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Enhancement of the properties of Biocomposites material by using natural fibers

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Abstract:

Emphasis has been given on applying green chemistry principle to get desire product, bio-composites have been prepared using sisal fiber and Maize starch by using homemade mold. Bio-composites have huge demand in many sectors from Building construction to auto sector due to conscious awareness regarding environment and therefore there is a need of an hour to synthesize Biocomposites materials. The materials and methods used for enhancement of properties of biocomposites materials have been given in details in this paper.Furthermore, characterization and testing have also been mentioned. Crystalline structure and Tg have been found out by SEM method and TGA method respectively. XRD chart has been given firm surface morphology and amount of crystallinity has been found to be maximum for S1.5 composite as compared to other two composites and it may be due to the thoroughly wetting the fibers by the matrix phase for S1.5 composite. SEM charts have been showing the hard surface morphology of the product. TGA/DTA analysis has been showing that the ratio of starch increases is directly proportional to Tg value. Therefore, more the percentage ratio of starch in product more the free mobility and molecular volume, which impacts the higher up Tg value.

Keywords: Biocomposites; polysaccharides; biodegradable; green chemistry; Environment.

Introduction:

Biocomposites:-It has been known to all that its need of an hour to do research and development on novel materials such as Biocomposites materials. The imprudent use of crude oils has generated environmental problems. Improper utilization of crude oil, fossil-based materials and contribution of plastics in the food chain and ecosystem generated growing concern of all types of pollution affecting the food, water and air thereby damaging the blue planet in every

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dimension. The overuse of crude oil has indirectly helped and created interest to work on biodegradable, harmless products made from eco-friendly materials that are Biocomposites materials[1]. Biocomposites materials are completely based on renewable feedstocks like biomass from vegetables, agriculture or from animal sources. This paper emphasizes on starch based Biocomposites materials. Profoundness of starch in humans, starch is digestible only not cellulose, because human's digestive system possesses enzymes which would be able to digest starch only but as far as animals are concerned, they can digest starch as well as cellulose[2]. To digest cellulose animals, have specific types of enzymes in their digestive system for breaking the beta-acetal linkages. The aim is to utilization of starch in the Biocomposites materials as a matrix phase and other constituents as reinforcing materials or ingredients for the sake of inculcating superior properties. The terminology Biocomposites is referred to use Biocomposites in bioengineering materials. The ingredients of the composite retain their identities in the Biocomposites. Generally, they do not get dissolved or alter their structural skeleton they do make cohesive bonds with matrix phase, they share each other's structural morphology to enhance overall Properties of Biocomposites materials. They do not dissolve or otherwise merge completely into each other. It is found that in the conclusion there is help of improving mechanical properties of Biocomposites materials[4]. Structural viewpoint analysis shows that Biocomposites are anisotropic in nature. Biocomposites are the materials made from biological sources broadly cheap from bio-fiber to bio-enzymes[5].

Starch **[amylum ($C_6H_{10}O_5$) n+ (H_2O)]:** Are an organic compound, polymeric carbohydrate, chief source and part of human foods. Starch is easily available, abundant in quantity and inexpensive. Starch is a polysaccharide containing glycoside bond and is made up of a D-glucose unit linked in a long polymeric chain. Two major components of the starch structures are amylose and amylopectin. Starch is available in the form of white powder[6]. Starch has unique qualities due to its structure, chemical formula ($C_6H_{10}O_5$) n+ (H_2O), it is tasteless, odor less, white in color, when mixed with water forms a white paste which can used as gluing agent, thinking agent and mostly it has been used in paper industries. It is degradable, environment friendly; harmless, nontoxic and for degradation it takes its own time period subject to working conditions[7].Maize starch possesses very much adaptive physiochemical characteristics. The starch can be easily modified it undergoes various reactions such as oxidation, esterification, etherification and hydrolysis and it is versatile kind of material. Therefore possess wide variety of application in industries.

