DEVELOPMENT OF VIRGIN POLYPROPYLENE COMPOSITE BY SUGARCANE BAGASSE REINFORCMENT

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ABSTRACT

This research is aimed to produce a high strength composite by reinforcement sugarcane bagasse as filler into virgin polypropylene. Bagasse fiber is a by-product of the sugar cane industry whose role is sugar or biofuel production. The bagasse filler is divided into two parent categories which are the pith and the rind. This study is focused on the determination of the optimum fibre content which gives maximum strength for each parent category and establishing which parent category gives optimum results with respect to strength. For each category extrusion was carried out at a temperature of 190^{o}C and screw speed of 50 to 70rpm, for fibre content of 10 wt% to 50 wt%. The compounded samples were then prepared into test specimens through injection molding and characterized by tensile testing, Fourier Transform Infrared Spectroscopy (FTIR) and Melt Flow Index (MFI). Based on the tests, the fibre content that gives the maximum strength is identified. Comparisons are made and it is established that the rind gives better strength as filler, compared to the pith and that a 30 wt% fibre composition gives maximum strength.

ABSTRAK

Objektif kajian ini adalah bertujuan untuk menghasilkan composite yang berkekuatan tinggi dengan menggunakan hampas tebu sebagai pengisi didalam polypropylene tulen. Serat tebu merupakan produk sampingan industri tebu yang berperanan untuk menghasilkan gula atau biofuel. Hampas atau serat tebu boleh dibahagikan kepada dua kategori induk iaitu serat buah dan serat kulit. Penyelidikan ini berfokuskan kepada pengenalpastian kandungan serat optimum yang memberikan kekuatan maximum bagi setiap kategori induk serta menentukan kategori induk yang memberikan hasil kajian yang optimum berdasrkan kepada kekuatan. Extrusion dijalankan bagi setiap kategori pada suhu 190^{o}C kelajuan skru dalam lingkungan 50 hingga 70rpm, bagi kandungan serat 10 wt% hingga 50 wt%. Sample yang telah dikmpoun kemudianya dijadikan sample ujian melalui "*injection molding*" dihantar untuk kajian "*tensile testing*", Fourier Transform Infrared Spectroscopy (FTIR) and Melt Flow Index (MFI). Berdasarkan ujian yang dilakukan, komposisi serat yang memberikan kekuatan yang maksimum ditentukan. Perbandingan dilakukan dan dikenalpasti bahawa serat kulit memberikan lebih kekuatan sebagai bahan pengisi berbandig dengan serat buah. Juga dikenalpasti bahawa komposisi serat 30 wt% memberikan kekuatan yang maksimum.

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Driven by increasing environmental awareness, automakers in the 1990s made significant advancements in the development of natural fiber composites, with end-use primarily in automotive interiors. A number of vehicle models, first in Europe and then in North America, featured natural fiber-reinforced thermosets and thermoplastics in door panels, package trays, seat backs and trunk liners. Promoted as low-cost and low-weight alternatives to fiberglass, these agricultural products, including flax, jute, hemp and kenaf, signaled the start of a "green" industry with enormous potential

The prominent advantages of natural fibers include acceptable specific strength properties, low cost, low density and high toughness (Biagiotti et al., 2004). The mechanical properties of some natural fibers such as jute, sisal, and flaw fibers were compared to glass fibers and it was observed that specific moduli of these fibers are comparable to or better than those of glass fibers (Nabi Saheb et al., 1999) . The physical and mechanical properties of wood, water hyacinth, Kenaf, banana and empty fruit bunch of oil palm fibers filled polypropylene composites has been reported (Myrtha Karina et al., 2007).

Different composites based on polypropylene and reinforced with flax and glass have been made and their mechanical properties are measured together with the distribution of the fiber size and the fiber diameter(Amirhossein Esfandiari, 2007). Composites of polypropylene and four different types of natural fibers including wood flour, rice hulls, kenaf fibers, and newsprint were prepared at 25 and 50% fiber contents and their dynamic mechanical properties were studied and compared with the pure plastic (Mehdi Tajvidi et al., 2006). The mechanical properties of bamboo fiber- reinforced polypropylene composites are compared with commercially available wood pulp board and it is reported that bamboo fiber composites are lighter, water-resistant, cheaper and has more tensile strength than wood pulp composites (Xiaoya Chen et al., 1998). A systematic study of the mechanical properties of the composites as a function of fiber loading, and fiber treatment time has been made for sisal polypropylene composites (Smita Mohanty et al., 2004, P.V.Joseph et al., 1999).

