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## PROJECT REPORT



### DEVELOPMENT OF COIR FIBRE REINFORCED GREEN POLYMERIC COMPOSITES FOR INJECTION MOULDING PRODUCTS

SUBMITTED TO  
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## Chapter 1

### 1.1 INTRODUCTION& SCOPE

In the current era of composites, natural fibre based polymeric biocomposites have drawn wide attention in the field of research and development. Due to many advantages and environmental friendliness in comparison with the conventional composites, green composites are beneficial to the future development and can reduce carbon foot print. As a renewable source, the incorporation of natural fibres as fillers/reinforcements improves the properties of the composites and fulfilling the market demand. Natural fibres such as coir, jute, palm, kenaf are most available fibres with light weight, biodegradable, inexpensive which are more generally competent to synthetic fibres.

Coir is a lignocellulosic fibers, which are hydrophilic in nature and their main constituents are cellulose, hemicellulose and lignin. As compared to other natural fibres, coir fibres have high lignin content due to the presence of strong polarized hydroxyl group,moisture absorption is high and lead to limited applications in industrial and technical field . Natural fibers using as reinforcement in polymer composite is their polarity which makes it incompatible with hydrophobic matrix. The results lead to poor interfacial bonding between the fibers and the matrix leads to diminish the mechanical properties of the composites. This defect can be rectified by modifying the fibers so as to make it less hydrophilic. The coir fibre is relatively water proof and is resistant to damage by salt water. Coir, being a natural fibre that is environment friendly in the strictest sense of the term, is now seen as the fibre of the future.

The green composites would serve as major drivers of sustainable developments to automakers, making significant shift towards eco-friendly composites to reduce manufacturing cost and fuel usage while meeting the consumer demand for greener

products. Natural fiber reinforced bio-composites can compete economically because of the low cost of natural fibers compared to synthetic fibers. It is, therefore, imperative to derive cost-effective bio-based products or bio-composites through the use of inexpensive natural fiber reinforcement. New applications and uses for bio-composites will spur large scale demand for bio-plastics which will help the attainment of long-term sustainability. The foundation for development of new and emerging bio-based composite materials industry lies in detailed understanding of natural fibers, bio-plastics and bio-composite formulations. Although natural fibers lag behind from the impressive property of synthetic fiber, their eco-friendly nature has made them attractive. The objective of present research is to develop green composite by using lignocellulosic coir fibres which are abundant, inexpensive and eco-friendly and improving the new era of green composite

In this current work, chemically treated coir fibre is used to reinforce polypropylene matrix to form a biocomposite material and fabricate value added products by injection moulding. The chemical treatment of coir fibre leads to minimize the hydrophilic characteristics and diminish the water absorption property of the composite.

## **1.2 OBJECTIVES**

The main Objective of this research project is to develop sustainable coir fibre reinforced green composite materials for commercial applications. The application target is driven by the current needs in different fields. The expected outcome of the project work is as follows

- To explore the value based use of coir fibre as reinforcement in composite development
- To find the variation in the effect of coir fibre content on Physical,mechanical,thermal and morphological properties of composite

- To develop at least two value added products of PP-Coir green composite such as flower pot, funnel etc

## Chapter 2

### LITERATURE SURVEY

Natural fibre based research works are more predominant in the present scenario of biocomposite field. High establishments of natural fibre related composites lead to a new trend in product development in polymers. Polymeric materials reinforced with natural fibres yielding relatively light weight and high specific properties [24]. Significant in cost effective and processing simplicity of biocomposites related to natural fibres makes demand in the current perspective of polymeric research area.

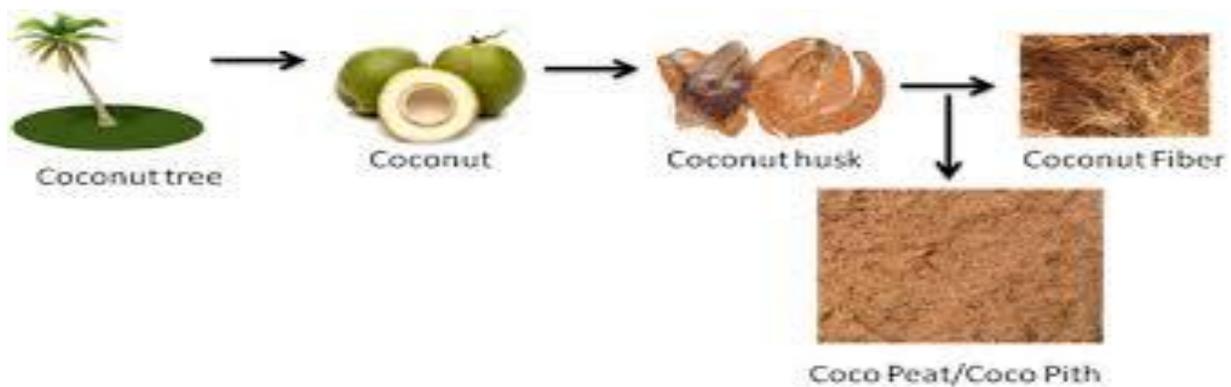
#### 2.1 Coir Fibre

Coir is extracted from the tissues surrounding the seed of the coconut palm (*Cocos nucifera*) [Fig.2]. Coir fibre measures up to 35 cm in length with a diameter of 12-25 microns. A coconut harvest occurs once in 45 days. From 1000 coconuts it would be possible to extract 10 kgs of coir. Among vegetable fibres, coir has one of the highest concentrations of lignin, making it stronger but less flexible than cotton and unsuitable for dyeing. The tensile strength of coir is low compared to abaca, but it has good resistance to microbial action and salt water damage and needs no chemical treatment.



Figure.1 Coir Fibre

Coconut fibre is the most ductile fibre amongst all natural fibres. Coconut fibres are capable of taking strain 4-6 times more than that of other fibres. There are variations in properties of coconut fibres, and makes it difficult for their frequent use as construction material. There are many general advantages of coconut fibres e.g. they are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean.[54] There are two types of coir: the more commonly used brown fibre, which is obtained from mature coconuts, and finer white fibre, which is extracted from immature green coconuts after soaking for up to 10 months.[2] Mature coir fibres



contain more lignin, a complex woody chemical and less cellulose than fibres such as flax or cotton.

Figure.2 Extraction of Coir Fibre

Table 1 Chemical Composition of coir fibre

ITEM	PERCENTAGE
Lignin	45.84%
Cellulose	43.44%
Hemi-Cellulose	00.25%
Pectin's and related Compound	03.00%

Water soluble	05.25%
Ash	02.22%

Table2 Physical Properties of Coir Fibre

ITEM	
Length in inches	6-8
Density (g/cc)	1.40
Tenacity (g/Tex)	10.0
Breaking elongation%	30%
Diameter in mm	0.1 to 1.5
Rigidity of Modulus	8924 dyne/cm <sup>2</sup>
Swelling in water (diameter)	5%
Moisture at 65% RH	10.50%

## 2.2 Advantages of coir Fibre

Coir is a material which is widely used to overcome the problem of erosion. When woven into geotextiles and placed on areas in need of erosion control it promotes new vegetation by absorbing water and preventing top soil from drying out.

