Sustainable Bioplastic Film From Rice Straw

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Bioplastic film was produced from rice straw which is generally considered as an agricultural waste and disposed or burnt in open fields which is incomplete combustion in nature; hence, a large amount of pollutants are emitted such as carbon monoxide (CO), dioxins, and furans, volatile organic compounds (VOC), carcinogenic polycyclic aromatic hydrocarbons (PHA), as well as fine inhalable particles. Fine powdered rice straw was dissolved using Tri-fluoroacetic acid (TFA), which acts as a volatile organic acid and is considered as a possible non-aqueous solvent for cellulose swelling. The material exhibits good mechanical behaviour and the morphology of the bio-based material was analysed by scanning electron microscopy which shows a compact structure. Mass loss test indicates the the material decomposes at a faster rate when compared to normal PET plastics. In summary, depending on the environmental humidity, the material can be made to obtain shrink films. Therefore, this bioplastic material can be suggested as a new potent material in different applications.

KEYWORDS

Cellulose, Rice straw, Tri-fluoroacetic acid, mechanical property, cellulose swelling

1. INTRODUCTION

1.1 Plastics

Plastics are light, strong, durable and inexpensive synthetic or semi synthetic organic polymers. Their characteristics justify the very large exploitation in a wide spectrum of human activities because plastics represent an essential element in modern life. About 99% of plastics are made starting from non-renewable resources such as charcoal, petroleum, and natural gas. Most plastic pollution comes from inadequate collection and disposal of larger plastic debris known as macro plastics, but leakage of micro plastics (synthetic polymers smaller than 5 mm in diameter) from things like industrial plastic pellets, synthetic textiles, road markings and tyre wear are also a serious concern.

Even if the use of plastics has several benefits, their environmental occurrence is currently a very dangerous issue due to the progressive abrasion until the particulate formation. Proper management of plastic wastes are accumulated at the end of their environmen tal path. Hence, the characteristics of durability and resistance of plastics become a great problem in non-correct plastic disposal. Currently, the huge amount of plastic waste production is one of the most faced issues over the world both for environmental problems and human health threat. Plastics are the major components in municipal waste should be addressed to an adequate management treatment . For this reason, it is mandatory to drive the demand for new and innovative material solutions, which should be cost-effective and environmentally biodegradable. Eco-friendly bio-composites from plant-derived fibre (natural/ bio-fibre) and crop derived plastics are novel materials produced by vegetable waste (Bayer et al.,2014). Bioplastics are defined as a new plastic generation that significantly reduce the environment impact in terms of greenhouse effect and energy consumption (Mohanty et al.,2002).

Fig 1.1 Improper disposal of plastic waste.

1.2 RICE STRAW

Rice straw (*Oryza sativa)* is a vegetable waste with abundant cellulose (32-47%), hemicellulose (19-27%) and lignin (5-24%). It is known as potential feedstock for fuel ethanol production (Binod et al., 2010). It is reported that for nearly each kg of crop harvested, approximately 1-1.5 kg of straw is produced. Rice straw is produced as a byproduct of rice production at harvest. Rice straw is removed with the rice grains during harvest and it ends up being piled or spread out in the field depending if it was harvested manually or using machines. However, rice straw is considered an agricultural waste, and in several countries, it is either dumped into rives or burned in the fields causing greenhouse gas emission, contaminations and pollution (Sangon et al., 2018).

Currently, several agricultural by-products and inedible food waste are considered in the production of some Eco materials: potato peels, sugar cane bagasse, whey protein, shrimp shell, lignocellulosic fibres derived from apple and orange fruit juice extraction, are some examples (Tiimob et al., 2017; Chiellini et al., 2001; Moro et al., 2017).

It is important to remember that different food waste categories are difficult to separate; therefore, the possibility to obtain bioplastic from these residue must be coupled with a suitable waste management strategy. Concerning rice straw, this waste can be easily managed because it does not require separation from other waste(Dominguez-Escriba and Porcar, 2010).

Fig 1.2 (a) Pilling up of Rice straw

Fig 1.2 (b) Burning of Rice straw

1.3 TRI-FLUOROACETIC ACID

Tri-fluoroacetic acid (TFA) has been widely used in organic synthesis as a solvent, catalyst and reagent. Many chemical transformations should be done with the aid of TFA, including rearrangements, functional group deportations, oxidations, reductions, condensations, hydroarylations and trifluoromethylations. This strong acid is water miscible and have low boiling point. TFA is a volatile organic acid and has already proved to be one possible non-aqueous solvent for cellulose swelling (Zhao et al., 2007).