This study is focused on reinforcing polypropylene with sugarcane bagasse which is a waste from the sugar industry. For each 10 tonnes of sugarcane crushed, a sugar factory produces nearly 3 tonnes of wet bagasse. Since bagasse is a by-product of the cane sugar industry, the quantity of production in each country is in line with the quantity of sugarcane produced. Generally, bagasse is stored prior to further processing. For electricity production, it is stored under moist conditions and the mild exothermic reaction which results from the degradation of residual sugars dries the bagasse pile slightly. For paper and pulp production, it is normally stored wet in order to assist in removal of the short pith fibres which impede the papermaking process as well as to remove any remaining sugar.

Bagasse is an extremely inhomogeneous material comprising around 30-40% of "pith" fibre which is derived from the core of the plant and is mainly parenchyma material, and "bast", "rind" or "stem" fibre which comprises the balance and is largely derived from sclerenchyma material.

Below follows a list of abbreviations and concepts that needs to be defined and clarified. These concepts will be used throughout the paper and therefore it is important to explain how they will be used to prevent misinterpretations as well as increase the understanding of the paper.

a) **Matrix** phase of fibre-reinforced composites serves several functions. First, it binds the fibres together and acts as a medium by which an externally applied stress is transmitted and distributed to the fibres; only a very small proportion of an applied load is sustained by the matrix phase. Secondly, the matrix protects the individual fibres from surface damage as a result of mechanical abrasion or chemical reactions with the environment. Finally, the matrix separates the fibres and, by virtue of its relative softness and plasticity, prevents the propagation of brittle cracks from fibre to fibre.

b) **Filler** is an inert material added to a polymer to improve its properties and/or to reduce its cost. On being mixed with the polymer resin, it forms a heterogeneous mixture which can be molded under the influence of heat or pressure.

c) **Bagasse Pith** is derived from the core of the sugarcane stalk and consists mainly of parenchyma material.

d) **Bagasse Rind** surrounds the core of the sugarcane stalk and is largely derived from sclerenchyma material

e) **Extrusion** is the molding of a viscous thermoplastic under pressure through an open-ended die. In this research however the extrusion process also provides a means for the compounding of the natural fibre into the polymer matrix. A set of twin screws propels through a chamber into which the polymer pellets and fibre are fed. The polymer pellets are melted by a series of heaters, the propelling screws act as a blending medium for the compounding of the plastic and fiber. Extrusion takes place as this molten and blended mass is forced through a die orifice in a continuous charge.

f) **Injection Molding** is used to mold most thermoplastic and some thermosetting material. The technique of injection molding consists of heating a charge to a consistent state of fluidity and transferring it under pressure by enclosed channels into a closed mold cavity where it is cooled to produce a solid product with the greatest degree of homogeneity. The high pressure is applied hydraulically through a plunger. The cooled object is physically ejected from the machine. The entire cycle is carried out in the shortest time.

1.2 Problem Statement

The need for minimizing the usage of plastic for the benefit of the environment has led to study ways on filling the plastic with natural fibres which would produce composite materials comparable (or better) in strength when compared with the plastic or composites derived from inorganic fibres such as fibre-glass. Substituting a large fraction of the plastic for natural fibre filler and maintaining or subsequently improving the strength of the material would be significant in reducing the world plastic consumption. Replacing inorganic fillers like fibre-glass would significantly reduce the cost of the material and also do the environment a favour because the production of natural fiber suitable for composites is some 60 percent lower in energy consumption than the manufacture of glass fibers.

1.3 Objective

The objective of this research is focused on the identification of sugarcane bagasse pith or rind as potential filler in producing a composite from virgin polypropylene.

1.4 Scope of Research

To accomplish the objective of this study, the scope of this research is focuses on:

a) Blending of bagasse (pith & rind) and virgin polypropylene through extrusion

b) Preparation of test specimens by injection molding

c) Study of the parameters to be tested and improved :

i. **Tensile Strength (Bending)**
ii. **Elongation at Break**
iii. **Modulus Of Elasticity (Young's Modulus)**
iv. **Melt Flow Index (MFI)**

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The most important aspects to concentrate on in producing a natural fibre reinforced composite is in determining the suitability of the fibre as reinforcement material and to identify properties or parameters that can be manipulated to produce a better strength composite. This research is focused on determining the most suitable part of the sugarcane that can be used as filler in virgin polypropylene. The two parts in focus here are the pith and the rind of sugarcane bagasse. Also to be discovered is the suitability of the usage of polypropylene as a matrix in composites.