Coir industry enjoys the status as the largest cottage industry in the state of Kerala, giving employment to over a million people. [1] Coir geotextiles have a natural ability to retain moisture and protect from the sun's radiation just like natural soil, and unlike geosynthetic materials, it provides good soil support for up to three years, allowing natural vegetation to become established. Geotextiles made from coir are durable, absorb water, resist sunlight, facilitate seed germination, and are 100% biodegradable. These

blankets have high strength retention and a slow rate of degradation meaning they last for several years in field applications.



Figure 2.3 Commercial applications of coir fibre

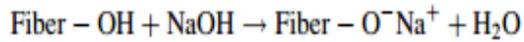
A substitute to plywood, coir ply is an innovative product that when is added together with resin and limited pre-treated timber veneers. In India the product has been well accepted by the market as an alternative to plywood. Substituting coir for other timber products could also save a substantial amount of tropical trees being logged for this purpose. Coir ply has all the properties of phenol-bonded ply with the added strength of fibre reinforced phenol bonding. It has high degrees of surface abrasion resistance and resists contraction/ expansion due to variations in temperatures. The waste product from milling the coir is peat or pith which makes for high quality mulch and fertilizer. Coir pith compost developed from coir waste is an excellent organic manure and soil conditioner applicable to agricultural crops. [2].

### 2.3Coir Fibre Modification

Modification of coir fibre for the preparation of composite is one of the predominant step as the treatment improves the end product properties. Various treatment mechanism were done in different literatures.

#### 2.3.1Alkali Treatment

The removal of hydrogen bonding in the network structure is the important modification occurring in alkali treatment [7]



Fiber leads to swelling reaction during alkali treatment in which the natural crystalline structure of the cellulose relaxes. Native cellulose which occurs in nature shows a monoclinic crystalline lattice of cellulose-I, can be changed into different polymorphous forms through chemical or thermal treatments. The important forms are alkali-cellulose and cellulose-II. The type of alkali used is NaOH and its concentration will influence the degree of swelling, and hence the degree of lattice transformation into cellulose-II. Studies have shown that NaOH have higher diameter, able to widen the smallest pores in between the lattice planes and penetrate into them. Consequently, sodium hydroxide (NaOH) treatment results in a higher amount of swelling. This leads to the formation of new Na-cellulose-I lattice, a lattice with relatively large distances between the cellulose molecules, and these spaces are filled with water molecules. In this structure, the OH-groups of the cellulose are converted into ONa-groups, expanding the dimensions of molecules. Throughout rinsing with water will remove the linked Na-ions and convert the cellulose to a new crystalline structure, i.e. cellulose-II, which is thermodynamically more stable than cellulose-I. NaOH can cause a complete lattice transformation from cellulose-I to cellulose-II, in contrast to other alkalis that produce only partial lattice transformation



Figure 2.4 Influence of alkali treatment on cellulose structure

The alkali solution influences not only the cellulosic components inside the plant fiber but also the noncellulosic components (hemicellulose, lignin, and pectin)

The alkali treated coir fibre –polyester composites with a volume fraction ranging from 10 to 30% show better properties than composites manufactured with untreated fibres, but the flexural strength of these composites was consistently lower than that of the bare matrix. About 42.3MPa was reported to a value of 48.5MPa for Polyester[8]

### 2.3.2 Silane Treatment

Silane solution having concentration ranging from 0.2 to 1% wt/wt was used to treat coir fibre for better reinforcing performance of the composite. Silane was diluted with distilled water and stirred for 15 minutes to form an aqueous solution. Acetic acid was then added until the  $p^H$  of the solution is 4. the coir fibre immersed in the solution for an hour and washed with distilled water and dried at room temperature for 2 days.[9]

### 2.3.3 Acetylation

The treatment of fibres by esterification method known as acetylation. The generation of acetic acid which must be removed from the lignocellulosic material before the fibre is used. Acetic anhydride which is used for chemical modification substitutes the polymer so that they become hydrophobic[10]. Untreated coir fibres were immersed in 18% aqueous NaOH solution at 28<sup>0</sup>C for one hour. The fibres were then washed several times with cold water and finally with acidified water (0.1N HCl). The fibre dried in an air oven and then soaked in glacial acetic for one hour at the temperature[11]

### 2.3.4 Benzoylation

Benzoyl chloride treatment of alkali pretreated sisal fibre exhibits higher thermal stability compared to untreated fibre composites. By benzoylation using benzyl chloride the hydrophobicity of fibres decreased and fibre matrix adhesion increased and lead to the strength of the composites. The alkali pretreatment was used to activate the hydroxyl groups in the fibres and soaked in to the benzoyl chloride solution for 15

minutes. Benzoyl chloride adhered in to the fibre surface removed by ethanol solution followed by washing with water and dried in an oven.

## 2.4 Composites

Composites consist of two or more distinct constituents or phases, which when combine together result in a material with entirely different properties from those of the individual components. A manmade composite would consist of a reinforcement phase of stiff, strong material, frequently fibrous in nature, embedded in a continuous matrix phase. The latter is often weaker and more compliant than the former. Two of the main functions of the matrix are to transmit externally applied loads, via shear stresses at the interface, to the reinforcement and to protect the latter from environmental and mechanical damage.<sup>6</sup> The advantage of such a coupling is that the high strength and stiffness of the fibres which in most practical situations would be unable to transmit loads may be exploited [14]

## 2.5 Biocomposites

Biocomposites are composite materials comprising one or more phase(s) derived from a biological origin. In terms of the reinforcement, this could include plant fibres such as cotton, flax, hemp, coir and like fibres from recycled wood or waste paper, or even by-products from food crops. Regenerated cellulose fibres like rayon are also included in this definition, since ultimately they too come from a renewable resource, as are natural 'nano fibrils' of cellulose and chitin. Matrices may be polymers, ideally derived from renewable resources such as vegetable oils or starches. Alternatively, and more commonly at the present time, synthetic, fossil-derived polymers preponderate and may be either 'virgin' or recycled thermoplastics such as polyethylene, polypropylene, polystyrene and polyvinyl chloride, or virgin thermosets such as unsaturated polyesters, phenol formaldehyde, isocyanates and epoxies [14]

## 2.6 Coir Fibre based biocomposites

Pretreatments are done on the coir fibre which are used for composite preparation namely alkali treatment, cyano ethylation, bleaching and vinyl grafting in general purpose polyester resin as matrix. [3] In alkali treatment the fibre was treated with NaOH and then washed in water.[12] After drying, Acrylo Nitrile and Methyl methacrylate are grafted on the surface of the fibre. In cyanoethylation the fibres were obtained by refluxing the alkali treated coir with AN ,acetone and pyridine (as catalyst )at 60<sup>0</sup>Cfor 2hours ,then washing the fibres with acetic acid and acetone followed by washing with distilled water and finally vacuum drying .The fibre content used was from 30 to 50%[3]. The mechanical properties of composites like tensile, flexural and impact strength increase as a result of surface modification. Among all modifications, bleached (65°C) coir-polyester composites show better flexural strength (61.6 MPa) whereas 2% alkali-treated coir/polyester composites show significant improvement in tensile strength (26.80 MPa). Hybrid composites comprising glass fibre mat (7 wt. %), coir fibre mat (13 wt. %) and polyester resin matrix are prepared. Hybrid composites containing surface modified coir fibres show significant improvement in flexural strength. Water absorption studies of coir/polyester and hybrid composites show significant reduction in water absorption due to surface modifications of coir fibres. [3]

