F.A YASAR IZMIR KATIP CELEBI UNIVERSITY 2019

IZMIR KATIP CELEBI UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

EFFECTS OF NATURAL FIBER WASTES ON POLYOLEFIN AND THERMOPLASTIC BASED MATERIALS

M.Sc. THESIS

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İZMİR KÂTİP ÇELEBİ ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

DOĞAL ELYAF ATIKLARIN POLİOLEFİN VE TERMOPLASTİK ESASLI MALZEMELER ÜZERİNDEKİ ETKİSİ

YÜKSEK LİSANS TEZİ

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Fadıl Anzer YAŞAR, an **M.Sc** student of **IKCU Institute of Sciences**, successfully defended the thesis entitled " **EFFECTS OF NATURAL FIBER WASTES ON POLYOLEFIN AND THERMOPLASTIC BASED MATERIALS**'' which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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FOREWORD

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TABLE OF CONTENTS

ABBREVIATIONS

PP	: Polypropylene
NaOH	: Sodium Hydroxide
MA-g-PP	: Maleic Anhydride Grafted Polypropylene
GFRP	: Glass Fiber Reinforced Polypropylene
UP	: Unsaturated Polyester
PET	: Polyethylene Terephthalate
SEM	: Scanning Electron Microscope
MFI	: Melt Flow İndex
GMT	: Glass Mat Reinforced Thermoplastics
Al	: Aluminium
Cu	: Copper
CFRC	: Continuous Fiber Reinforced Composites

LIST OF TABLES

Page

LIST OF FIGURES

Page

EFFECTS OF NATURAL FIBER WASTES ON POLYOLEFIN AND THERMOPLASTIC BASED MATERIALS

ABSTRACT

Global environmental issues have led to a renewed interest in bio-based materials, with the focus on renewable raw materials which can be biodegradable or recyclable at reasonable costs. As a result of the increasing demand for environmentally friendly materials and the desire to reduce the cost of traditional fibers, many natural fiber composites have been developed. Natural fibers like flax, hemp, banana, cotton, coir, sisal, and jute have attracted the attention of scientists and technologists for applications in consumer goods, low-cost housing, and other civil structures. The objective of this study is to evaluate natural fiber waste and thermoplastic process waste. This master thesis evaluates the potential of adding “jute” as a natural consolidation agent in order to enhance the strength of PP raw material gained from the production of Polypropylene (PP). The characteristics of PP/Jute composite material was also examined. It has been seen that the addition of jute is effective in increasing the tensile strength of PP material, but decreases its ductility. Also it has been determined that jute has a great potential in composite production as a natural consolidation agent.

DOĞAL ELYAF ATIKLARIN POLİOLEFİN VE TERMOPLASTİK ESASLI MALZEMELER ÜZERİNDE ETKİSİ

ÖZET

Küresel çevre sorunları, biyo-temelli malzemelere olan ilginin artmasına neden olmuştur. Yenilenebilir hammaddelere odaklanmak, biyolojik olarak parçalanabilir veya makul bir maliyette geri dönüştürülebilir malzemelerle uğraşmayı sağlayabilir. Çevre dostu malzemelere olan talebin artması ve geleneksel liflerin maliyetini azaltma isteği sonucunda, birçok doğal lif kompoziti geliştirilmiştir. Keten, kenevir, muz, pamuk, hindistan cevizi, sisal ve jüt gibi doğal lifler bilim ve teknoloji ile uğraşan kişilerin tüketim malları, düşük maliyetli konutlar ve diğer sivil yapılardaki uygulamalar için ilgi odağı olmaktadır. Bu çalışmanın amacı, doğal elyaf atıklarını ve termoplastik proses atıklarını değerlendirmektir. Yürütülen bu yüksek lisans tezinde Polipropilen (PP) üretiminden elde edilen PP hammaddelerinin dayanımını arttırmak amacıyla doğal bir takviye ajanı olarak "jüt" ekleme potansiyeli ve PP / Jüt kompozit malzemenin özellikleri incelenmiştir. Gerçekleştirilen çalışmada, PP malzemenin çekme mukavemetinin geliştirilmesinde jütün etkili olduğu ancak elastikiyetini azalttığı, jütün doğal takviye ajanı olarak kompozit üretiminde kullanım potansiyelinin bulunduğu belirlenmiştir.