2.2 Polypropylene Composites

2.2.1 Properties of Kenaf/Polypropylene Composites

Combining kenaf fiber with other resources provides a strategy for producing advanced composite materials that take advantage of the properties of both types of resources. It allows the scientist to design materials based on end-use requirements within a framework of cost, availability, recyclability, energy use, and environmental considerations. Kenaf fiber is a potentially outstanding reinforcing filler in thermoplastic composites. The specific tensile and flexural moduli, for example, of a 50% by volume of kenaf-polypropylene (PP) composite compares favourably with a 40% by weight of glass fibre-PP injection molded composite. Results indicate that kenaf fibres are a viable alternative to inorganic/mineral-based reinforcing fibres as long as the right processing conditions and aids are used, and for applications where the higher water absorption of the lignocellulosic-based fibre composite is not critical.

From this study it is discovered that natural fibres are a potential replacement for inorganic fibres. (Roger M. Rowell et al., 2007)

2.2.2 Tensile strength of elephant grass fibre reinforced polypropylene composites

The main objective of this paper was an Elephant grass fibre(Scientific name: Pennisetum purpureum), is identified as potential reinforcement for making composites. Elephant grass fiber reinforced polypropylene matrix composites have been developed by injection molding technique with varying percentages of weight (0%, 10%, 15%, 20%, and 25%). The developed composites were then tested for their tensile Properties.

Vegetation associated with agriculture and forestry is a large source for extracting fibers, which has been largely under utilized. Fibers that can be extracted from the vegetation with water retting process are inexpensive.

The process of extraction of Elephant grass fiber is simple and results in an excellent quality of fiber. 10 percent fiber weight composites has better tensile strength compared 5, 15, 20&25 weight percent fiber composites. 25 percent fiber weight composites have better tensile modulus compared to other fiber weight percentage composites.

The density of the Elephant grass fiber is less than that of well established natural and synthetic fibers. So, elephant grass fiber can be used as natural reinforcement in the composites for the design of light weight materials. (N. Ravi Kumar et al., 2008)

This study explores the possibility of elephant grass as a substitute for inorganic fibres as filler for polypropylene composites. It informs the methods by which the fibre is prepared and compounded with the polypropylene matrix and how the resulting composite is tested for strength.

2.2.3 Mechanical and Morphological Properties of Sisal/Glass Fibre-Polypropylene Composites

Natural fiber reinforced polymer composites became more attractive due to their light weight, high specific strength, biodegradability. However, some limitations e.g. low modulus, poor moisture resistance were reported. The mechanical properties of natural fiber reinforced composites can be improved by hybridization with synthetic fibers such as glass fiber. In this research, mechanical properties of short sisal-PP composites and short sisal/glass fiber hybrid composites were studied. Polypropylene grafted with maleic anhydride (PP-g-MA) was used as a compatibilizer to enhance the compatibility between the fibers and polypropylene. Effect of weight ratio of sisal and glass fiber at 30 % by weight on the mechanical properties of the composites was investigated. Morphology of fracture surface of each composite was also observed. **(**Kasama Jarukumjorn et al., 2008)

2.2.4 Improvement of Physico-Mechanical Properties of Jute Fibre Reinforced Polypropylene Composites by Post-treatment

Jute fiber reinforced polypropylene composites were manufactured using injection molding method. Raw jute fiber was oxidized and manufactured composites were post-treated with urotropine. Both raw and oxidized jute fiber at four level of loading (20, 25, 30 and 35 wt%) was utilized during manufacturing. Microstructural analysis and mechanical tests were conducted. Post-treated specimens yielded better mechanical properties compared to the oxidized and raw ones. Based on fiber loading, 30% fiber reinforced composites had the optimum set of mechanical properties. Authors propose that the bonding between the polypropylene matrix and urotropine treated jute fiber must be improved in order to have better mechanical properties at higher fiber content. (Md. Rezaur Rahman et al., 2008)

