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Production of Bioplastic from the Plant Biomass

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***Abstract*: Plastic has been a vital part of our life. Conventional plastics are made from petroleum. However, disposal of these non-degradable petroleum-derived plastic has threatened our ecosystem. To overcome this, Rice straw and jute are used for cellulose extraction because it is a challenging, cost effective and promising for the conversion to produce bioplastic. Cellulose is found in many plants, bacteria and seen in different varieties of fungi. Generally, jute fibres consists of around 59.8% cellulose, hemi cellulose 12% and lignin 11.8% and the rice straw consists of around 40%-50% cellulose, Hemi cellulose 28% and lignin 8 -20%. The present study deals with the extraction of cellulose from rice straw and jute fibres and conversion of cellulose in to bioplatic. This research highlighted the production of bioplastic from jute and rice straw.**

I. Introduction

Plastics are the most common thing used everywhere in the world for packaging, tables, water bottles, many electronic devices etc. Not only is that it also utilized in pharmaceutical products to the advance industry work. So, plastics have been used everywhere and it has led to many problems such as soil infertility, stop up in the water bodies and the worst thing is they are not biodegradable (Bruno et al. 2011). All over the world around hundreds to thousands of year’s people have been using petrochemical based plastics as it is produced in large amounts because it is cheap and easily available. People use plastic very often and after use the plastic it is been sent into the garbage and here comes the actual problem that is plastic is non-degradable which means plastic cannot be removed from the environment and this releases out lots of harmful gases. Plastics can neither be burnt or it can neither be degraded into the soil. Many scientists and the government authorities are very much worried about this problem (Ezgi et al. 2015). To overcome such a big problem the researches have worked a lot with obtaining different methods and finally brought a solution to it that is the bioplastic. Bioplastic are the plastics which are acquired from the renewable biomass sources like starch, vegetable oils, fats and microbial communities. Bio plastics were procured from sugar derivatives like starch, cellulose, lactic acid etc. Bioplastic are the biodegradable substances that come from the renewable sources and can be helpful to reduce the plastic waste which affects the planet and also leads to many inappropriate gases which also affects the existence (Anggun et al. 2018).

Bioplastic is the best replaceable of petrochemical plastic. There are many different types of bioplastics such as Polyacetic acid (PLA), Poly-3-hydroxybutyrate (PHB) which is considered as consumption and leads to biodegradation in less volume. PLA Production of all bioplastics results in lowering the carbondioxide emissions compared to the other conventional plastics (Melissa et al. 2014). But the only problem with bioplastic is it too costly. To solve this problem researchers are working with many biopolymers, biobased products and now a day’s they are even using the biowaste like potato starch, corn starch, banana starch, newspaper waste, rice straw, cotton, jute, hemp etc. Plant and animal withdrawn the proteins like casein, collagen, gelatine and lipids which include cross link between the triglycerides (Logeshwaran et al. 2020). Here, the raw materials used are Rice straw fibres and Jute fibres where cellulose is been extracted for the production of bioplastic instead of other starch sources as they are extracted from the edible sources.

Rice straw is scientifically called as Oryza sativa of the lignocellulosic material. Rice straw has high fiber content and is

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the major food producer which is considered as livestock in India. (R.B. Singh et al. 1995). Rice straw is produced in high quantities worldwide (nearly annual production of rice straw is 731 million tons) Asia 667.6 million tons, Europe contents nearly 3.9 million tons, Africa 20.9 million tons. More than 570 million tons of Rice straw is been produced all over the country (M. Kapoor et al. 2016). Rice straw is used for the cellulose extraction because it is a challenging and promising for the conversion to produce bioplastic, it is cheap and effectively grown. Rice straw is biodegradable and these are mostly rich in renewable materials. It has high cellulose and hemicelluloses content in it which can be hydrolyzed into fermenting the sugars. Rice straw production mainly depends on variety of cultivation, fertilization levels, climatic conditions, soaking, spraying and sprinkling. Rice straw are rich in assets and their complexes constitute low density, renewable nature and biodegradable attribute in which other complexes cannot match. Such complex substance has low water immersion and greater auditive insulation properties, high internal bond strength and flexibility and convolution strength, huge breakage coefficient (Rob Bakker et. al. 2013).