1. INTRODUCTION

The difficulties encountered in the recycling of composite materials are supported by natural fibers of polymeric materials. As well as increased health and safety concerns synthetic fibers, *"natural fiber reinforced composites"* production and uses of have reached a remarkable point nowadays. In particular, subjects such as the production of fiber reinforced composite materials, process availability, concentration of reinforcement agents, their behaviour in composite materials and influence on material have been the focus of researchers.

In this study, it is aimed to evaluate the thermoplastic process wastes with natural fiber waste. For this purpose, the use potential of "jute" as a natural consolidation agent and the properties of polypropylene (PP) / jute composite material have been examined in order to provide high strength and modulus of PP raw material, which is produced as a powdered waste in the production of polypropylene (PP) granules.

Jute, native to India, is an herbal fiber containing amorphous microfibrils, which spontaneously decomposes in soil, is a cellulose based (70%), hemicellulose (20%) and lignin (13%) material. Jute fabrics used in the production of sacks are not utilized in any way because following manufacture and cutting, they are burned, providing an energy gain. However, these wastes have the potential to be inexpensive, easy to handle and as an alternative natural reinforcement agent to synthetic fibers, such as glass fibers and kevlar, due to their mechanical properties. In the study, jute sack edge wastes (10-cross-stitch: 311 grams/yard^2) obtained from the Ege Çuval (Sack) company were evaluated. After manufacturing, the jute sack edges that emerged as waste were separated into 15-18 mm long yarns and the formation of jute fibers were provided by blowing compressed air. For cleaning the oil on the surface of the jute fibers, the oily layers of the wax, the materials were held in the laboratory environment (23 °C, 50% RH) for 2h in a solution of 2% NaOH, then dried in an incubator at a temperature of 50 °C for 24 h. In order to achieve maximum adhesion on the PP and jute interface, jute fibers which were dried in the previous stage were kept 2h in 0.3% silane (Dow Corning, Product code Z-6030) solution. The PP/jute mixture materials were compounded in a double screw extruder at a temperature of 190 ºC. Obtained from PP/jute mixture granules, standard tensile specimens are produced at 180 ºC temperature in the injection molding machine and physical and mechanical properties of the composite material are examined. The tensile strength of the control specimen without a natural consolidation agent (jute) is 28.3 MPa, while the tensile strength of the PP/jute composite material with 5% jute increased to 29.6 MPa, the elongation value before breaking decreased from 13.55 mm (control) to 9.34 mm. In the study carried out, 5% of maleic anhydride polypropylene (MA-G-PP) in each mixture with the inclusion of non-consolidation agent pp, 2.5%, 5%, 10%, 15% and 20% jute additive pp and 20% glass fiber additive PP materials samples were obtained for tensile testing and the strength values were compared according to the test results. The PP/jute composite material with 2.5% and 5% jute had increased tensile strength. the PP/jute composite material containing 10% and 15% jute decreased in tensile strength by 10.5% and 13.1%, respectively compared with the one containing 5% jute, according to the strength values. The tensile strength value of the PP/jute composite material containing 20% jute decreased by 3% compared to the PP/jute material containing 5% jute, falling to 28.4 MPa. In accordance with the results, jute was determined to be effective in the development of tensile strength of the material, but reduced the elasticity of the material. Thus, the use of jute as a natural reinforcement agent in the production of composites was confirmed. It is thought that the widespread use of jute, especially due to it being a plant based fiber, contributes to cost advantage and decrease environmental problems in the production of composite materials.