2.2.4 Mechanical Properties of Flax Fibres and Their Composites

Generally, plant or vegetable fibers are used to reinforce plastics. The main polymers involved in the composition of plant fibers are cellulose, hemicelluloses, lignin and pectin. Let us consider very popular flax fibers to understand the intricate structure of plant fibers. The ~1 meter long so-called technical fibers are isolated from the flax plant for the use in textile industry. These technical fibers consist of elementary fibers with lengths generally between 2 and 5 cm, and diameters between 10 and 25 m. The elementary fibers are glued together by a pectin interface. They are not circular but a polyhedron with 5 to 7 sides to improve the packing in the technical fiber. What are elementary fibers? They are single plant cells. And cellulose (C6H10O5)n is a common material in plant cell walls. It occurs naturally in almost pure form in cotton fiber. Chemical structure of cellulose monomer is represented in Figure 3. Most of the elementary fiber consists of oriented, highly crystalline cellulose fibrils and amorphous hemicelluloses. The crystalline cellulose fibrils in the cell wall are oriented at an angle of about ±10 degrees with the fiber axis and give the fiber its high tensile strength.

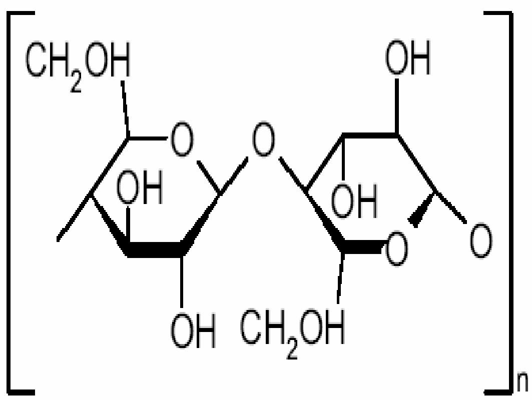


Figure 2.1: Chemical structure of cellulose monomer

Thermoplastic natural fibre reinforced (NFC) is manufactured mainly by different extrusion methods followed by injection or compression molding. Fibres are chopped during process therefore composites have short fibers (few millimeters at most). Orientation is three-dimensional, but not necessarily isotropic (depends on method: injection process, shape of mould etc.). Besides, natural fiber mat thermoplastic composite plates with different fiber contents can be manufactured using the film-stacking method. Thermoplastic pultrusion can also be applied for continuous process. Compression molding processes is very typical for thermosets. Resin transfer molding and resin infusion are used as well. These methods ensure relatively longer fibers and more or less inplane orientation in resulting composite. Since the thermal stabilityof the flax fibers may be increased by chemical treatment, then even autoclave molding technique can be applied.A very important task of NFC manufacturing is to have elementary fibre, not technical fibre, as the reinforcement in the composite. On the other hand, using technical fibres or textile yarns, it is possible make long fibre composites with predefined fibres orientation. However in both cases the basic problem is fibre/matrix adhesion.

All the plant fibres are hydrophilic in nature. That is because of their chemical structure the hemicelluloses and the pectin are very hydrophilic. In contrary, many of the common matrix polymers in composites are largely hydrophobic in nature. Only thermosets such as phenol formaldehyde and related polymers are less hydrophobic and are therefore less problematic. This discrepancy can lead to the formation of ineffective interfaces between the fiber and matrix. Problem can be solved applying different fiber treatments (both chemical and mechanical) or modifying chemical composition of the matrix. Unfortunately, surface treatments have a negative impact on economical aspect of NFC manufacturing. There are many publications reporting that properties of PP based composites are improved using maleic anhydride grafted PP (MAPP) as matrix additive. The same MAPP, acetilation and stearic acid treatment are used for fiber processing. Adhesion increases also after boiling of the flax fibres. For epoxy resin, alkali (NaOH), silane (3-aminopropyltriethoxysilane), isocyanate (phenyl isocyanate), urea and other treatments can be employed. Acrylic acid and vinyl trimethoxy silane of different concentrations are considered for several other thermosets. (M. Janarthanan et al., 2007)

This paper gives an over view of natural fiber reinforced composites, the advantages of using natural fibres, the problems faced with natural fibres and ways to improve adhesion.

