Naturally Available Materials and Manufacturing Processes for Development of Biodegradable Composite

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Abstract. The hazardous effect of plastic is increasing day by day due to its usage in household and kitchen appliances. The researchers all over the world are looking for alternate material and Sustainable development without appropriate and biodegradable material is not possible. Use of natural resources in various material applications will give support for a rural development as well as it will help ecosystem. The present work provides information about availability of various natural substances which possesses great potential to be used in composite material. The present work also provides information of various techniques useful for manufacturing natural composites

1. Introduction
Presently use of plastic is increased tremendously in domestic household and kitchen appliances which have so many human health hazards. Also plastic is popular material for food packaging like polythene bags, foams, sheets etc which is non degradable, affecting on ecosystem and requires tremendous amount of man power as well as for recycling. Though reason behind using the plastic material is its low weight and less cost, it has many health hazardous characteristics as it includes the chemical Bisphonol A (BPA) [1]. Worn Polycarbonate food and beverage products can lead to serious exposure to Bisphenol A [2] hence there is need to find alternative material which can efficiently replace the plastic. It will help in elimination of health hazards and disposal issues.

1.1 Motivation behind using natural ingredients
The hazardous effects of the plastic accelerated the rate of research in the field of natural fibre composites. Natural ingredients are likely to be harmless for the human health as well as eco system. Also, natural ingredients will degrade easily and thus eliminate issues regarding disposal. Moreover the use of natural ingredients will lead to the rural development by creating employment in agricultural sector.

The biodegradable composites have scope of application in kitchen appliances like food storage, containers, Tiffin boxes, vegetable cutting boards etc. Also it can further be used in packaging industries as replacement for polythene bags, foams, polypropylene sheets etc [3]. Xiaozhi Tang et. al. [3] identified the potential of starch Polyvinyl alcohol blend to efficiently replace LDPE film where good moisture barrier properties are not necessary.
Along with biodegradability the composite materials are cost competitive as compared to plastic materials. The matrix material like Polylactic acid (LPA) is little bit costlier than the polymeric matrices but the starch based matrices like corn starch and potato starch are cost competitive as compared to polymeric matrices. As all natural fibres like jute, coconut, sisal etc are naturally available; they are much cheaper than the conventional synthetic fibres like glass fibres and carbon fibres. Natural fibres have some advantages over polymeric matrices like low density, low cost, recyclability and availability [4].

2 Naturally available materials as reinforcements
Researchers have found potential in several natural materials to be used as reinforcement during natural composite manufacturing. Some commonly used natural reinforcements are as follows

2.1 Jute fibre
Jute fibre is one of the most affordable natural fibre and also available in adequate quantity. It has been found that around 19 lakhs tones of jute are being produced in India per annum. It has high toughness and aspect ratio as compared to other natural fibres [6]. However a Jute fibre possesses inconsistent mechanical and physical properties due to the factors such as growing conditions, fibre extraction technique and processing [7].

2.2 Coir fibre
Coir fibre is fibrous material found between the hard internal shell and outer coat of coconut and it has found various applications in floor mats, doormats, brushes [8]. It is also used for rope production over centuries due to its high strength [8].

2.3 Bamboo fibre
Bamboo is highly growing plant and possesses high strength with low density and low cost. Bamboo fibres are studied and used as reinforcement in a biodegradable Polylactic Acid (PLA) matrix to make ecofriendly composite [9].

2.4 Flax fibres
Flax fibre is soft, lustrous and flexible fibre extracted from the burst beneath the surface of stem of flax plant. It has been produced majority in Canada and being exported to Europe, US and Japan since 1994 [8]. Hamdy Ibrahim et al [10] illustrated the use of flax fibre and date palm fibre as reinforcement in a starch based matrix to make a biodegradable composite where the hybrid composite of flax and date palm with 25 wt% has shown good properties which in turn indicate that it can be used as competitive natural fibre as reinforcement.

2.5 Kenaf fibre
Kenaf is also known as Hibiscus Cannabinus and it is native to Southern Asia. Kenaf fibres are mostly preferred as reinforcement in polymeric matrices. Kenaf fibres require low processing cost as compared to other synthetic fibres along with comparable specific properties [11] hence they are preferred to be reinforced with polymeric matrices.

2.6 Coconut spathe fibres
Coconut spathe is covering of coconut inflorescence and though it has potential to be used as reinforcement in natural composite it is not rigorously studied as compared to other fibres from coconut plant [12].