1.1 Literature Summary

Nowadays, the use of natural fibers instead of synthetic fibers such as carbon, glass and aramid in the production of composite materials has become an interesting area for researchers. Studies have shown that natural fibers such as flax, hemp, jute, sisal, kenaf and similar can be an effective consolidation agent for the production of composite materials. The reasons for increasing interest in natural fibers are that they are abundant in nature, do not harm the environment and become renewable raw materials. Natural fibers have very good thermal properties and very good acoustic performance. However, the products made from natural fibers have low mechanical properties compared to synthetic fibers, limiting their use in applications.

In the literature, studies have been conducted to increase the mechanical properties of natural fiber reinforced composites with different processes, such as chemical or physical modification of the matrix, fiber or both components [1].

Recycling of composite materials that completed its lifespan is difficult and expensive. They are therefore sometimes buried and sometimes destroyed by burning. The pollution and the rapidly decreasing natural resources created by the destroyed materials constitute a major challenge for the future. In recent years, the high cost of composite materials, reinforced with high-performance fibers such as glass, carbon and aramid, and increasing concerns about environmental hazards. Therefore, they have been replaced by composites with hard natural fibers such as jute, flax, hemp and low cost-effective, biodegradable, renewable, sustainable and light-weight compounds. In this context, the utilization rate of natural fiber reinforced composites in sectors such as automotive, construction, furniture and packaging is increasing [2].

However, in natural fiber reinforced thermoplastic polymeric materials, the compatibility between hydrophilic natural fiber surfaces and hydrophobic thermoplastic polymer is very weak. This incompatibility will cause the intermediate superficial adhesion between the natural fiber and thermoplastic polymer to be inadequate and will also weaken mechanical properties [3].

The mechanical performance of composites depends on not only the matrix type, fiber type, fiber volumetric ratio and fiber orientation, but also the fiber-matrix intermediate surface adhesion. Various surface modification processes are applied to the fiber surface to improve the compatibility between natural fiber surfaces and the matrix. The modification processes used are generally alkaline processes, chemical processes with a silane harmonizer agent, chemical processes with an acetic anhydrate, polymethylene, polyphenyl, isocyanate and chemical processes, and plasma modification processes. With this surface modification process, fiber and chemical substances are able to interact and the fiber surface is improved within the matrix.

1.1.1 Literature review on natural fibre reinforced composite materials

Examined the mechanical and physical properties of cellulose-based fibers used as reinforcement elements in natural fiber-reinforced composite materials. In the production of fiber reinforced composite materials, the most applied intermediate surface modification techniques have been explained in detail. Table 1.1 gives the mechanical properties of cellulose based fibers according to this study[2].

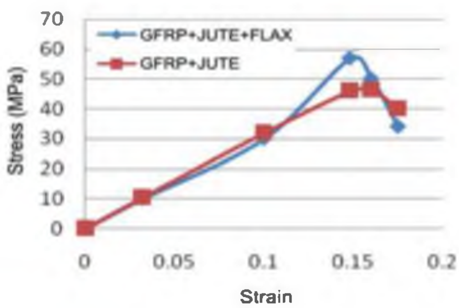
Table 1.1: Mechanical properties of cellulose based fibers [4].

Material	Density (g/cc)	Tensile strength (MPa)	Elastic modulus (GPa)	Specific strength (σ/γ)	Specific modulus (ε/γ)	Elongation at failure (%)	Moisture absorption (%)	Cost ($/lb)
E-glass[11]	2.62	3400	73	*1297*	*28*	4.8	N/A	*1.10*
Hemp[12]	1.4	550–900	70	*393–643*	*50*	1.6	6–12	*0.30*
Flax[13]	1.4	800–1500	60–80	*571–1071*	*43–57*	2.7–3.2	8–12	*0.33*
Ramie[14]	1.5	500	44	333	29	3.6–3.8	8–17	0.34
Kenaf[14]	1.45	930	53	*641*	36	1.6	10–12	*0.24*
Coir[13]	1.25	220	6	176	5	1.5–4	8	0.20
Sisal[13]	1.33	600–700	38	451–526	29	3–7	10–22	0.36
Jute[13]	1.46	400–800	10–30	*281–548*	*7–21*	1.5	12–14	0.20

Conducted a study on the improvement of mechanical properties with the alkaline process of natural fiber reinforced epoxy composites. Following the alkaline process, they observed that the tensile and bending properties were increased. As a result of their work, the tensile and bending strengths of the alkali-made linen-epoxy composite materials were determined to increase by 21.9% and 16.1%, respectively, compared to the non-alkaline materials [5].