2.3 Bagasse Composites

2.3.1 Silane Treatment of Bagasse Fiber for Reinforcement of Cementitious Composites

Silane coating of fibers is a promising process for improving durability and adhesion of vegetable fibers used as reinforcement material in a cementitious matrix. The work presented in this paper gives an insight into the effect of combining pyrolysis treatment with silane treatment. Indeed, this study focuses on silane treatment of unpyrolyzed and pyrolyzed sugar cane bagasse fibers with an alkyltrialkoxysilane (RSi(OR0)3), S1 or a dialkyldialkoxysilane (R2Si(OR00)2), S2. The silane solutions used vary from 0.5% to 8% by volume. This paper describes the effect of two silane compounds on parameters such as the porosity, dimension, morphology and hygroscopic character of silane-coated sugar cane bagasse fibers.
Preliminary studies on natural fiber reinforced composite setting time show the importance of the silane chemistry/structure, for fiber treatments with silane solution containing up to 6% (volume percent) silane. In the case of composites reinforced with unpyrolyzed bagasse fibers, setting time increases with silane coating. Combining pyrolysis and silane treatment improve the water resistance of the fibers, which become more hydrophobic.

The advantage of vegetable fibre reinforced cement composites (VFRC) lies in the improvement of mechanical and thermal properties, and in the reasonable cost. However, the wide use of these materials is hampered by their low stability. The vegetable fibre in the porous alkaline matrix is slowly damaged and the reinforcing effect of the fibre decreases. To improve aging of the VFRC, two techniques were tested: (1) modification of the matrix and (2) fibre treatment. This second approach can have the advantage of improving the fibre–matrix interface. In the case of VFRC with kraft or hardwood, silane treatment has been found to increase moisture-cycling resistance. The effects of silane treatment on mechanical properties vary with the nature of the vegetable fibre: silane treatment increases toughness of newspaper and kraft fibre-cement while the modulus of rupture (MOR) and the modulus of elasticity (MOE) decrease for newspaper fibre-cement and increase for kraft fibre-cement. (K.Bilba et al., 2008)

This study provided a means of identifying the weaknesses of sugarcane bagasse fibre and ways to handle them. This would be of help to enhance the strength of the resulting composite.

2.3.2 Utilization of Bagasse in New Composite Building Materials

This paper describes two composite building material systems and processes that utilize major percentages of bagasse filler and minor amounts of phenolic binder. Their composite concept, the choice of bagasse filler and the selection of the binder resin, is sound based *on* a thorough Rve-year research investigation. The phenolic bonded composite building materials developed are identified as bagasse-phenolic and oriented bagasse-phenolic. Potential applicatlons of these composites in home and commercial building are wall panels, ceiling, roofing, flooring, counter tops, fences, siding, acoustical panels, sinks, furniture, doors, and shutters. The product can be economically manufactured in any geographic location that produces signlficant quantities of sugar cane. This work represents a substantial technological breakthrough in value upgrading and utilization of the plentiful agricultural residue bagasse and merits further development leading to commercialization. (Ival 0. Salyer et al., 1982)

In this study the possibility of using bagasse as filler in composite materials is explored. It helped in the identification of the components of bagasse and the ways to handle the fibre to optimize its strength.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This research was divided into two categories, whereby the experiment was conducted using the pith and the rind bagasse fibres exclusively.

In this study extrusion process is used to compound the bagasse fibre and polypropylene followed by an injection molding process to form test specimens. This process route is chosen as it provides a homogenous blend of fibre and matrix. The composites were developed with 0, 10, 20, 30, 40 and 50% (by weight) of pith and rind fibre.

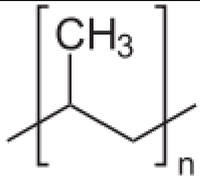
3.2 Materials

3.2.1 Polypropylene

Polypropylene (**PP**), also known as **polypropene**, is a thermoplastic polymer, made by the chemical industry and used in a wide variety of applications, including packaging, textiles (e.g. ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids. Most commercial polypropylene is isotactic and has an intermediate level of crystallinity between that of low-density polyethylene (LDPE) and high-density polyethylene (HDPE). Polypropylene is normally tough and flexible, especially when copolymerized with ethylene. This allows polypropylene to be used as an engineering plastic, competing with materials such as ABS. Polypropylene is reasonably economical, and can be made translucent when uncolored but is not as readily made transparent as polystyrene, acrylic, or certain other plastics. It is often opaque or colored using pigments. Polypropylene has good resistance to fatigue.