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Starch molar mass is variable subject to formulating conditions. Starch auto ignition temperature is almost 410^{O} Celsius. Starch is the chief source of biomass or biofuels such as ethanol. It is also used in the manufacturing of beer, whiskey. Starch contains different proportional ratios of amylose and amylopectin ranges from about 10–20% amylase to 80–90% amylopectin and it completely depends on the source. Amylose is generally soluble in H_2O and forms a helical like structure[8].

Cellulose $(C_6H_{10}O_5)$ n: Research work shows that cellulose would be the major part of the Biocomposites materials. In the nature cellulose is most easily available biomassin abundant quantity. Cellulose is a homo-polymer polysaccharides organic compound. Its structure consists of a β (1→4) linkage. It is thermoplastics in nature. It is transparent, crystal form, fairly rigid thermoplastics[7].It is insoluble in water and most organic solvents, no taste; odourless, hydrophilic in nature, and it is chiral and biodegradable.   It has glossy finish, reasonably chemical and UV resistant. Generally it is available in the white color [2]. Density is almost 1.5 g/cm³. Molecular Weight/ Molar Mass: 162.1406 g/mol and melting point 250 ^{O} Celsius to 260^{O} Celsius, tensile strength is high 5 to 7 Gpa due to firm hydrogen bonding in micro-fibrils. Cellulose derived from plants and cottons can be useful for the synthesis of Biocomposites materials that can compete with crude oil-based material[3].

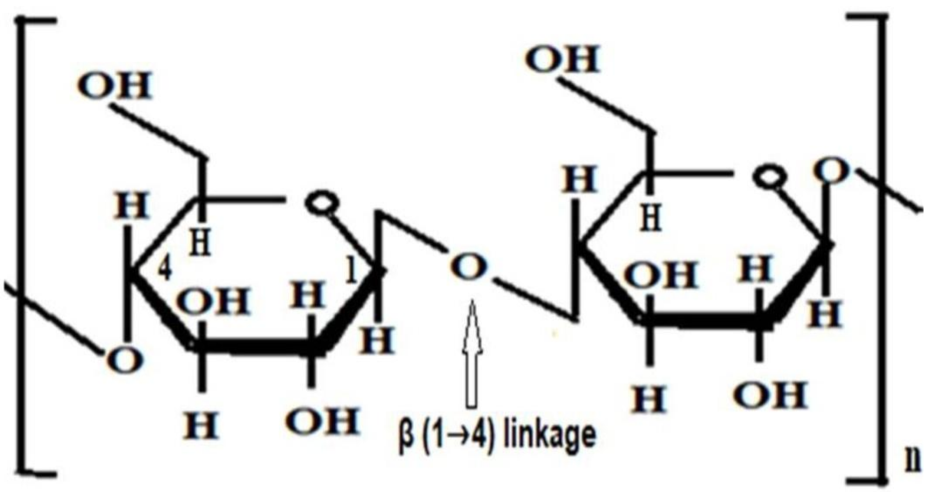

Fig 1.1 β (1-4) Structural linkage

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The properties of cellulose make it vulnerable to be part of an eco-friendly harmless and nontoxic kind of Biocomposites material[9]. Cellulose has its time period requirement for degradation; it completely depends upon the procedure we use to synthesize, constituent's ratio, last but not least most importantly working conditions of biocomposites material. Various forms of cellulose can be used to formulate and synthesize biocomposites materials such as cellulose – I, II, III, VI, cellulose fiber, processed cellulose, hemp, jute, cotton based raw cellulose. The applications of cellulose are mainly found in the textile industries rayon, paper industries in paper products, special ingredients in food items, anti-clumping agent preservatives.