Examined the mechanical behaviour of single direction linen and glass fiber reinforced composites. It has been seen that the stacking order of linen and fiberglass affects the strength and deformation of the material [6].

Examined the mechanical properties of jute, flax and glass fiber reinforced composites and compared them with a jute and glass fiber reinforced composite. According to the results of the experiment, it has been reported that jute, flax and glass fiber reinforced mixed natural composites have better tensile and bending properties, as seen in Figure 1.1. Table 1.2 summarizes the obtained test results [7].



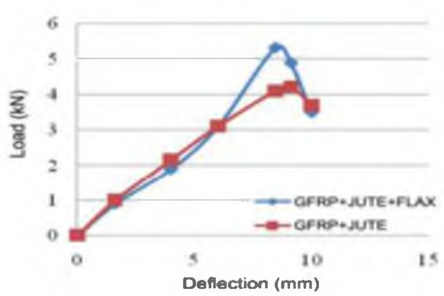


Figure 1.1: Tensile and elasticity graphs of jute, flax and glass fiber reinforced mixed composites [7].

Table 1.2: The resulting values of jute, flax and glass fibre reinforced mixed composites [7].

Composite specimen	Break load (kN)	Maximum displacement (mm)	Elongation (%)	Ultimate tensile strength (MPa)	Tensile modulus (GPa)	Specific strength (kNm/kg)	Specific stiffness (kNm/kg)
GFRP+JUTE	4.42	9.12	16	46.5	0.29	38.21	238.3
GFRP+JUTE+FLAX	5.33	8.455	14.8	56.88	0.3385	46.74	278.158

Examined the mechanical properties of mixed composites with epoxy matrix reinforced with cellulose based jute and linen woven fabrics under varying environmental conditions. In order to increase surface adhesion, jute and linen woven fabrics are subjected to alkaline machining. The composites produced were placed in acid and alkaline environments for 168 hours. Later, tensile and impact tests were applied to determine the effects of environmental conditions on the strength of composites. They have determined that the strengths of specimens held in a solution of hydrochloric acid were less than the samples held in a sodium hydroxide solution [8].

Examined the mechanical properties of the production of mixed composites using a cellulose-based jute fiber-woven jute fabric, a protein-based wool fiber-nonwoven fabric, and a felt and glass weaving fabric. As a result of tensile and three-point bending tests, the tensile strength of composites in the fibers was seen to be higher [9].

1.1.2 Literature review on jute reinforced composite materials

Examining the low-speed impact damage characteristic of jute/glass reinforced polyester mixed composites, indicated that the jute layers have the ability to absorb more energy. However, they have reported that the jute layers have less damage tolerance than jute/glass mixed layers [10].

He has experimentally examined the impact behaviors of jute-epoxy composite materials with different thicknesses using knitted fabrics obtained from the jute plant as a reinforcement element. As a result, as the thickness increases, the energy needed to cause the specimen to be damaged has also increased, Figure 1.2 [11].