Table 3.1: Properties of Polypropylene

IUPAC Name	poly(propene)

Other Names	Polypropylene; Polypropene; Polipropene 25 [USAN];Propene polymers; Propylene polymers; 1-Propene
Molecular Formula	$(C_3H_6)_n$
Molecular Structure	
Density	0.946 g/cm^3, crystalline
Melting Point	130–171 °C
CAS number	9003-07-0

3.2.2 Sugarcane Bagasse

Sugarcane (Saccarhum officinarum) bagasse is a residue produced in large quantities by sugar industries. In general, 1 ton of sugarcane bagasse generates 280 kg of bagasse, the fibrous by-product remaining after sugar extraction from sugarcane. However, the utilization of sugarcane bagasse is still limited and is mainly used as a fuel to power the sugar mill. A typical chemical analysis of bagasse might be (on a washed and dried basis):

- Cellulose 45–55%
- Hemicellulose 20–25%
- Lignin 18–24%
- Ash 1–4%
- Waxes <1%

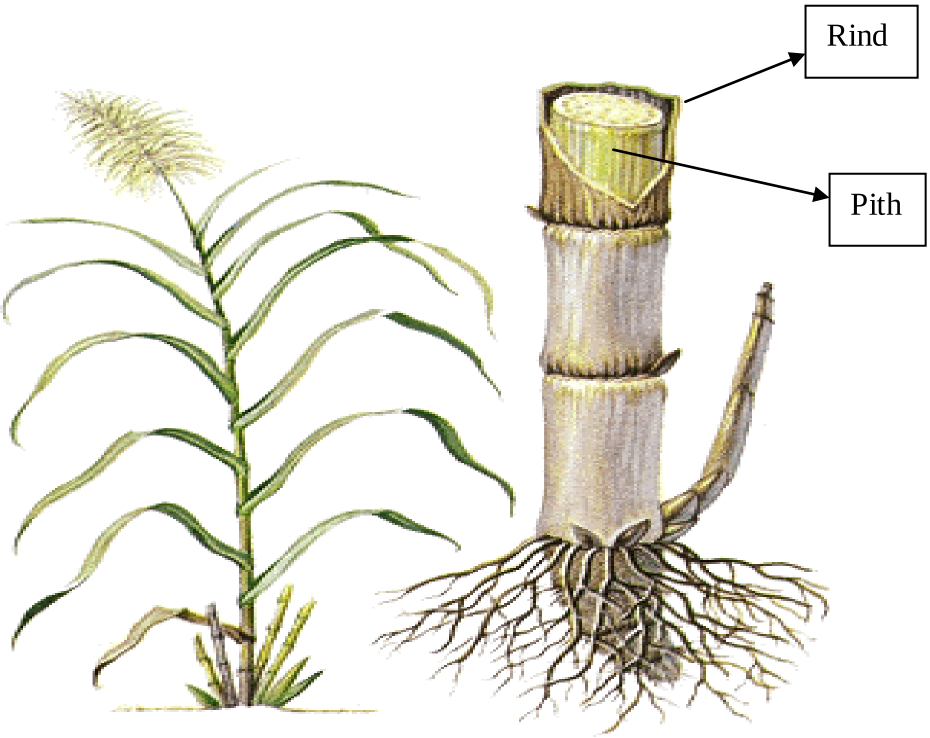


Figure 3.1: Sugarcane Stalk

3.3 Method of Research

3.3.1 Extraction of Fibre

In this method, the before crushing the sugarcane stalks are skinned first to obtain the rind. After that, the sugarcane stalks are crushed (this remove the sweet juice within) to obtain the pith. Both the pith and rind are washed to remove any excess sugar contained within and then dried under sunlight or in an oven at 60-75°C to remove moisture content. This is done in order to prevent fungal growth. Once dry, the pith and the rind are ground separately.

3.3.2Composite Fabrication

An oven of size 450 X 450 X 450 mm (model CIC-12) is used to dry the extracted fibres and the polypropylene pellets at 80^{o}C to remove any moisture on remaining. For each category (i.e. the rind and the pith) proper portions of fibres (0, 10, 20, 30, 40 and 50% by weight) and polypropylene pellets were thoroughly mixed to obtain a mixture of 250g total raw material per composition. Each composition was then extruded using a twin screw extruder. The temperature was set at of 190^{o}C and the screw speed at 70 -170rpm. Through this composites of different weight fractions were developed for each category.

The extruded material is then pelletized to form pellets. The pellets are then injection molded using Nissei Injection Molding Machine to form dumbbell shaped test specimens. The injection molding is carried out at 190 ^{o}C and a pressure of 28%.