Glycerol: [$C_3H_8O_3$] is a simple organic polyol compound also named glycerin. Main components of glycerol are found in lipids and are called glycerides. Glycerol is a non-toxic, harmless, odorless, colorless simple compound[11]. It is viscous in nature, taste is off sweet, glycerol has uniqueness in its properties such as antimicrobial and antiviral therefore it has tremendous use in food and drugs industries. Because of the three –OH groups in glycerol it is miscible in water and hygroscopic in nature [9]. Density of glycerol is 1.261 g/cm ^{3} Melting point is 17.8 ^{O} Celsius and boiling point 290 ^{O} Celsius, Viscosity is 1.412 Pa[9]·s, flash point is 160 ^{O} Celsius (closed cup) 176 ^{O} Celsius (open cup). Glycerol plays vital role in making biocomposites or bioplastic, it acts as a plasticizer, glycerol reduces tensile strength, young modulus and higher up the elongation break. Glycerol forms a film which is biodegradable. It makes products more pliable, workable, springy, limber, malleable, and ductile. Addition of glycerol impacts the Physical characteristics of bioplastic such as texture, appearance. It is a fundamental chemical required in various uses[11].

Rate of Biodegradability is also accelerated with the addition of glycerol. at least 20% of glycerol is recommended to get a desirable product.

Acid vinegar: It is a blend of acetic acid and water with flavoring constituents. The vinegar used for bioplastic or biocomposites are acetic acid vinegar[11]. It contains more than 5 percent and less than 8 percent of acetic acid by volume. Vinegar is commercially manufactured by fermentation process. Fermentation of grains, fruits, fruit wines, fermentable materials. Inculcation of a small quantity of acid vinegar in bioplastic / composites helps to break the polymeric chains and thereby making the product less brittle. Matrix phase or starch for bioplastic is mixed with acid vinegar boiled, there is a chemical reaction that occurs that turns reactants into bioplastic. Acid

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vinegar cut-off the long polymeric chain of starch and makes it less brittle. Product reaction is given as[12]: Ethanol reacts with oxygen and forms acetic acid.

CH3-CH2-OH + O2 —-> CH3COOH + H2O

Method:-

Following Biodegradable, non-hazardous, eco-friendly reactant materials are the part of the formulation and synthesis of Biocomposites materials:

a. Starch [maize]
b. Cellulose [fibers]
c. Glycerol
d. Acid vinegar
e. Handmade mold.

Experimental procedure:

By keeping in mind 12- principles of green chemistry, dry and clean glassware's are arranged in sequence as per their requirements, all renewable feedstock taken into account and arranged in sequence as per their need. In the beaker 20 ml of Distilled water taken then added 35 gm of starch for sample (A) mixed into it stirred well. After 15 minutes, keep the mixture in the water bath. Gradually the temperature rises and at the 220-degree Celsius temperature, the mixture begins to show some crystallinity. Then as temperature rises gradually addition of glycerol is carried out total up to 7 ml, meanwhile addition of acid vinegar 2 ml added. Continuous stirring makes the product uniform, smooth and semi solid state then cellulose fibers are spread uniformly and accurately at almost equal distance in the handmade mold[5]. Hot bioplastic mixture is poured into the mold and pressure given from all sides thereby the product would be in well shape[13]. Further product samples are kept in the oven for 90 degrees Celsius for 5 hours. Total of two samples have been synthesized keeping proportion of cellulose fiber, Distilled water and other constituents proportion kept the same and only starch proportion changed for both the sample. For sample (B) the same procedure executed only starch quantities have been changed to 40 gm (B).

Results and Discussion:

X- ray diffraction is named as XRD: which is not a destructive type of analytical method. XRD essentially provides the information about crystalline phases in structure thereby

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revealing the chemical composition of the sample. For the purpose (Model: PW 1830 diffractometer) model has been utilized at room temperature powder X-ray diffraction with filtered 0.154 nm Cu Kα radiation. Product sample Has been scanned continuously at mode from at 10°-80° with a scanning rate of 2^0 / minute, just except for fiber, because its scanning range is 5^0-45^0. XRD analysis has shown that crystallite size and degree of crystallinity which is calculated and XRD plot of S1.25, S1.5, and S1.75 are shown in the Fig 1.2XRD Analysis

