1.67	0.42	36	No change in dimension	Water absorption	Water absorption
E	1.15	1.52	0.37	30	No change in dimension	Water absorption	Water absorption
F	1.2	1.59	0.39	48	No change in dimension	Water absorption	Water absorption
G	1.25	1.57	0.32	22	No change in dimension	Water absorption	Water absorption
H	1.2	1.55	0.35	47	No change in dimension	Change in dimension but slight water absorption	Slight water absorption

3422 cm^{-1} is due to the stretching of hydroxyl group. The peak at 2945 is mainly due to the symmetric stretching of C-H cm^{-1} bond in CH_3 and CH_2. The peaks at 1640, 1611 and 1044 cm^{-1} are ascribed to C=O and COO asymmetric stretching respectively. The peak at 1401 is attributed to OH bending. Even the peak at 667 cm^{-1} is due to C=O bending. Darni & Herti explained that bioplastics containing C=O functional groups and ester carbonyl(C-O) groups are biodegradable. Presence of these groups in the synthesized bioplastics was reported by Thammahives *et al.* as well[12].

Biodegradability test

The produced bioplastics when exposed to alpha amylase degradation study, the sample was stable for more than 2 h. After 2 h, its surface started degrading that indicates hydrolysis of starch demonstrating its degradability by bacteria and fungi in the soil that contains various enzymes**.** The bioplastics were also checked for natural degradation. About 1.5 g of the synthesized bioplastic was kept in 500 mL beakers with soil in it. Water was sprinkled on it to retain moisture content to promote natural degradation. The sample was checked periodically and it was found to be degraded after a period of 2 months leaving a trace amount of sample buried.

Conclusion

In this study environment friendly bioplastics were synthesized from waste jackfruit (*Artocarpus heterophyllus*) perianth and characterized. The results suggest that the glycerol, cellulose and starch composition of jackfruit perianth influence the properties of synthesized bioplastics It is also found that higher concentration of glycerol give lower tensile strength. This study demonstrates the potential of the waste agricultural raw materials such as jackfruit perianth to produce bioplastic as an alternate greener substitute to petrochemicals based plastics.

Conflict of interest

The authors declare no conflict of interest

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