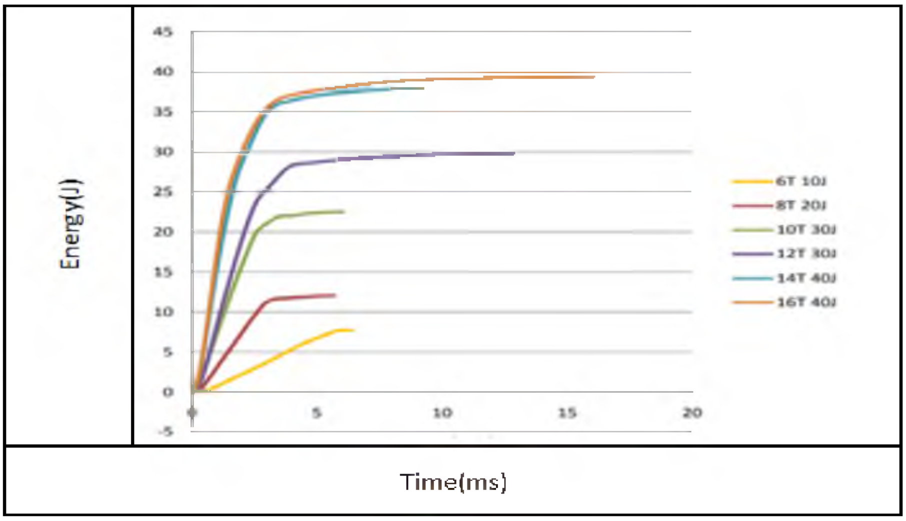


Figure 1.2: Energy/time graph according to sample thickness [11].

Examined the effect of high-density polyethylene composites with jute fibers reinforced with alkaline and siloxane surface treatment of thermal cycles on its interlayer shear strength. As the adhesion amount increases, the effect of the thermal cycle was found to decrease. The composites reinforced with alkali-treated jute were less affected by thermal-cycle compared to the composite produced with jute fibers that were not processed [12].

Found that fiber formation and thickness differences have a great impact on impact resistance of low-speed impact loads of jute-reinforced bio-composites. With the increase in thickness, they determined that the total absorbed energy and the maximum peak load were linear increases [13].

Produced jute reinforced composites by stacking jutes (0/0/0/0), (0/+ 45/-45/0) and (0/90/90/0). Experimental results were obtained by tensile and three-point bending tests on the composites produced, and these results were compared with theoretical results. Experimental results for all composites produced showed that tensile properties largely depend on the tensile strength of jute fibers and defects in the structure of the jute fibers [14].

Investigated the mechanical properties of woven jute/polyester composite materials after a surface modification process with NaOH. Jute fabrics were kept for 4 hours in a solution of NaOH at 2%, 10% and 15% after 20 hours of application in NaOH solution with a 2% ratio. The results of the experiments showed that the adhesion ability of woven jute fabrics increased as the amount of NaOH and the mechanical properties of woven-type jute/polyester-layered composites improved, Figure 1.3 [15].

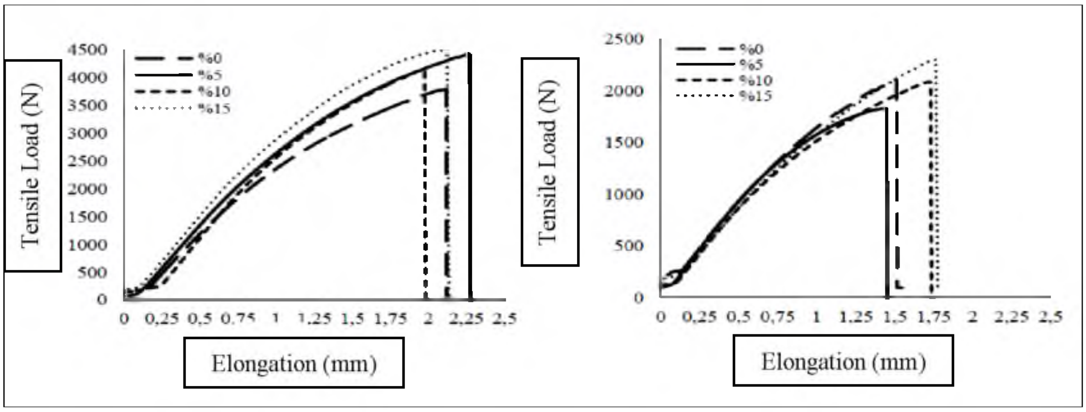


Figure 1.3: Graphs of jute/polyester samples held in different proportions of NaOH solution [15].