Table1 gives the brief information about various types of natural materials which are used as reinforcement, manufacturing method and effect of reinforcement on mechanical as well as wear properties
Table 1. Natural materials used as reinforcement

| Sr No | Name of Reinforcement | Manufacturing Method | Effect on various Properties | Ref. |
|-------|-----------------------|----------------------|------------------------------|------|
| 1     | Jute Fibre            | Film stacking and compression moulding | It is observed that impact resistance increases when jute fibre is used as reinforcement | [6]  |
| 2     | Bamboo fabric         | Film stacking followed by compression moulding | Tensile, Flexural and impact properties have been increased when Polylactic acid is reinforced with bamboo fibres' | [9]  |
| 3     | Date palm and Flax fibre | Hot pressing | Maximum Tensile strength is observed when 50wt% fibre content of Date palm and flax fibres is used as reinforcement | [10] |
| 4     | Coconut Spathe fibre  | Hand lay up          | Tensile strength of spathe fibres have been increased when reinforced in epoxy | [12] |
| 5     | Coir sheath           | Hand layup followed by compression moulding | Decrease in wear rate is observed when coir sheath is used as reinforcement | [13] |
| 6     | Areca Frond Fibre    | Hand layup followed by compression moulding | Flexural strength is increased when Areca Frond Fibres are used as reinforcement | [14] |

3 Effect of chemical treatment of natural reinforcement on mechanical properties

Along with some advantages of natural fibres there is a main challenge of adhesion between the polymeric matrices and natural fibres. The natural fibres are likely to have hydrophilic nature (i.e. natural fibres are water loving) and the polymeric matrices are hydrophobic in nature i.e. they repel water which causes adhesion quite difficult [5]. Adhesion problem can be resolved by treatment of the natural fibres which have been studied by several researchers. Table 2 represents the different practices conducted for chemical treatment of natural reinforcement along with its effect on properties.

4 Naturally available matrix materials

From last two decades the use of natural fibres has been trending as reinforcement in polymeric matrices in order to replace conventional synthetic fibres like glass and carbon fibres. There is need arising to make completely biodegradable material which accelerated the rate of research to find the biodegradable and efficient matrices as alternative to the conventional polymeric matrices. Following are some matrices which are identified and used to make green composite.

4.1 Starch based matrices

Starch is mostly used for producing biodegradable plastics. It is easily available, cheap and biodegradable. Starch in its original form lacks strength, water resistibility, process ability and thermal stability [3]. In order to eliminate these drawbacks it is blended with some synthetic polymer such as Poly (C- capro lactone)(PCL), Polylactic acid (PLA), Polyvenyl alcohol (PVOH). Starch can be extracted from plants such as corn, wheat, rice and potatoes. Some ingredients are needed to be added in starch to make completely biodegradable matrix. Some binders are added in order to improve the bonding [14]. Kaith et al [17] used resorcinol formaldehyde cross linker as binder material in starch
| Sr. No | Type of treatment and Chemicals Used | Process carried | Effect of treatment on properties |
|-------|-------------------------------------|----------------|-----------------------------------|
| 1     | Alkali treatment with NaOH and Acetic acid | Fibres were washed several times with water and are dried at room temperature. Dried coconut sheaths are then immersed in 5% NaOH solution for an hour and neutralized with 5% acetic acid solution | Cellulose percentage was found to be increased accompanied by decrease in hemicelluloses and lignin. Also treated composite shown higher tensile, flexural and impact strength | [4] |
| 2     | Alkali Treatment with NaOH and Acetic acid | Fibres were washed and dried for a week and treated to 105-110°C and treated with 5% aqueous solution for an hour and neutralized with acetic acid. Finally it is washed and dried with distilled water | Crystallinity of fibres increased with alkali treatment | [15] |
| 3     | Benzoyl peroxide treatment with acetone | Fibres were soaked in 6% benzoyl peroxide solution in acetone for 30 minutes and dried for 24 hours in air | Least weight loss in thermogravimetric analysis is observed | [22] |
| 4     | Stearic acid treatment | Solution of 1% Stearic acid in ethyl alcohol was added drop by drop to the fibres. These fibres were then dried at 80°C for about 45 minutes | More weight loss in thermogravimetric analysis is observed compared to fibres treated with Benzoyl peroxide | [22] |
| 5     | Alkali with NaOH | Fibers were soaked in a 1% NaOH solution and washed thoroughly to remove excess amount of NaOH, it is then finally washed with acetic acid and dried | Alkali treated natural fiber composite shown better performance than potassium permanganate treated composite and poor performance as compared to stearic acid treated fibre composites | [22] |
| 6     | Potassium permanganate treatment with acetone | Fibres were soaked in 0.5% Potassium permanganate solution in acetone for 30 minutes and dried for 24 hours in air | Higher weight loss in thermogravimetric analysis is observed for fibres treated with Potassium permanganate | [22] |
based biodegradable composite. Glycerol is used as plasticizer in starch based biodegradable matrix preparation which induces flexibility in the matrix resisting the cracking of starch based plastic film. Cinelli et al [20] illustrated the use of potato starch and corn fibres to produce foamed tray which can efficiently replace single use packaging material made of expanded Polysterene (EPS).