Some of the main advantages for using rice straw as the raw material, it is cost effective, flexible, and biodegradable which releases out few gases like carbondioxide which does not affect the environment. These are ecofriendly and are completely recyclable to form different products (Junjun Liu 2012). The chemical composition of rice straw includes on average 40 to 50% cellulose, 20 to 25% hemicelluloses, 15 to 20% lignin content in it and it also consists of minor organic compounds. Rice straw is one of best biodegradable product and it is used as the raw material where the pre-treatment is done and the cellulose is been extracted from it (Rob Bakker et al. 2013). Here, another raw material is also used for the extraction of cellulose that is, Jute fibres. Jute is long, shiny, bast fiber and it consists of strong threads. Jute is also called as Golden fiber for its texture, colour and high cash worth. Jute fibers are 100% biodegradable and they are recyclable and thus they are environmental friendly. Jute is a lignocellulosic fiber that is rather a textile fiber and relatively a wood fiber (Duan et al. 2017). Jute is a very important agro-fiber which contains lignin (lignocellulosic fiber). It has mechanical properties like low density, high tensile modulus and high strength by conducting the alkali treatment (delignification). It improves the mechanical properties of jute fiber (M.A. khan et al. 2009). The chemical composition of jute fiber includes cellulose content 64.4%, hemicelluloses 12%, lignin 11.8%, pectin 0.2% and was content is 0.5%. Jute fibers are obtained from two species of Corchorus, namely C. capsularis and C. olitorius. A square measure of jute plant consumes 15 tones of carbondioxide and 11 tones of oxygen. It is extracted from the bark of white jute plant (Corhorus capsularis) (Duan et al. 2017).

Jute plant is belonging to the family Filiaceae. Some of the advantages of jute include good enclosing and antistatic properties as well as having low thermal conductivity and average moisture retention. Jute is a product of south Asia and specifically a product from India and Bangladesh. About 95% of jute is grown worldwide and in that two south Asian countries grow the jute fiber. A Jute stick is woody section of jute plant, which residuum as leftover after extracting bust fibre. By using these two as the raw materials cellulose is been extracted for the production of the bioplastic. Cellulose is an organic compound, with the molecular formula $(C_6H_{10}O_5)_n$ and it is a polysaccharide which consists of more than hundred to thousand of β (1→4) linked D-glucose components. Cellulose is a straight chain polymer (S.S. Shrirakshaya et al. 2020). Cellulose is a rich organic polymer on Earth. Cellulose is found in many plants, bacteria and seen in many different fungi. Cellulose is extracted from many plants like cotton, corn, hemp and many other plants. When compared with the starch, cellulose is usually found in a mixture with hemicelluloses, lignin and pectin. Cellulose pulp maybe treated with strong acids to hydrolyze the amorphous fiber regions, thereby producing short rigid cellulose nanocrystals and few are 100nm in length (Deb Prasad Ray et al. 2017). Cellulose is combustible. Incompatible with strong oxidizing agents including bromine pentafloride, sodium nitrate and sodium peroxide etc. Now a day, the biggest sources of cellulose are extracted from higher plants. Cellulose is seen in plants as microfibrils and forms a structure which is strong frame for the cell walls. It is arranged into fibrils which are adjoined by the matrix of lignin and hemicelluloses. Cellulose is partially made up of crystals and they are mainly two types of crystal forms, they are I α cellulose and I β cellulose (Wan et al. 2009).

Cellulose is mainly seen in the combination with different components like hemicelluloses, lignin and lignocellulosic material. The fragments of cellulose, hemicelluloses and lignin acquired have different characteristics depending on the particular process conditions. Cellulose fibre is acceptable for either papermaking or enzymatic conversion to glucose. There are even many types of cellulose esters which are obtained naturally from cellulose by adding organic acids, acid chlorides and anhydrides. From this one of the cellulose ester is cellulose acetate which is frequently used for bioplastic production. Cellulose acetate is important esters of cellulose which are acquired by reacting the cellulose with acetic anhydride and acetic acid in the presence of sulphuric acid (Fischer et al. 2008). Cellulose acetate-based polymers are used in making of various products like textiles, plastic films and fibers. Many different methods are done by many scientists for extracting of cellulose from the cellulosic materials. Cellulose is one of the major compounds which help the best production of bioplastic (Wan et al. 2009).