Fig. 1.3(a) Trifluoroacetic acid

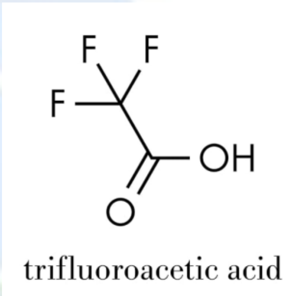


Fig. 1.3(b) Structure of TFA

1.4 APPLICATIONS OF BIOPLASTIC

Application field of bioplastics are numerous: food packing, medical care, horticulture, agriculture, electronics, etc.

Different tests performed on bioplastic shows another advantage compared to conventional plastics, their shape memory capabilities. This means they are able to change their shape upon application to external stimulus. Material loss test under soil moisture is carried out. Finally, sustainability of the proposed bioplastic in terms of energies and emissions required for the synthesis is evaluated.

The aim of this work is to propose a method to realise new bioplastic from rice straw and to investigate the new obtained eco materials properties.

2. MATERIALS AND METHODOLOGY

2.1 Collection of sample:

Dried rice straw were collected from Koyambedu market, Chennai. The dried rice straw were grinded and sieved to obtain fine powdered form.

2.2 Preparation of the sample:

Approximately 5 grams of powdered rice straw was mixed with 100 mL of Tri-fluoroacetic acid and kept under magnetic stirrer for three consecutive days. After obtaining the slurry was spreaded even to obtain a thin film of sheet and TFA was allowed to evaporate for 30-40 minutes.

2.3 Phytochemical analysis:

a)Qualitative Phytochemical Analysis:

Qualitative phytochemical analysis were done for confirming the presence of Alkaloids, Glycosides, Proteins, Tannins, Terpenoids, Phenols, Carbohydrates, Steroids and Saponins.

b) Quantitative Phytochemical Analysis:

Quantitative phytochemical analysis were done for confirming the presence of Tanins, Alkaloid, Phenols, Flavonoids, Steroids and Glycosides.

2.4 Antimicrobial analysis:

The antimicrobial analysis is carried out using agar diffusion method using Muller-Hinton agar by using microoganisms like *Staphylococcus aureus, Aspergillus niger, Streptococcus spp., Escherichia coli, Pseudomonas spp. etc.*

2.5 Antioxidant analysis:

Antioxidant analysis was carried out using DPPH method using DMSO as a solvent and incubated in a dark room. Ascorbic acid was used as a reference.

2.6 Cytotoxicity test:

Cell lines were obtained from King's Institute, Guindy, Chennai and maintained in a Minimal Essential Mediain a humified atmosphere of $C0_2$ at 37ºC. The cytotoxicity was determined by the MTT assay.

2.7 Fourier - Transform Infrared Spectroscopy (F-TIR)

All Infrared Spectroscopies act on the principle that when Infrared radiations (IR) passes through sample, some of the radiation is absorbed. The functional groups characterization tests were carried out by analysing FTIR.

2.8 Scanning Electron Microscope (SEM)

SEM uses a focused beam of high energy electrons to generate a variety of signals at the surface of solid specimens. To characterize the composites, the morphology of the bioplastic film of rice straw was scanned under secondary electron mode under dimensions 1µm, 5µm, 10µm.

2.9 Tensile strength:

Tensile strength, the maximum load that a material can support without fracture when being stretched, divided by cross sectional area of the material. To characterize the mechanical parameters such as elastic modulus as well as elongation at break were considered for the bioplastic film.

2.10 2D-XRD:

2D image processing and 2D diffraction involves the pattern manipulation and interpretation.

2.11 Material decomposition test:

A normal packaging material and the bioplastic film were taken into considerations for analysing the decomposition rate of bioplastic rate of the bioplastic film. Material mass loss test were performed in the month of March - April

3. RESULTS & DISCUSSIONS:

3.1 Preparation of the sample:

Approximately 5 grams of the powdered rice straw were made paste by mixing with TFA in a magnetic stirrer under three consecutive days. A thick slurry was obtained after three days which was evenly spreaded to obtain a thin sheet of bi-oplastic film.

Fig.(a)

Fig. (b)

Fig. (a) Powdered rice straw; (b) Bioplastic film.