4.2 Polylactic acid as matrix material

Polylactic acid (PLA) is versatile thermoplastic produced from polymerization of heterocyclic dilactone (Lactide) monomer. Lactide is produced by fermentation of potato, corn, sugar beet, sugarcane. PLA shows properties which are quite similar to Polystyrene. PLA is little bit costlier than polystyrene but still used in industrial packaging and medical applications because of its degradability.

5 Different Manufacturing techniques to manufacture biodegradable composite

In case of natural fibre reinforced polymeric composites various manufacturing techniques are available, but in case of biodegradable composites only few manufacturing techniques are available. Table 3 shows some commonly used techniques for manufacturing of biodegradable composite.

| Sr. No | Name of Process | Reinforcement | Matrix | Maximum process temperature | Name of equipment | Ref |
|-------|----------------|---------------|--------|----------------------------|-------------------|-----|
| 1     | Extrusion process followed by compression moulding | Bamboo Fabric | PolyLactic Acid | 210°C | Conventional compression moulding press (Dake press model 44-251) | [9] |
| 2     | Hot Pressing | Date Palm and Flax fibres | Corn starch | 160±3°C | Carver Laboratory Press (Model C) | [10] |
| 3     | Hand layup followed by compaction | Areca Frond Fibres | Corn starch | 140°C | Pneumatic Press | [14] |
| 4     | Hot pressing | Saccharumspontaneum L fibre | Corn starch | 90°C | Carver Hydraulic hot press | [17] |
| 5     | Extrusion | Montmorillonite | Corn starch | 120°C | Single Screw plastic extruder SJ25 | [18] |
| 6     | compression/ explosion | - | Wheat starch, Corn starch and Potato starch | 230°C | Hydraulic Press (Carver Model-C) | [19] |

Porras et al [9] produced the laminate composite of bamboo fibres reinforced in polylactic acid matrix by using extrusion process followed by compression moulding. PLA films were prepared by extrusion and composite panels were produced by film stacking procedure followed by compression moulding. Hamdy Ibrahim et al [10] produced thermoplastic starch blend separately and then prepared composite by hot pressing the thermoplastic starch with chopped fibres. Srinivas Shenoy et al [14] prepared the biodegradable matrix by mixing base materials, binders and plasticizer followed by heating and
mixing with fibres using hand layup process which is then compacted using pneumatic chamber and cured in a hot chamber.

Jun Young Jang et al [16] prepared coconut fibre reinforced PLA composites by using compression moulding technique. Kaith et al [17] employed hot pressing process for starch based composite preparation where as Mingfu Huang et al [18] prepared corn starch / Montmorillonite biodegradable composite in twosteps firstly granular cornstarch molecules were prepared using extrusion and mixed with montmorillonite powder which is further extruded to produce composite. G.M. Glenn et al [19] used compression/explosion process for making starch based foam whereas P.Cinelli et al [20] produced potato starch based foam tray by baking starch, corn fibres, magnesium stearate and PVA

6 Potential applications and Future prospectus

As a biodegradable composite is sustainable development it has great potential to contribute rural development along with employment in agricultural sector. Use of these composites will lead to save man power, machinery, and cost related to the waste management of existing single use plastic by replacing it with biodegradable composite. Starch-PVOH blends have potential to replace LDPE films in several applications [3] in packaging industry. Also starch based foam can be produced which has wide scope of applications in food and industrial product [20] which can replace single use expanded polystyrene (EPS) material significantly[19]

Biodegradable composites have stimulating potential to develop new material which can replace plastic material from kitchen and household appliances resulting in elimination of various hazards from plastics

7. Concluding Remarks

1. As jute fibres are produced in adequate quantity and also possesses good strength there is great potential in jute fibres to be used as reinforcement.
2. As corn starch is easily available and less costly, it will be the best alternative to the polymeric matrices.
3. Naturally available matrix material possesses great potential in case of impact resistance properties Manufacturing is quite simple using hand layup and compression moulding in case of biodegradable composites.
4. Biodegradable composites have potential to be used as replacement for Low density polyethylene and also possess future prospects to be used as replacement to plastic material in household and kitchen appliances.

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