3.3.3Testing

A 5kN loaded universal tensile testing machine was used to measure the tensile properties. The samples were tested at a crosshead speed of 3mm/min. Five samples were tested for each composition from each category. The density of the composite was measured using gas pycnometric procedure. The flow properties of the composites were also measured using a Melt Flow Index machine.

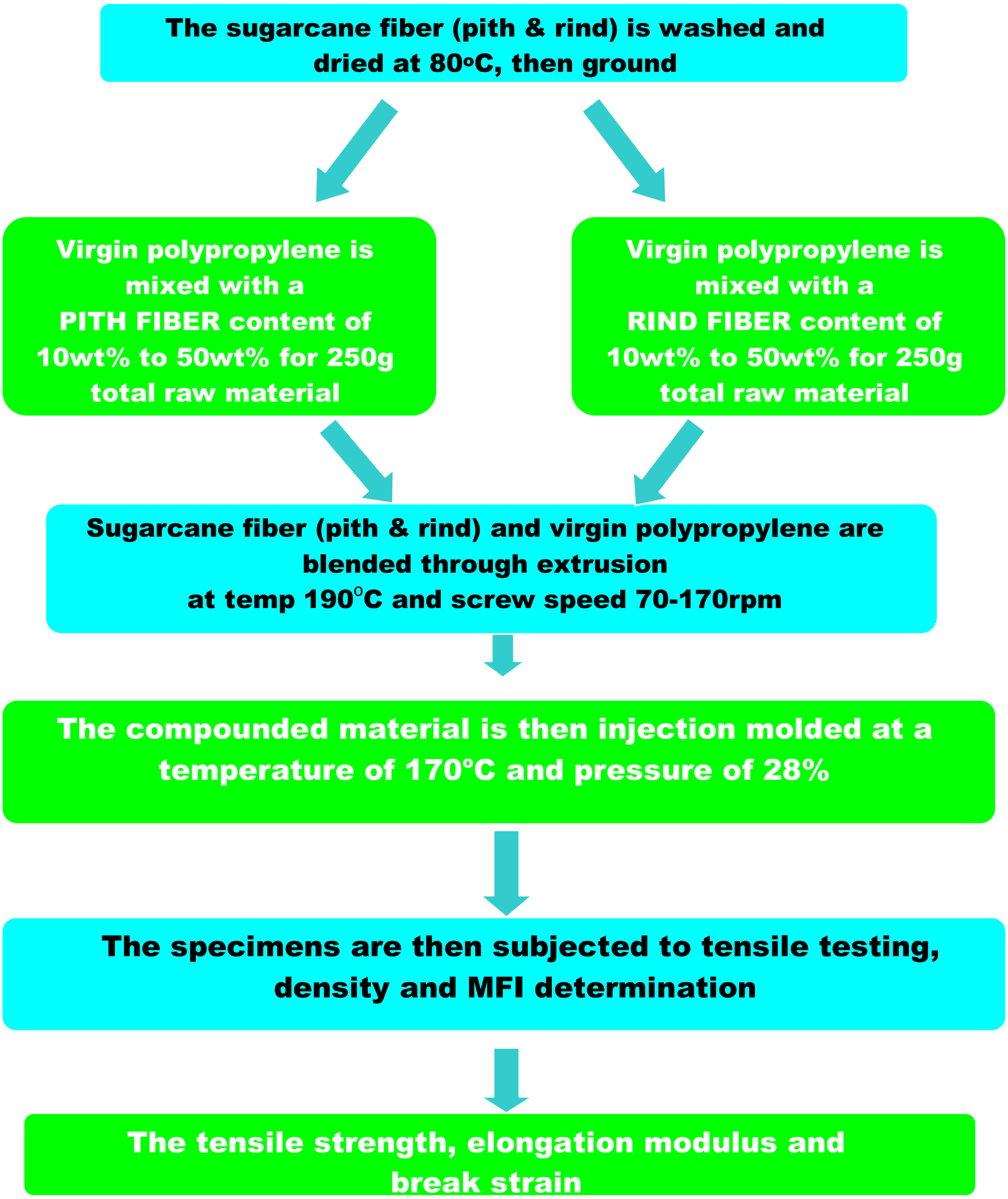


Figure 3.2: Flowchart of Research Methodology