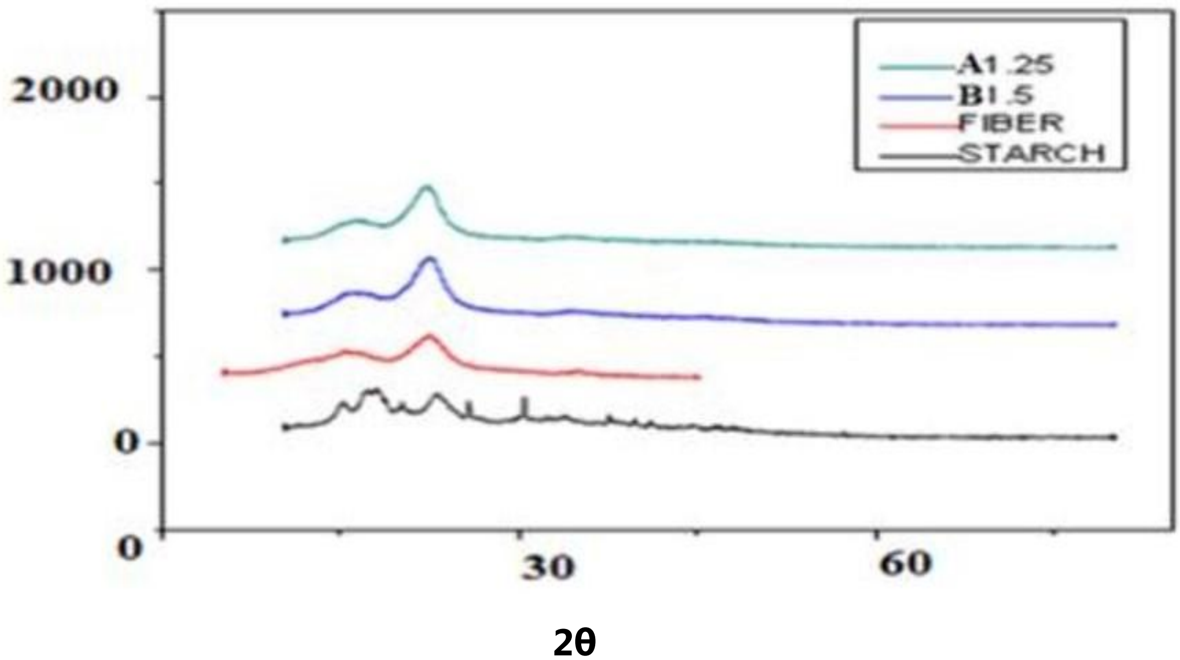

Fig 1.2XRD Analyses

From the XRD analysis method it has been found that the crystallite size of S1.25 is 9.9982 nm and degree of crystallinity is 59.89. The crystallite size of S1.5 is 12.997nm and degree of crystallinity is 65.476

Above analytical result shows that sample A1.5 Biocomposites materials possess crystallite size and degree of crystallinity is higher comparatively to other biocomposites. which shows that if we take equal proportion of starch and cellulose fiber then starch is appropriately wetting the fiber. Therefore A 1.5 Bio composite comparatively possess better quality than sample B Biocomposites. Therefore, we can conclude that with the higher the proportion matrix phase (starch) compared to the other constituents mostly cellulose fibers in Biocomposites materials, and then orientation of fiber is lowered which results in the decrease in the crystallinity[14].

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Scanning Electron Microscope (*SEM)*: Features such as microstructure have been studied by using Scanning Electron Microscope (JSM 6480 LV JEOL, Japan). The SEM microstructure of both the samples is represented in the given images. The variation in the morphology of biodegradable matrix surfaces was studied with varying concentrations of maize starch with cross linked cellulose fiber. It has been observed that the surfaces of matrix phase undergo biodegradation. By using Scanning Electron Microscope (*SEM)* stresses, fractures of the surfaces of Biocomposites material have been examined properly.