3.2 Phytochemical analysis:

(a) Qualitative analysis:

TEST	OBSERVATION
Alkaloid	+
Glycoside	+
Proteins	+
Flavanoids	—
Tannins	+
Terpenoids	+
Phenols	+
Carbohydrates	+
Steroids	—
Saponins	+

Fig. 3.2(a) Qualitative analysis

(b) Quantitative analysis:

TEST	OBSERVATION
Alkaloid	0.2
Glycosides	0.40
Proteins	0,34
Flavonoids	NIL
Tanins	0,03
Terpenoids	0,28
Phenols	0,19
Carbohydrate	0,80
Steroid	NIL
Saponins	0,26

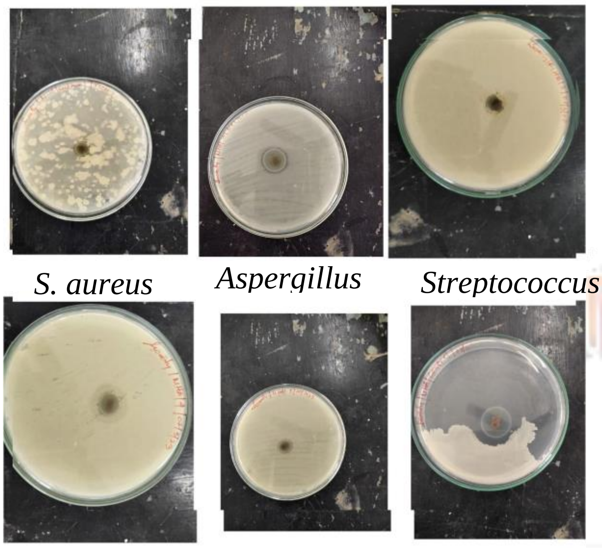
Fig. 3.2(b) Quantitative analysis

Phytochemical screening confirmed the presence of phyto-constituents like Alkaloids, Flavonoids, Glycosides, Phenols, Tannins, Terpenoids, Carbohydrates, Steroids and Saponins.

The absorbance of the sample was calculated as 0.972nm and the absorbance of the sample was observed as 0.230nm. By putting into the formula, the %RSA of the sample was found out to be 76.3%.

3.5 Cytotoxicity assay:

3.3 Antimicrobial analysis:



S. aureus *Aspergillus* *Streptococcus*

E. coli *Pseudomonas spp.* Control

Fig. 3.3 Antimicrobial culture plates

The zone of inhibition formed by microorganisms used inhibited a diameter of 4 mm for *S. aureus, Aspergillus spp., Streptococcus spp., E, coli* and 3 mm for *Pseudomonas spp.,* which inhibits good antimicrobial properties.

3.4 Antioxidant analysis:

The radical scaverging activity (RSA) of different extracts was determined by using DPPH assay according to Chsng et al., 2001. The DPPH assay uses this character to show free radical scaverging activity.

The % RSA of the plant extract was calculated using the formula,

%RSA= Absorbance of control - Absorbance

of

sample X 100

Absorbance of control

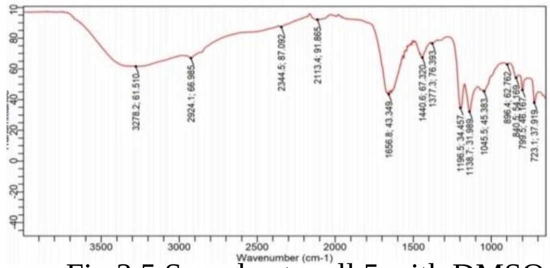


Fig 3.5 Sample at well 5 with DMSO.

The %cell viability of the sample was calculated by the formula;

%cell viability = A570 of treated cells / A570 of controll cells X 100

Accordingly to the formula, the %cell viability of the sample was foumd out to be 90.75%.

3.6 FT-IR analysis:

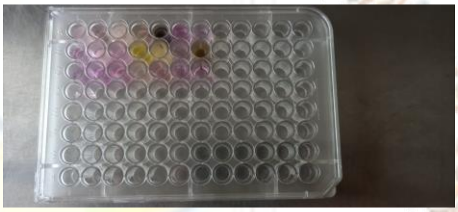


Fig 3.6 FT-IR measurments of the rice straw film

Fig depicts the typical bonding associated with cellulose, namely O-H stretching mode at 3278 cm^{-1}, C-H stretching mode at 2942 cm-1, absorbed water at 1656 cm-1 and C-O stretching mode at 1045 cm-1. The peak at 1440 cm-1 presents the C-H deformation both for asymmetric stretching of cellulose, hemicellulose and lignin.

3.7 Scanning electron microscope analysis:

Fig (a),(b),(c) indicates the images collected from the surface of the rice straw bioplastic film. The images were viewed under 1µm, 5µm, 10µm respectively.