Surface treatment of coir fibre was determine the effect of water absorbtion behavior and moisture absorption of the composites was studied. [4].Coir fiber was treated with NaOH solution, Acetic Acid, Potassium permagnate and also treated at 150<sup>0</sup>C and their moisture absorption capacity and surface topology were comparing with untreated coir. Water absorption property is higher in untreated coir than chemically treated coir. This was due to the more water soluble portion (may be hemicelluloses) present on the surface. In humid conditions the moisture absorption capability is highest in case of alkali treated coir fiber. But the trends are not same for all the temperatures [4]

Coir fibers were treated with ethylene glycol methacrylate (EGDMA) mixed with methanol (MeOH) under UV radiation [5]. A series of solutions of different concentrations of EGDMA in methanol along with a photo initiator, Irgacure-500 (mixture of 1-hydroxycyclohexylphenylketone and benzophenone), were prepared. Monomer concentration, soaking time, and radiation intensity were optimized in terms of polymer loading (PL) and mechanical properties. EGDMA (50%), 5 min soaking time at the 4th pass of radiation, produced higher PL and tensile strength (TS), and the values of PL is 17% and TS is 1.3 times of the untreated one. Then, coir fiber was pretreated with detergent and then treated with the optimized monomer formulation, which exhibited a higher PL of 69% and produced TS of the coir fiber of 4.4 times of the untreated one. Coir fiber pretreated with detergent along with UV radiation showed the highest TS, which is 18.2 times of untreated one. Water uptake, degradable properties, and simulated weathering of treated and virgin fibers were also monitored, which showed that EGDMA treatment under UV radiation improved the degradable property. [5]

Natural fibers such as coir fiber and rice husk were selected as reinforced in epoxy resin. Brown coir fibers and rice husk are treated with 6% of NaOH separately to increase the fiber strength and the treated natural fibers are reinforced in epoxy matrix to fabricate the composite.[6] It was found that on examining the mechanical behavior such as its tensile strength and flexural strength of various combinations of coir fiber and rice husk reinforced epoxy composites, higher tensile strength and flexural strength is found in mixing ratio of coir to rice husk ( 80:20) which shows the rice husk acts as a filler to increase the strength. It is also evident that chemical treatment alters the properties of fiber such as adhesion, surface morphology and so on [6]

Fiber was divided into two parts, namely the untreated fibers and fibers with early treatment. Fiber with initial treatment NaOH soaked with a solution of 3% by various time 1,2,3,4 and 5 hours. After soaking the fiber is washed with distilled water to remove the chemical effects after it is dried at room temperature without sunlight. [8]

Alkali treatment causes a decrease in cross-sectional area, but did not significantly affect the immersion time. Treatment of alkali in the fiber gave the effect of decreasing the tensile strength of the fiber caused by the release of a binding component between micro fiber [8]Coir yarn PP based unidirectional composite were prepared through compression moulding.20% yarn content was optimized to show higher mechanical properties. Incorporation of jutefibre to coir PP composite performed better results.[17]

## 2.7 Poly propylene

Thermoplastics offer many advantages over thermoset polymers. One of the advantages of thermoplastic matrix composites is their low processing costs. Another is design flexibility and ease of molding complex parts. Simple methods such as extrusion and injection molding are used for processing of these composites. In thermoplastics most of the work reported so far deals with polymers such as polyethylene, polypropylene, polystyrene, and poly (vinyl chloride). This is mainly because the processing temperature is restricted to temperatures below 200°C to avoid thermal degradation of the natural fibers. For thermoplastic composites, the dispersion of the fibers in the composites is also an important parameter to achieve consistency in the product. Thermoplastic composites are flexible and tough and exhibit good mechanical properties. However, the % loading is limited by the processability of the composite. [31].



## Figure 2.5 Polypropylene

Polypropylene provides superior qualities and is the most versatile and cost effective plastic in comparison to other thermo-forming and polyolefin materials. It has good impact strength, surface hardness, dimensional stability and excellent abrasion resistance. Polypropylene is resistant to a wide variety of acids, alkalis and solvent solutions with a temperature range up to 200<sup>0</sup>F. Polypropylene is highly responsive to injection speed and pressure and sets up quickly in the mold, enabling molders to attain high production rates. This combination of performance properties gives polypropylene a position in the injection molding field that is unique among thermoplastics. Polypropylene also demonstrates excellent chemical resistance, good abrasion resistance, good dimensional stability, and a high surface gloss on finished pieces

### 2.8 MAPP used as compatibilizer

Treatment of cellulosic fibres with Poly Propylene Maleic anhydride (MA-PP) copolymers provides co-valent bonds across the interface. The reaction mechanism involves 2 steps. The activation of co-polymers by heating 170<sup>0</sup>C before fibre treatment and esterification of cellulose.

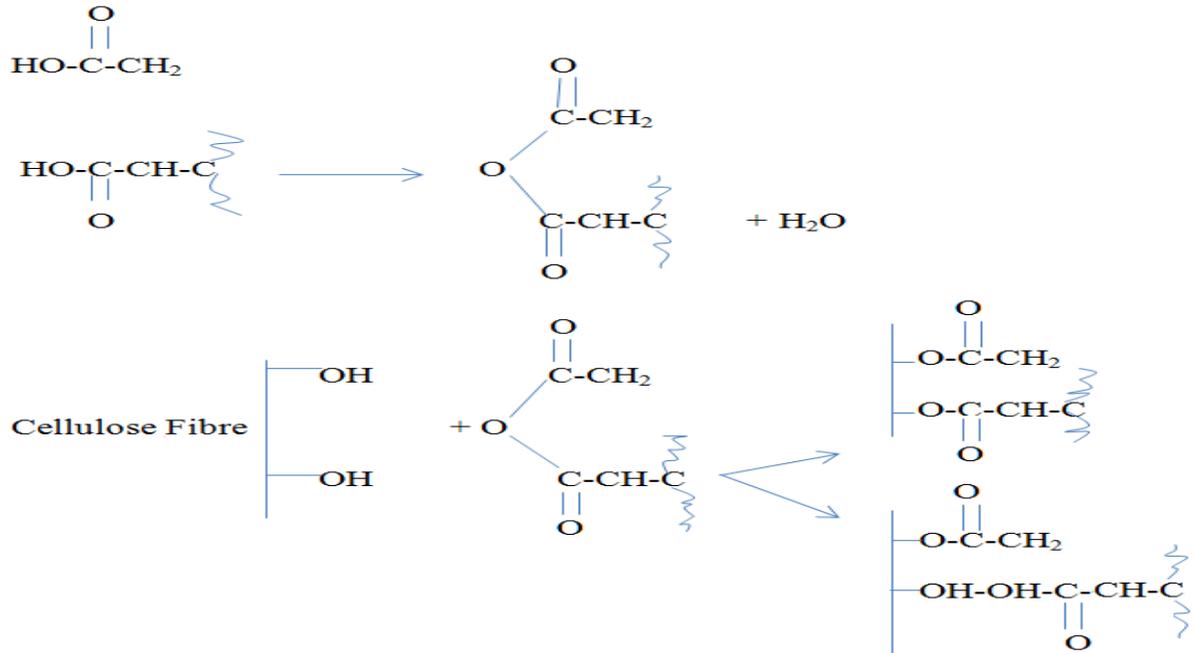


Figure 2.6 Reaction mechanism of Cellulose with MAPP

After the treatment the surface energy of the fibre is increased to a level much closer to the surface energy of matrix. Thus better and higher interfacial adhesion is obtained. The PP chain permits segmental crystallisation and cohesive coupling between modified fibre and PP matrix.