II. MATERIALS AND METHODOLOGY

The chemicals used are Sodium hydroxide (NaOH), Sodium chlorite ($NaClO_2$), Sodium bisulfite ($NaHSO_3$), Hydrogen peroxide (H_2O_2), and Sulphuric acid (H_2SO_4) are procured from HIMEDIA Laboratories, Secunderabad, Telangana. Jute sticks are procured from National Jute Board, Hyderabad and Rice straw is procured from Moinabad, Hyderabad, Telangana.

III. METHODOLOGY

A. Collection of Rice straw and Jute, Cut, Blend into Fine Powder:

Jute and rice straw are cut into small fragments and then blended so as to obtain in the form of powder. Then the powder was sieved to obtain fineness. The powder is then weighed ranging from 5 to 10 grams for various trails.

B. Pretreatment with Distilled Water:

Jute and rice straw powders are washed with distilled water to remove the contaminants and waxy matter. The powder is then diffused in 500ml for 10minutes at room temperature. It is then stirred for 2 hours at 50°C (Junjun Liu 2012).

C. Delignification :

Washed rice straw and jute was treated with 17.5% to 18% alkali sodium hydroxide (NaOH) for around two hours at 80ºC to 90ºC in the water bath. It is treated with sodium hydroxide to weaken the fibre structure present in the raw material. Then the mixture was taken out from the water bath and kept at room temperature and it was washed with distilled water by filtration process.

D. Bleaching:

For the removal of lignin from the jute and rice straw bleaching is done. One of the chemicals used for bleaching is sodium chlorite ($NaClO_2$) as it is the bleaching agent. 0.7% $NaClO_2$ was treated with jute and rice straw for two hours at a temperature 90ºC in the water bath maintaining p H at 4. Then again after two hours it was taken out and kept at room temperature and was filtered with distilled water. Then the next step is antichlor the substances which where decomposed particles i.e. chlorine based which are present in the substances should not affect the fibre. So for that reason bleaching is done (Melissa B Agustin et al. 2014). 2% of sodium bisulfite ($NaHSO_3$) was treated for 20minutes at room temperature and it was washed, filtered and was dried. Then it is treated with 50% hydrogen peroxide (H_2O_2) considering 3 to 6% of it on the rice straw and jute fibre and kept for around 2 hours with maintaining the p H to neutral. It was then dried to a constant weight. By this step complete delignification was done where the complete lignin is removed.

E. Alkali Treatment:

In this step, 17.5% NaOH was taken and treated with the powder for around 1 hour at room temperature. In this process, the complete hemicelluloses were removed.

F. Acid Hydrolysis:

Cellulose crystals can be prepared from delifnifying cellulose by the process called Acid hydrolysis. This process is done because acid hydrolysis mainly affects in dissolving the amorphous cellulose. So, in this step, 47-48% of diluted sulphuric acid (H_2SO_4) is treated with the rice straw and jute which is digested at room temperature for three hours. It is then washed with distilled water and filtration was done.

G. Neutralization:

In this process the rice straw and jute fibres are thoroughly washed with distilled water and are filtered. The p H is checked simultaneously and it is brought to neutral for formation of pure neutral jute and rice straw fibres. Then the fibre is weighed where the cellulose is extracted.

H. Conversion of Cellulose into Bioplastic:

Bioplastic composite is prepared by production of cellulose-starch composite solution by casting and evaporation process with the use of cassava starch and glycerol. 30grams of cassava starch is suspended into 1000ml of distilled water at heated for 15mins at 60°C. Then cellulose solution is added slowly to the gelatinized starch and stirred until the cellulose is mixed with the gel. Amount of cellulose and glycerol is added accordingly. Then it is cooled and casted in the acrylic plates and air dried. The film produced is peeled and kept in the zipper bags and stored in desiccator (Isroi et al. 2017).