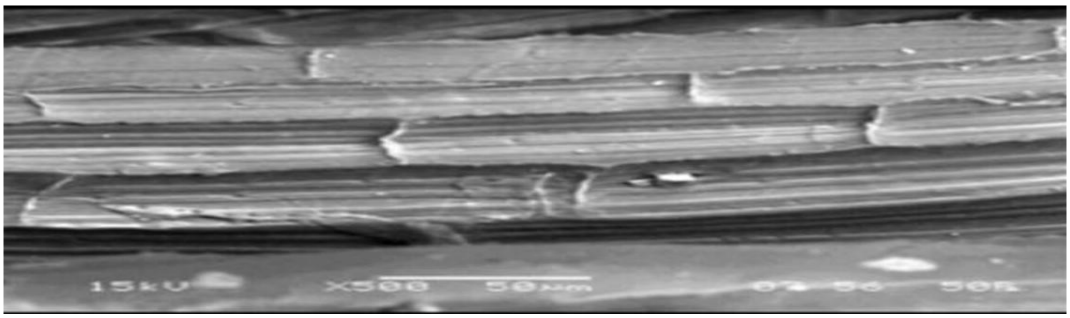

Fig 1.3 Sample A scanned image

The above figure has been interpreted as the roughness of Biocomposites materials. Biomaterials' surface has become heterogeneous and rough, irregular and uneven. It has been observed that the surface of the biomaterial's material sample of the matrix phase undergoes biodegradation which is more irregular, rough.

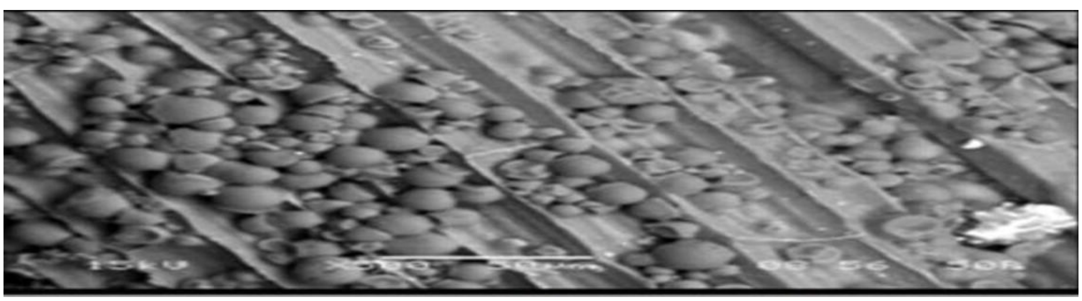

Fig 1.4 Sample B scanned image

In the above figure it has been observed that there is good cohesive force or adhesion taking place between starch i.e., matrix phase and cellulose fiber. Therefore, we can interpret that reinforcement of cellulose fiber has worked properly[15].

Glass transition temperature (Tg): Determination of DTA and TGA**.** The difference between DTA and TGA is that in DTA there is decomposition of constituents of organic matter in the sample at specific temperature and in TGA means there is loss of organic matter at specific temperature. There are three ways to determine Glass transition temperature, here DTA (differential Thermal Analysis) and TGA (Thermo gravimetric Analysis) has been done using DTG-60H. Heating of the sample carried out 5 degrees Celsius from zero degrees Celsius to 80 degrees Celsius. The graph plots of sample A 1.25, B 1.5 have been shown.