Addition of 2 wt. (%) MAPP showed to increase the tensile strength of the composites for all filler loads, indicating that it can be efficiently used as a coupling agent for Rice husk fibre-PP composites. [16] This behavior can be attributed to the reaction of the hydrophilic -OH groups from the filler and the acid anhydride groups from MAPP, thus forming ester linkages, as it has been proposed in the literature. The highest effect of MAPP was observed in the composite containing 40 wt. (%) of filler, showing an improvement of 37% in tensile strength. [16] Addition of MAPP also reduced the degree of water absorption (> 20%), making these materials more suitable for using in damp environments. MAPP coupled composites showed more homogeneous morphology due to the better compatibility among the filler and the matrix. [15]

In this current work, chemically treated coir fibre is used to reinforce poly propylene matrix to form a biocomposite materials and fabricate products such as flower pot, funnel via injection moulding. The chemical treatment of coir fibre leads to minimize the hydrophilic characteristics and diminish the water absorption property of the composite

## Chapter 3

### EXPERIMENT

This chapter deals with modification of coir fibre and the treated fibre weight percentage optimized for the preparation of composite specimen samples for testing and Product preparation

#### 3.1 Materials

Coir fibres are collected from local ventures from Alappuzha and having fibre length in between 120-140mm. Virgin Polypropylene of injection moulding grade (Moplen HF500N having MFI/230°C/2.16 kg=11g/10 min produced by LyoundellBasell Ltd purchased from K V N Implex Kochi was used as the matrix material. Maleic anhydride-grafted PP (MAPP, Optim P-445) the reactive modifier maleic anhydride content of 3 wt. % was used as compactabilizer, supplied by Pluss Polymers Pvt. Ltd. in India

#### 3.2 Method

##### 3.2.1 Modification of coir fibre

Mechanically retted coir fibres collected from local ventures were cleaned and sized at a range of 5-8mm. The sized fibres were washed with large amount of water to remove the surface dirt present in the fibres. Dried it in an oven at 80°C until obtain a constant weight. The cleaned and sized fibres were soaked in 5% NaOH solution for 48 hours having fibre to liquid ratio of 1:50 and stirred occasionally. Drained off the alkali and washed with 3% acetic acid for neutralize the alkali and then followed with demineralized water. After washing, the treated fibres were dried in an oven at 80°C

##### 3.2.2 Preparation of PP-Coir Composite

Chopped and treated fibres were predried at a temperature of 60-70°C for 12 hours in order to reduce the moisture content. The polymer used is Polypropylene and

compactabilizer, MAPP were also predried at 70to 75<sup>0</sup>C to remove the adsorbed moisture. The compounding of the material were done by using a Twin Scew Extruder of Model –ZV 20.The zonal temperature and speed was in the range of 166-220<sup>0</sup>C and 40 RPM repectively. The process of extrusion was done by following formulation given in Table 3,to optimize the fibre weight with respect to the matrix. The extruded compounds are obtained as long strand and cut in to small granules of size 3-5mm length using pelletizer. The extruded composite samples were dried in a hot air oven at 80<sup>0</sup>C for 12 hours. The specimen samples were prepared by using the Injection moulding technique (Machine model-OMEGA 80 WIDE) .The moulding temperature at a range of 170 to 210<sup>0</sup>C. The prepared specimen samples were cooled anddried.

Table 3 Formulations for compounding

	Formulati on I	Formulation II	Formulation III	Formulation IV	Formulation v	Formulation VI (Untreated Coir Fibre)
PP %	100	87	77	67	57	67
Coir %	0	10	20	30	40	30
MAPP%	0	3	3	3	3	3



Figure 3.7 Specimen of testing Sample

### 3.2.3 Testing & Characterization

Determination of the mechanical thermal and surface Properties, after fabrication the test specimens were subjected to various tests as per standards.

#### 3.3.1 Density

Density of the coir fibre composite is determined according to ASTM C 693, Water Displacement Method. A clean specimen is weighed accurately in air using a laboratory balance. The same specimen is weighed while suspended in water or other liquid of such density that the specimen will sink. Deducting the mass of the suspension wire from the weight in liquid, the volume of the specimen is calculated from the effect of displacement by a liquid of known density (Archimedean principle). This allows the determination of density of specimens with irregular shapes, uneven surfaces, or porosity. Caution must be exercised to assure that no air is trapped within the specimen

#### 3.3.2 Water Absorption

Water absorption studies were performed according to ASTM D 570-98 standard. The impact test samples for each formulation were dried in an oven for 1hour at  $110 \pm 2$  °C. The dried samples were weighed to a precision of 0.001 g and then immersed in distilled water at room temperature for 24hr. After 24hr, the samples were taken out and weighed immediately after wiping out the surface water. The percentage of water absorbed at any time,  $M_t$  (%) was calculated by the following equation:

$$M_t (\%) = [(W_{(t)} - W_{(0)}) / (W_{(0)})] \times 100$$

Where  $W_{(t)}$  is the weight of the sample at time 't' and  $W_{(0)}$  is the initial weight of the sample.

### 3.3.3 Heat deflection temperature (HDT)

Heat deflection temperature (HDT) represents the upper limit of the dimensional stability of polymers in service without significant physical deformations under a normal load and thermal effect. HDT was evaluated in DMA Q800 with three point bending clamps operated in the DMA controlled force mode. The ramp rate 2 °C/min was used. All the samples were heated from room temperature to 130 °C and the HDT was recorded at a deflection of 0.25mm. The sample geometry was same as the one used for DMA analysis. Three samples of each formulation were tested to assure the repeatability of the results.

### 3.3.4 Hardness

Hardness is defined as the resistance of a material to deformation, particularly permanent deformation or scratching. Durometer hardness or shore hardness test used for measuring the relative hardness of soft materials. Shore hardness is a measure of the measure of the resistance of material to indentation by 3 spring loaded indenter. The higher number gives the greater resistance. Two types of durometer are most commonly used-Type A and Type D. Type A is used with relatively soft materials while Type D durometer is with slightly harder materials.

The test is carried out using ASTM D 2240 test method by first placing the specimen on a hard, flat surface. The pressure foot of the instrument is pressed on to the specimen, making sure that it is parallel to the surface of the specimen. The durometer hardness is read within one second after the pressure foot is in firm contact with the specimen.

### 3.3.5 Tensile Testing

Tensile test is a measurement of the ability of a material to withstand forces that tend to pull it apart and to determine what extent the material stretches before breaking. Tensile strength is defined as the maximum tensile stress sustained by test piece during

the tension test or ultimate strength of a material subjected to tensile loading. Tensile modulus is an indication of the relative stiffness of a material can be determined from stress – strain diagram.