IV. RESULTS AND DISCUSSION

In the present study Rice Straw and Jute was procured from rice fields and jute plant stem. Then the raw materials where blended to fine powder. The fine powder was pretreated with distilled water so that the cellulose undergoes maceration. In the maceration process, it undergoes dissolving of polar, non-polar, wax, carbohydrates, amino acids and other compounds present in jute and rice straw. After pretreating they are stirred for around two hours (Harrizul Rival et al. 2018).

The delignification process was done by using 17.5% to 18% sodium hydroxide (NaOH) to the raw materials and kept in water bath for removing the lignin present in it and to weaken the material. (Harrizul Rival et al. 2008 and Wan et al. 2009). Then the material was filtered with distilled water. Then the material was bleached with different chemicals for the removal of lignin and cellulose (Carla Almeda Correia, Ticiane Sanches Valera 2019). The chemicals used are the bleaching agents which helped in removal of lignin and hemicelluloses. 0.7% sodium chlorite ($NaClO_2$) was treated with the raw material for around 2 hours where the p H was also maintained up to 4. Then the antichlor was added to the raw material. The antichlor substances should not affect the fiber so for that 2% sodium

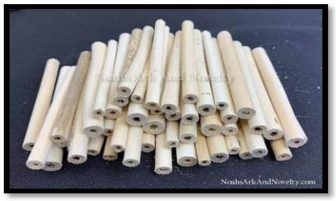

Fig: 1. Jutesticks

Fig: 2. Rice straw

bisulfite ($NaHSO_3$) was treated for 30minutes and washed and dried it (Melissa B Agustin et al. 2014). The powder which was dried was then treated with 50% hydrogen peroxide (H_2O_2). Considering 3 to 6% was extracted from it was used for the raw material. While undergoing this process, the p H was maintained to neutral and treating and filtering it with distilled water. Then again it was treated with 17.5% to 18% sodium hydroxide (NaOH) for around one hour at room temperature, by these treatment complete hemicelluloses was removed.

Acid hydrolysis is the next step, in this the pure cellulose is been extracted. 47-48% of diluted sulphuric acid (H_2SO_4) was diluted and the solution was mixed with the raw material for around three hours at room temperature. Then the acid is washed and filtered. After this, neutralization process occurs where the p H is brought to neutral and the pure form of the cellulose is been obtained. The cellulose which was extracted is 4.28% of rice straw and 1.5% of jute (Fig 3). Generally, cellulose is faster in biodegradable when compared to cellulose acetate. Cellulose acetate is frequently used for the production of bioplastic whereas it takes lots of harmful gases. But when comparing with them cellulose works better in degradation process and cellulose decays in soil with in span of works or months as the microbial enzymes play an active role in speeding up this process.

Then the cellulose-starch composite was used for the bioplastic preparation. The starch which was used is the cassava starch and it is the polymer matrix and another component was glycerol which was used as plasticizer. These two components are used for the bioplastic flexibility, elastic modulus, elongation and tensile strength. After mixing the components slurry is obtained, hence we come to a conclusion that this is suitable for the production of bioplastic.

Fig: 3 Cellulose extracted from Rice Straw and Jute

CONCLUSION

In the present study, the cellulose was extracted from the rice straw and jute and it was then converted into bioplastic. However, we need to characterize cellulose and the bio plastic product.

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REFRENCES

Anggun.R, Khaswar. S, and Isroi. (2018) Biodegradability of Bioplastic from Oil Palm Empty Fruit Bunch. Journal of Natural Resources and Environmental Management, 9(2): 258-263.

Abbasi R, Baheti.V. (2012) Preparation of Nanocellulose from Jute Fiber Waste J Textiles Engineering Fashion Technology: 4(1):101-104.

Bruno.R.M and Stephen.M.M (2011). A Review on Starch Based Nanocomposites for Bioplastic Materials. Journal of Materials Science and Engineering.239-245.

Carla.A.C, Ticiane. S. V (2019) Cellulose Nanocrystals and Jute Fiber-reinforced Natural Rubber Composites: Cure Characteristics and Mechanical Properties. DOI: http://dx.doi.org/10.1590/1980-5373-MR-2019-0192.