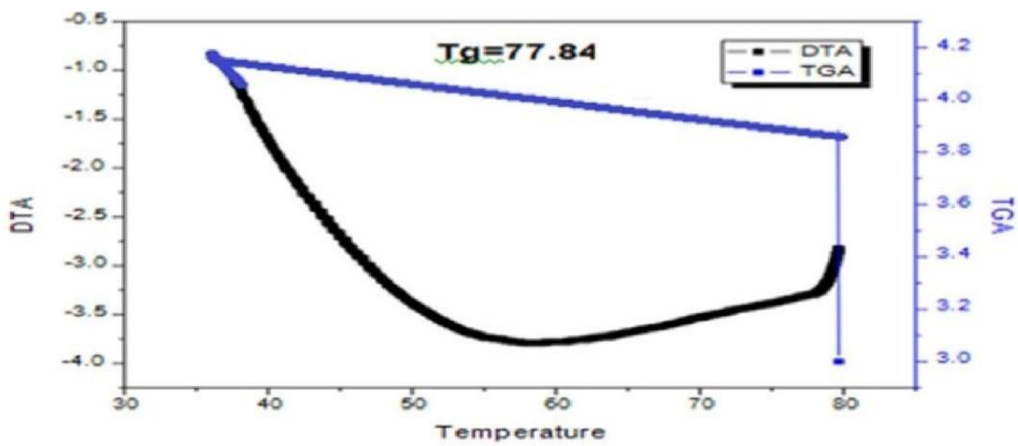

Fig 1.5 shows DTA, TGA for sample (A)

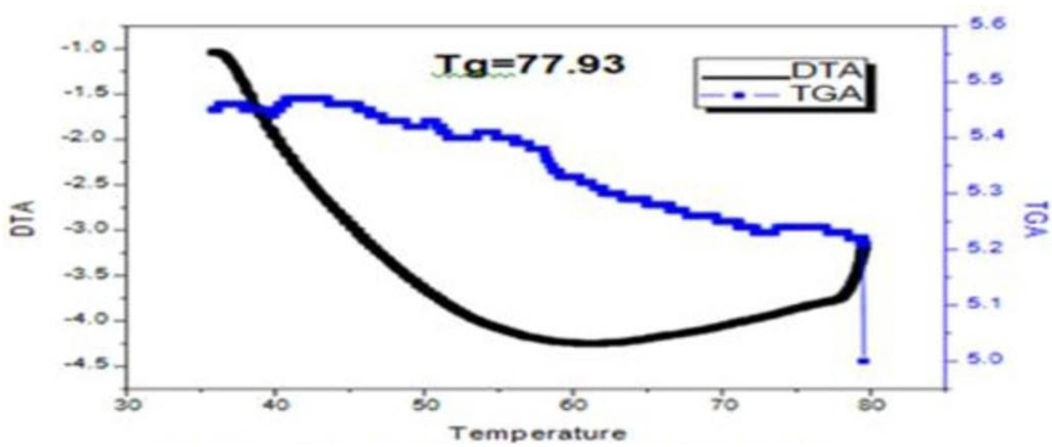

Fig 1.6 shows DTA, TGA for sample (B)

From the above analytical determination, it has been found that glass transition temperature is directly proportional to the amount of starch in the Biocomposites materials. Tg depends on molecular mobility. Therefore, it is possible due to the molecular mobility and free area volume in biocomposites materials. Increased Tg indicates that Biocomposites material is changing state from rubbery (elastic) to crystalline[16].

Conclusion:

In the above method it has been understood that the challenge of achieving efficient Biocomposites material with appropriate biodegradability, one must be sentimental towards the ecosystem and need to possess a huge interest in the environment and its sustainability Generating ideas and forming products is continuous process, there is huge scope in this area of carbohydrates i.e., polysaccharides[13]. In the field of polysaccharides to achieve efficient, competitive and novel Biocomposites materials or bioplastic by considering green chemistry principles researchers need to adopt various methods and alter the ratio or proportion of constituents thereby making a variety of product samples available. In this case physical as well as mental strength of the researcher is tested[14]. In the formulation and synthesis of Biocomposites materials it has been concluded that to get efficient Biocomposites materials which possesses most of novel properties such as mechanical strength, workability as well as biodegradability to achieve this task researcher has to face the challenge compatibility of ingredients. To overcome these challenge researchers, need to invest maximum time on the stoichiometric composition of reactions thereby one can achieve or overcome the compatibility issues. Biodegradability can be achieved by applying proper conditions to the scrap material thereby providing a suitable atmosphere to degrade the material within a stipulated period of time.

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