Tensile properties of composite samples were measured using universal testing machine (-SHIMADZU, JAPAN) according to ASTM D 638-08. The load capacity was 50KN and cross-head speed was 100mm/min using gauge length of 115mm.

$$\text{Tensile strength} = \text{Force (load)} / \text{Cross section area}$$

$$\text{Tensile modulus} = \text{Difference in stress} / \text{Difference in corresponding strain}$$

### 3.3.6 Flexural Properties

Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. The stress induced due to flexural load is combination of compressive and tensile load. Flexural properties of composite samples were measured using universal testing machine (SHIMADZU, JAPAN). For bending tests, cross-head speed was 2.5mm/min and span distance was 96 mm. The test was carried out according to ASTM D790 standard method.

### 3.3.7 Impact Test

Impact test measures the resistance to failure of a material when subjected to a suddenly applied force such as collision, falling object or instantaneous blow. It measures the impact energy, or the energy absorbed prior to fracture. Methods like Izod, Charpy, Gardner, tensile impact, and others are used to measure the impact resistance of plastics. The notched Izod impact test is the most common test method. This test results helps designers to compare the relative impact resistance of a sample under controlled laboratory conditions. Therefore, it is often used for material selection or quality control. However, these tests are not considered as explicit design parameters.

In a notched Izod impact test, a pendulum swings on its track and strikes a notched test sample that is mounted in vertical position. The energy lost or in other words, the energy required to break the sample as the pendulum continues to trace its path is measured from the distance it follows through. Notched Izod impact strengths of the composites according to ASTM D 256-10 standard were measured using TMI 43-02 impact tester machine. The impact energy of the pendulum used is 5 ft-lb and notches of 4.0 mm depth are cut on the impact samples using a TMI notching cutter. According to the standard, sample thickness is usually 1/8 in. (3.2 mm) but may be up to 1/2 in. (12.3 mm). The samples tested for this project were having a thickness of 3.2 mm.

### 3.3.8 Scanning Electron Microscope

Surface morphology of the fractured impact sample was observed for Scanning electron microscopy(SEM).An accelerating voltage of 10 kV was used for imaging.

### 3.4 Result & Discussion

#### 3.4.1 Density

Density of the biocomposite increases by increasing the fibre weight percentage.

Table 4 Density of different PP-Coir Composite

	Density(g/cc)
PP	0.9056
PP+10% COIR	0.9316
PP+ 20% COIR	0.9629
PP+30%COIR	0.9878
PP+40% COIR	0.9913
PP+ 30%UNTREATED COIR	0.9899

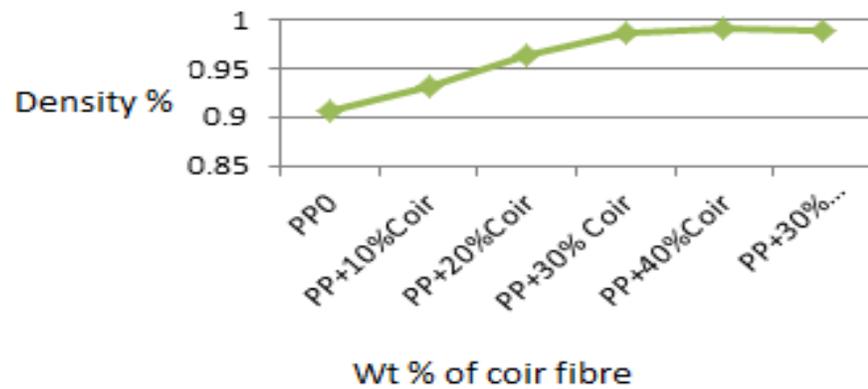


Figure 3.9 comparison of density

#### 3.4.2 Water Absorption

Water absorption of the composite sample increases with respect to the increase in fibre content. No dimensional change is noticed, but the weight change occurs with respect to the fibre weight percentage.

Table 5 Water absorption property of PP-Coir Composite

	Water Absorption (%)
PP	0.0630
PP+10% COIR	0.1595
PP+ 20% COIR	0.4605
PP+30%COIR	0.5853
PP+40%COIR	0.663
PP+30%UNTREATED COIR	0.591

In natural fibre polymeric composites, the hydroxyl groups increases with increase in fibre content. Consequently the water absorption also increases. Here untreated coir fibre reinforced composite is high as compared to the treated fibre. The alkali treated coir reinforced composite of 30% coir fibre having perfect match for making value added products like flower pots.

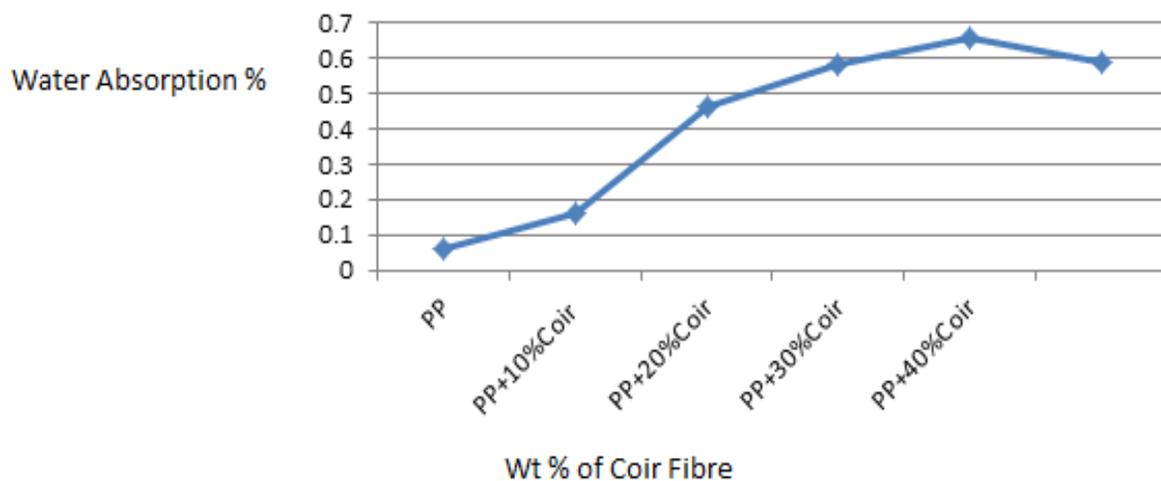


Figure 3.9 Water Absorption properties

### 3.4.3 Heat Deflection Temperature

The following results show that the HDT value of the composite increases with increase in coir fibre content. It indicates the better adhesion of polymer and matrix part due to high compactability and also coir having better heat resistant capacity due to high lignin content. Here untreated coir fibre treated biocomposite shows highest HDT value reveals that the lignin content in the fibre increases the thermal property of the composites.