Deb Prasad Ray, Rakesh Kumar Ghosh, Ipsita Das, Subhash C S and Gautam Roy (2017). Nanocellulose Extraction from Jute Wastes through Chemical Pre-treatment 181-183 4(2).

Ezgi Bezirhan Arikan and Havva Duygu Ozsoy (2015). A Review: Investigation of Bioplastics. Journal of Civil Engineering and Architecture.188-192.

Harrizul Rival, Annisa S H, Ramdani, Rika S L, Regina A, F Armin, Akmal D. (2018) Production and Characterization of Alpha Cellulose Derived from Rice Straw (Oryza sativa L.) .52(1)45-48.

Isroi, A Cifriadi, T Panji, Nendyo A Wibowo and K Syamsu. (2017) Bioplastic Production from Cellulose of Oil Palm Empty Fruit Bunch. DOI: http://10.1088/1755/65/1/012011.

Jonathan T O, Dipankar C. 2018. Jute Cellulose of Nanofribrils/ hydroxypropylmethylcellulose Nanocomposites: A Novel material with potential for application of packaging and transdermal drug delivery system. Industrial crops and products. 112, 633-643.

Junjun Liu and Chuanhui Huuang. (2012) Biodegradable Composites from Rice Straw and Cornstarch Adhesives. Advance Journal of Food Science and Technology 5(1): 41-45.

Jianlei Yang, Yern Chee Ching and Cheng Hock Chaah. (2019) Applications of Lignocellulose Fibers and Lignin in Bioplastics: Polymers 11(5), 751.

J. Puls, S.A. Wilson, D. Holter. (2011) New Aspects of Cellulose Acetate Biodegradation. 19:152-165

Klemm.D, Heublein.B, Fink.H-P., Bohn.A (2005). Cellulose: Fascinating Biopolymer and Sustainable Raw Material, Angewandte chemie international edition, 44(22), 3358-3393.

Logeshwaran.V, Dr. Arun. (2020). Review on Bioplastic from Cassava Starch. International Journal for Research in Applied Science and Engineering Technology (IJRASET). DOI: http://doi.org/10.22214/ijraset.2020.7038.

Ling Duan, Weidong Yu, Zharhing Li. (2017) Analysis of Structural Changes in Jute Fibers after Peracetic treatment.12(1).

Melissa B Agustin, Bashir A, Shanna Marie M Alonzo and Famile M Patriana. (2014) Bioplastic based on starch and cellulose nanocrystals from the Rice straw. Journal of reinforced Plastics and Composites published online. DOI: 10.1177/0731684414558325.

M. Kapoor, D. Panwar, G.S. Kaira (2016). Bioprocess for Enzyme Production Using Agro-Industrial Wastes: Technical Challenges and Commercialization Potential. 61-93.

Mubarak. A. Khan, Johannes G Hans peter Fink (2009). Hybrid composites of Jute and Man Made Cellulose fibers with Polypropylene by Injection Moulding.846-851.

R. B. Singh, R.C.Saha, Mahendra Singh, Dinesh C, S.G.S hukla, T.K.Walli, P.K.Pradhan and H.P.P.Kessels (1995). Rice Straw – Its Production and Utilization in India. 325-339.

Rob Bakker, Wolter Elbersen, Ronald Poppens, Jan Peter Lesschen. (2013) Rice straw and Wheat straw Potential Feed stocks for the Biobased Economy.

S. S. Shrirakshaya, M. Vignesh, M. Dhananandhini, N. Kavya, Dr. M. Poongothai· 2020 Cellulose and Starch as the Source of Bioplastic. International Journal for Research in Applied Science and Engineering Technology (IJRASET) DOI: http://doi.org/10.22214/ijraset.2020.6089.

Wan Norhanis Binti Ahmad Yarani (2009) Isolation and Characterization of Cellulose from Rice Straw and Sugarcane Bagasse, Department of chemistry, Faculty of Resource Science and Technology Universiti Malaysia Sarawak.

Zahid Anwar, Muhammad Gulfraz, Muhammad I· (2014) Agro-industrial lignocellulosic biomass a key to unlock the future bio-energy: A brief review. Journal of Radiation Research and Applied Sciences 7(2), 163-173.

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