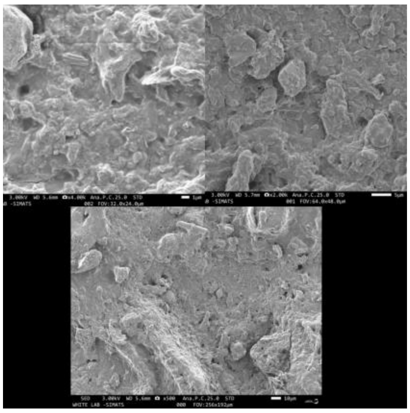
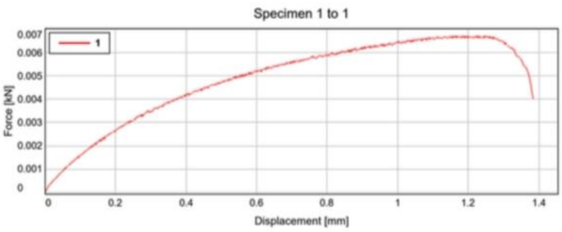


Fig 3.7 Images viewed under SEM.

3.8 Tensile test:

Tensile analysis was analysed equipped with INSTRON. Fig demonstrates the tensile strength of the bioplastic film.



	Maximum Force [N]	Tensile stress at Tensile strength [MPa]	Tensile strain (Displacement) at Break (Standard) [%]
1	6.71	2.76	4.61

	Specimen label	Tensile stress at Break (Standard) [MPa]
1	1	1.73

Fig 3.8 Tensile strength of the biofilm

The tensile properties of the bioplastic film in the Fig indicates a maximum force of 6.71% and tensile stress of 2.76% and tensile strain of 4.61% which has a close relation with the other works done which indicates the maximum force of 63% at which the bioplastic can break due to the presence of external stimuli.

3.9 2-D XRD analysis:

Fig demonstrates the crystalline peak obtained in the 2-dimensional X-ray diffraction of the rice straw bioplastic film.

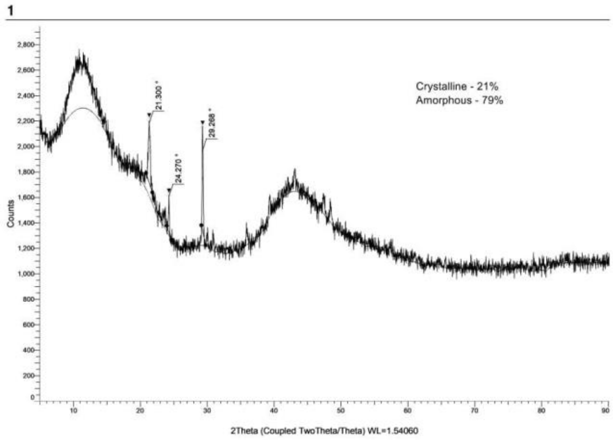


Fig 3.9 Amorphous and crystalline peak obtained during 2-D XRD analysis of rice straw bioplastic film.

3.10 Material mass loss test:

The material mass loss test was recorded as 0.48 for the sample weight with the diameter of approximately 5 centimeters on the first day before buring in the soil and after three days the mass loss test was recorded as 0.39 which showed a faster rate of degradation of the sample when compared to the same dimension of normal plastic bag.

4. CONCLUSION:

In this study, application of rice straw, classified as an agricultural waste, for bioplasic film production is reported. Rice straw, a vegetable waste rich in cellulose, is used toproduce a new biomaterial film. The solid matrix is treated only with Trifluoroacetic Acid which is capable of co-solubilizing the cellulose with other organic matter present in the rice straw.

Test conducted like SEM analysis proved that the film obtained has a uniform and compatible matrix. After TFA is evaporated from the surface of the biofilm, the sheets appears to contínous, flawless, flexible and resistant to tearing. The tensil strength specifies a good mechanical property with an external stimuli force of 6.71%. Regarding the mass loss test, the newly obtained biofilm shows a good degradation rate of 0.1% in just 2 days, because the days were limited due to time limitations. In terms of sustainabilty, this process requires less man power and energy power in comparision to the other plastic components. Furthermore, rice straw can be easily extracted and need not require seperation from other waste materials. This benifited the work to go on a fast process as compared to other waste materials.

The application of rice straw bioplastic seems realistic as it provides many benefits rather than the harmful chemical based plastic materials. One such application carried out through this film is the production of small disposable bags used for the medical waste like the syringes, blood soaked cottons, and other hazardous health issues created due to medical waste can be put in these small bags made from rice straw bioplastic and then incinerated.

5. SUMMARY:

In summary, depending upon the environmental humidity, the material shows a dual mechanical behaviour that can be exploited to obtain shrink films and sheet or to drive shape of the film. Therfore, it is suggested that the rice straw bioplastic has as a new potential eco- material for different aplication field. Today, it is used to produce engineering plastics, optical films, medical films and sheet forming for electronic applications.

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