Table 6 Heat Deflection Temperature of PP-Coir Composites

	HDT (264psi) ( <sup>o</sup> C)
PP	65
PP+10% COIR	94.2
PP+ 20% COIR	99.93
PP+30%COIR	105.2
PP+40%Coir	108.3
PP+30%Untreated Coir	109.9

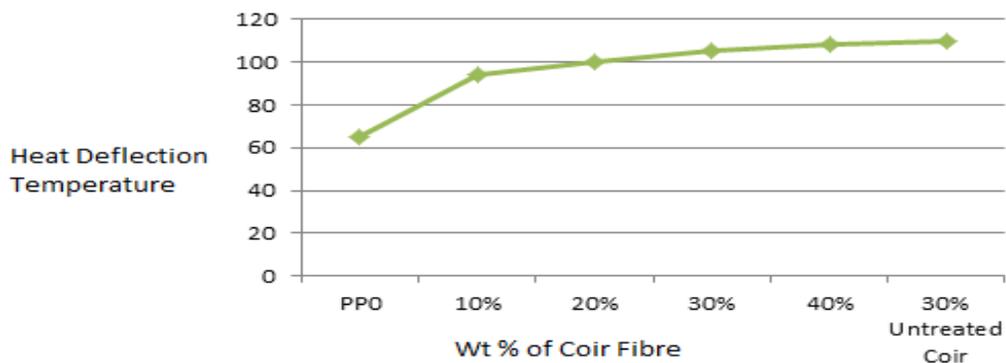


Figure 3.10 Heat Deflection Temperatures

### 3.4.4 Impact strength

The impact strength behavior of coir-PP composites increases as a function of coir content. It is evident that the impact strength increases with increase in the values coir content. The impact strength of composites is governed mainly by two factors: first, the capability of the coir to absorb energy that can stop crack propagation and second, poor interfacial bonding which induces micro-spaces between the coir and the matrix, resulting in easy crack propagation

Table 7 Impact Strength of PP-Coir Composite

Composites	Impact Strength (K J/m <sup>2</sup> )
PP	2.2313
PP+10% COIR	2.0119
PP+ 20% COIR	2.7236
PP+30%COIR	3.1515
PP+40%COIR	2.97923
PP+30%UNTREATED COIR	2.2759

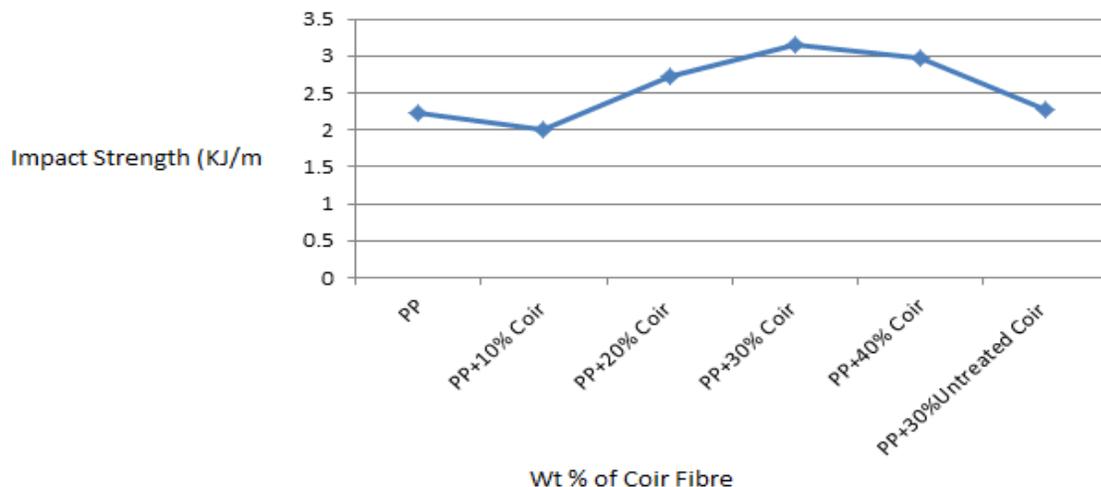


Figure 3.11 Impact Strength of PP-Coir Composites

### 3.4. Flexural Strength & Modulus

Table 8 shows the flexural strength and modulus of the biocomposite reinforced with coir. Both the properties are directly increased up to 30% coir content, then it decreases. In 40% PP-Coir Composites, the properties diminish due to poor mixing and having poor internal bond adhesion between matrix and fibre.

Table 8 Flexural Strength and Modulus of PP- Coir Composite

Composites	Flexural Strength (MPa)	Flexural Modulus (MPa)
PP	41.1250	1165.21
PP+10% COIR	52.0779	1675.3
PP+ 20%COIR	61.5041	2325.5
PP+30%COIR	63.2916	2767.89
PP+40%COIR	55.4444	1783.59
PP+30%UNTREATED COIR	46.6307	1826.34

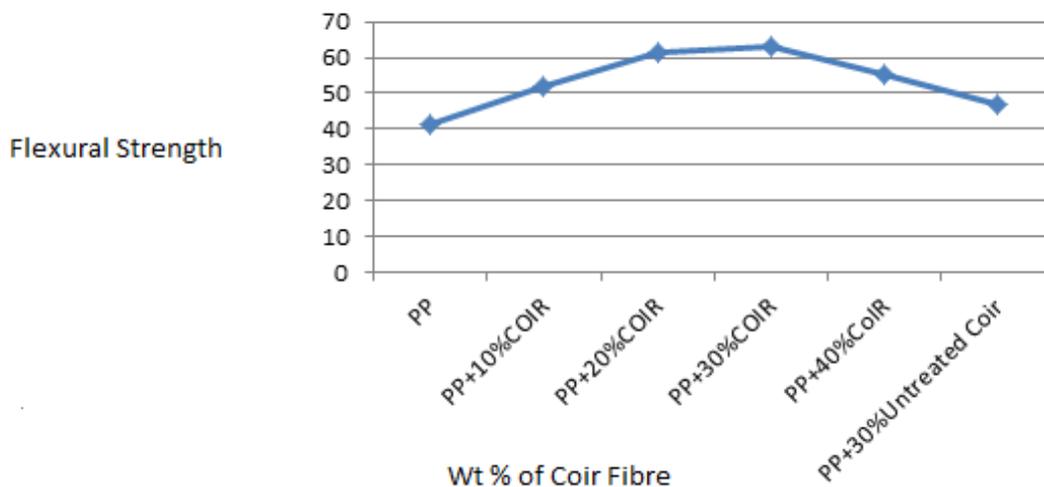


Figure 3.12 Flexural Strength of PP Coir Composites

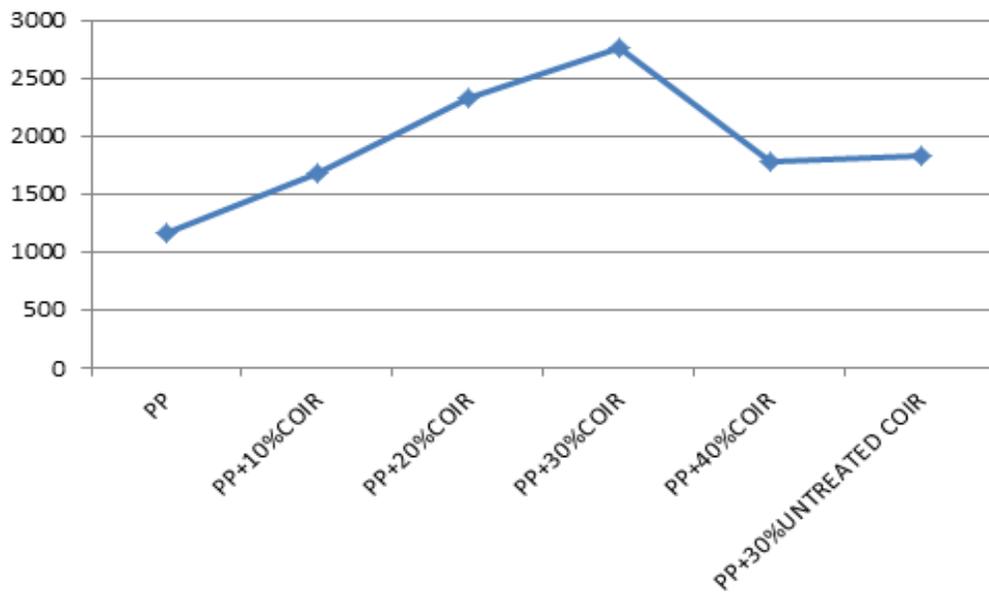


Figure 3.13 Flexural Modulus of PP Coir Composite

Addition of coir has resulted in an increase in the flexural modulus of the composites, which is found to be in graph. Since coir is high modulus material higher fiber concentration demands higher stress for the same deformation and higher degree of interfacial adhesion between the coir and the matrix provides better stress transfer from the matrix to the coir. Here, the formulation IV ie, 30% of coir fibre reinforced PP have high flexural modulus.

### 3.4.6 Tensile Properties

Natural fibers are able to improve strength but some of the fibers are not consistent, or irregular in shape influences the strength of the composite. In the study, coir fibre reinforced PP composites has retained the tensile strength even after addition of compatibiliser and coir fibre, though there was a steady decrease in elongation values.

Table 9 Tensile Property of PP-Coir Composite

	Tensile Strength (MPa)	Elongation at break (%)	Modulus (MPa)
PP	30.0324	55.3773	455.7334
PP+10% COIR	28.7425	11.24	664.2154
PP+ 20% COIR	30.8129	9.1334	740.2152
PP+30%COIR	31.11	7.5000	822.3808
PP+40%COIR	32.01	5.3	928.4542
PP+30%UNTREATEDCOIR	30.22	5.6	720.3453

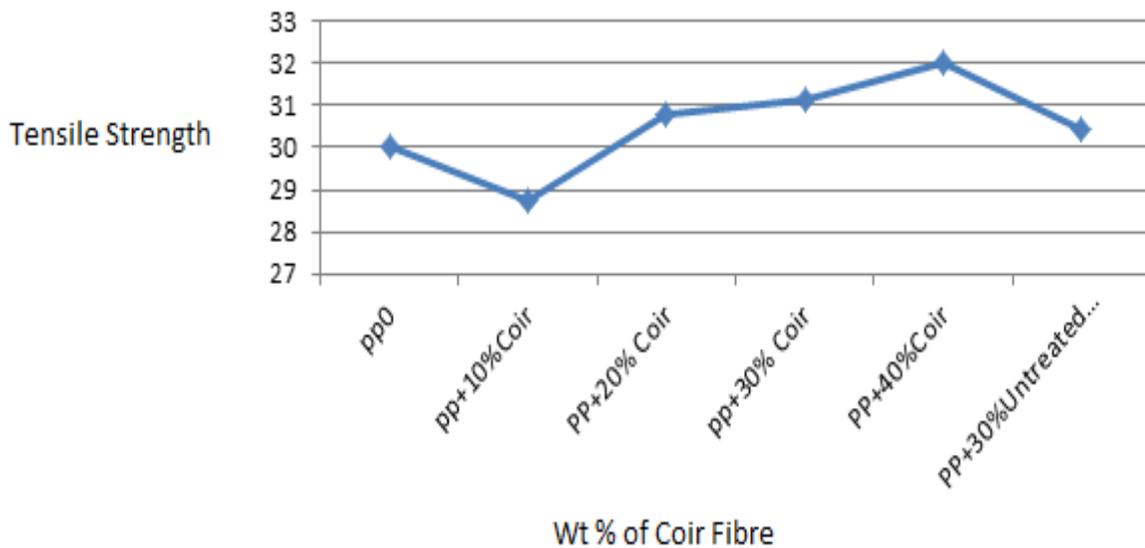


Figure 3.14 Tensile Strength of PP-Coir Composites

The result shows that the short fibers are finely distributed and the interfacial bonding between the fiber and matrix is good, that contributed to higher tensile strength and tensile modulus

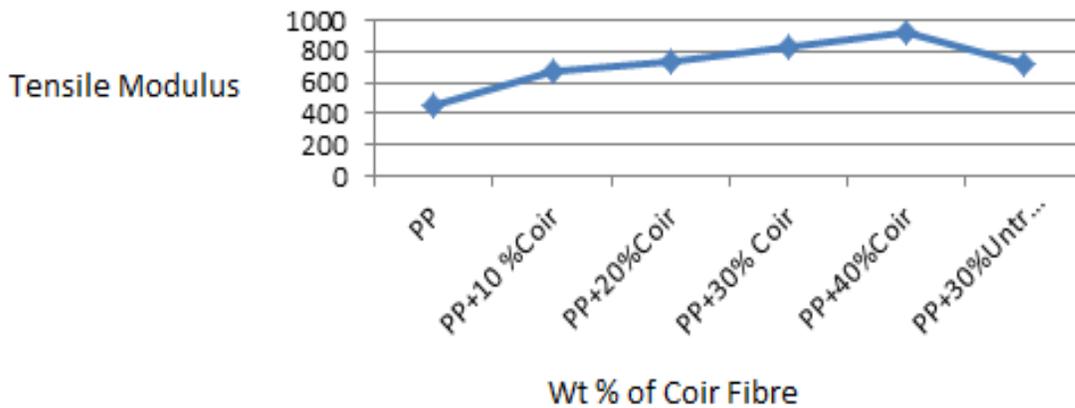


Figure 3.15 Tensile Modulus of Coir PP composites

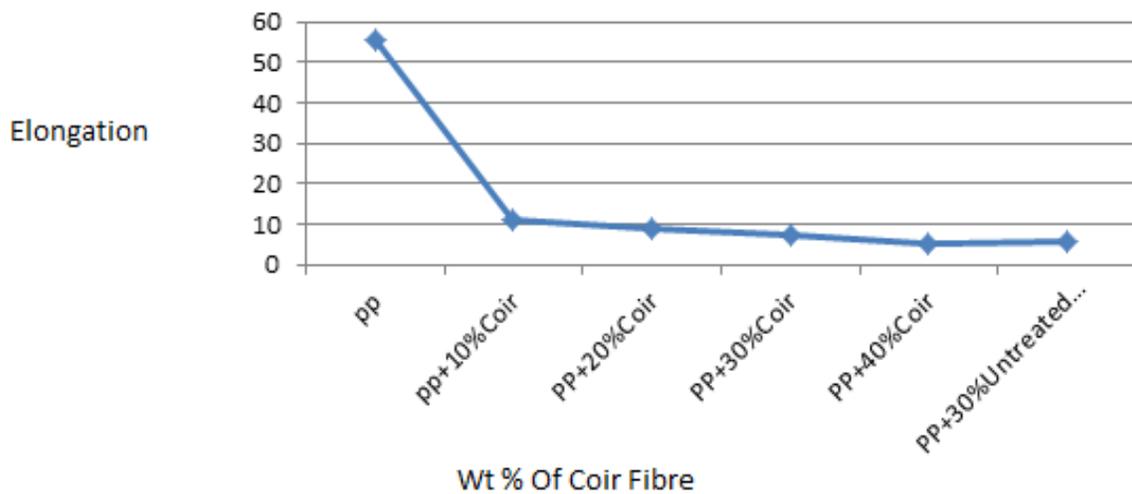


Figure 3.16 Elongation at break of PP-Coir composite

As the fibre content increases, stiffness of the composite increases leads to decrease in elongation.

### 3.4.7 Hardness

Hardness refers to the resistance and stiffness of the of the sample from permanent change in shape or dimension when load is applied. to indicate crack

resistance,whensudden application of force to the sample. The hardness test is so beneficial for end use application of product made by this biocomposite

Table 9 Hardness of PP-Coir Composites

	Hardness (Shore D)
PP	79
PP+10% COIR	82
PP+ 20% COIR	85
PP+30%COIR	87
PP+40% COIR	88
PP+30% UNTREATED COIR	83

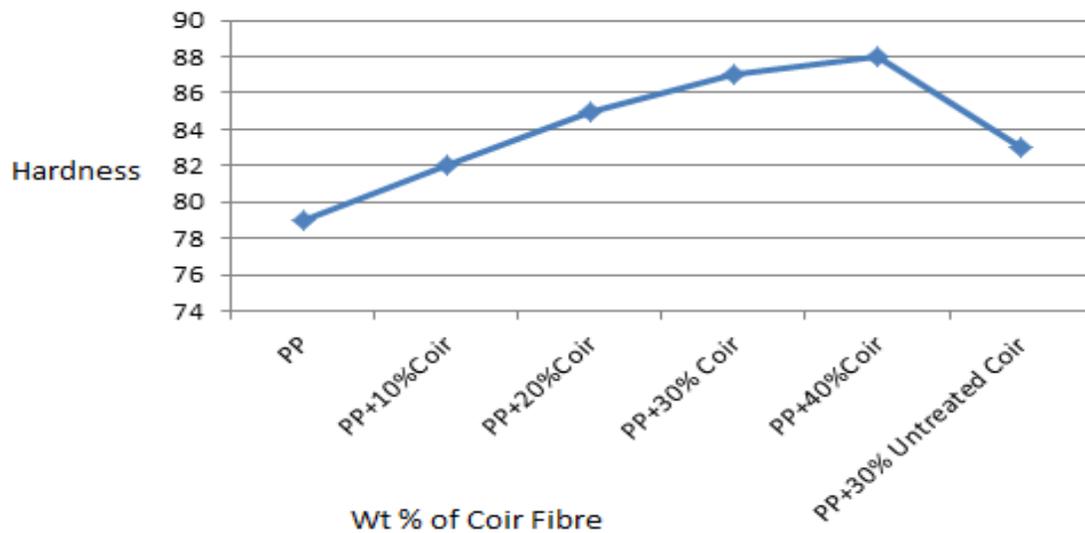


Figure 3.17 Hardness of PP-Coir Composites

### 3.4.8 Scanning Electron Microscopy

The surface morphology was investigated through Scanning Electron Microscope. The result shows that the Formulation IV ie the coir fibre content of 30% having high internal bond strength and adhesion between the matrix and reinforcing part .It indicate that above formulation can achieve maximum mechanical and thermal strength and should be beneficial for the product development

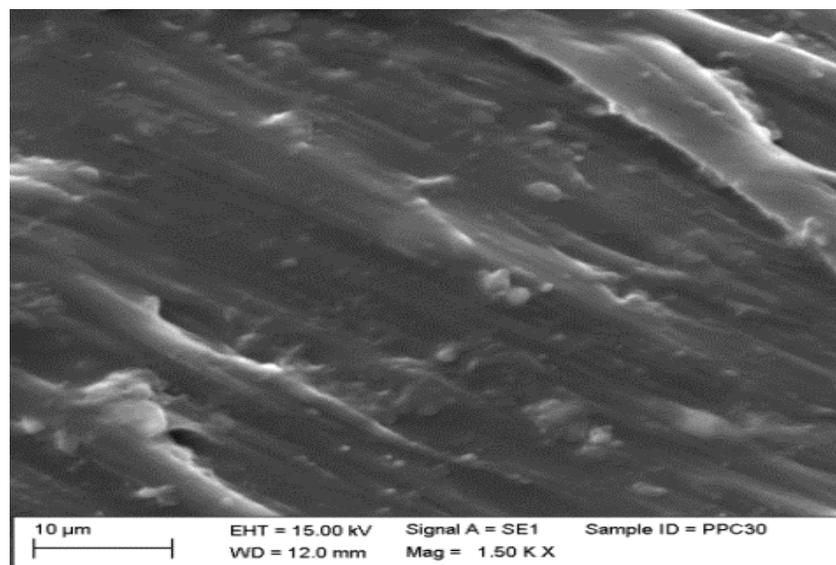


Figure 3.18 SEM Image of Formulation IV

### 3.2.5 Product Development

According to the result obtained from the testing and characterization, the prepared biocomposite of 30wt% of coir fibre reinforced PP is suitable for making value added products. The coir fibres could achieve better properties as a filler in biocomposites. The use of 5% NaOH treated coir fibre of 48 hours, having reduced hydrophilic character, achieve better internal bonding with the hydrophobic polypropylene matrix. By applying the above experimental methods and successful formulation, ecofriendly sustainable coir fibre reinforced green composite was prepared for commercial application.



Figure 3.19 PP-Coir Biocomposite Products

As per the project proposal two products were manufactured. The first product made by this biocomposite was a Funnel, which have good mechanical and dimensional strength and have high surface finish. The second one was the flower pot, which is more suitable for PP-Coir biocomposites. Water retention property is one of the highlight criteria for flower pot and can achieve through this biocomposites .

## Chapter 4

### CONCLUSION

Natural resources are the gift of the God to the human. It is essential to sustain and procure them for the future. The usage of such renewable resources should be economically and wisely to reduce or replace the petroleum based sources. We should aware more fruitful ways to explore the maximum potential and utilization of natural fiber for the development of science and technology. According to the experimental studies, the outcome of the project was as follows

- The green polymeric value added products of PP-Coir biocomposite such as flower pot and funnel were successfully developed.
- The developed product can reduce the carbon foot print as it could incorporate 30 weight percent of renewable, natural Coir fibre.
- The Comparative studies with Virgin PP and the biocomposites with coir fibre showed positive output in the case of material, mechanical and thermal strength and surface morphology.
- Coir Fibre reinforced Poly Propylene biocomposite, having 30 weight percentage of coir fibres which were treated with alkaline solution of 5% NaOH for 48 hours, shows better properties for further preparation of molded products.
- Density increases with increase in coir fibre content.
- Mechanical properties such as flexural Strength, flexural modulus, impact strength etc showed high in 30% fibre loading.
- Due to high weight percentage of Coir fibre(Formulation V) have low mechanical property, causing mixing difficulties;also occur air entrapment in testing samples.
- Thermal properties such as HDT were improved from 65<sup>0</sup>C to 105.2 <sup>0</sup>C.

- Water Absorption tests revealed that water absorption is higher with the increase of coir content as the coir is hygroscopic. Treated Coir fibre bio composites shows lower absorption than untreated.
- The developed PP-Coir bio composites having 30% fibre loading showed better dimensional stability.

The research based on coir fibre green composite was successfully completed and the prepared PP-Coir green composite can satisfy the laws and regulations of green technologies which will help the environment with low CO<sub>2</sub> emissions and reduction the dependency on the petroleum based polymers.

## Chapter 5

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