Examined the moisture retention capacities of mixed composites reinforced with jute and glass fiber. They determined that tensile and bending strengths have reduced with an increasing moisture amount [16].

Examined the mechanical properties and life cycle evaluation of woven jute fabric and mixed composites. The bending and impact properties of woven jute/glass composites were higher than just woven jute composites. The environmental impacts of the production of mixed composites containing jute composites and only jute were investigated. Accordingly, it was emphasized that the production of jute/glass fiber composites have more adverse environmental effects than only jute-fiber composites [17].

Examined the effect of temperature and impact velocity on the impact behaviour of jute fiber reinforced unsaturated polyester (UP) matrix composites produced by hand lay-up and vacuum packaging. It was seen that the increase in test temperature significantly reduced the bending strength after impact [18].

He has characterized mechanical properties by producing natural fiber reinforced sandwich composites. In the production of sandwich composites, he used a surface element to reinforce jute/polypropylene (PP) mixture containing jute fiber in different proportions with nonwoven surface fabric. As a central element in sandwich composites, balsa wood, polyester (PET) foam and polypropylene (PP) honeycomb structures have been used in different thicknesses. Experimental examination of the mechanical properties of the produced sandwich composites, as well as analytical and numerical modeling were done [19].

In the study of K. Samal et al. in 2009, a short banana fiber-glass fiber polypropylene matrix mixed material was produced in a Haake twin-screw extruder, with maleic anhydride as a binding chemical with the pressure casting method. Subsequently, the mixed materials produced with polypropylene (MAPP) and pure polypropylene material were examined. The presence of MAPP, the glass fiber and the bonding chemical, has been found to reduce the water absorption ability of the mixed material. As a result of increasing the proportion of banana fibers to 30%, the ratio of glass fiber to 15% and the MAPP ratio of the binding chemical to 2%, the tensile, bending and impact stress values of the mixed material increased [20].

In 2008 of A. Haneefa and colleagues, examined the effect on mechanical properties of various features such as the fiber content of mixed material with banana fiber-glass fiber reinforced polystyrene matrix, fiber loading and mixing effect, tensile stress, modulus of elasticity, break elongation and bending. The effect of the interfacial exchange of mixed material on mechanical properties has also been observed to improve the tensile properties of chemical processes such as thinned, alkaline, benzene chloride and polystyrene which has maleic anhydride applied. As a result of chemical processes and advanced fiber distribution in mixed materials, the ability of the banana fiber to reduce water absorption, fiber-matrix compatibility by improving the mechanical stability, physical and chemical connection were observed to take place [21].

He found that the alkali process has indicated that the fracture strength of the flax fiber reinforced composite had increased by approximately 30% and removed the pectin substance from the fiber [22].

They have stated that in their study, a purine surface occurs after alkaline processing in the jut fibers and the alkaline process increases the strength of the jut/polypropylene surface [23].

He stated that treatment with NaOH in 5% concentration improves the mechanical features of epoxy and polyester composites reinforced with jut fibers. However, in addition to alkaline machining, the modification process of the siloxane binding substance is significantly increased by increasing the surface resistance of composites from 13.00MPa to 19.85MPa for epoxy composites and from 8.85MPa to 17.64MPa for polyester composites [24].

The effectiveness of the alkaline process varies depending on the concentration and type of alkaline solution, process and its temperature.

He found that the modification process with a 5% NaOH solution gives higher tensile strength to the sisal reinforced composite compare to treating it with a 10% NaOH solution. The removal of excess lignin from the alkaline process in high concentrations causes the fiber to weakened due to damage. For this reason, the alkaline process can only be applied in optimum conditions to develop the mechanical capabilities of the composite [25].

He prepared the aqueous solution of the silane at a concentration of 0.033% for modifying hemp and palm fibers and the ethanol solution of the silane at 1% concentration. As a result of the tests, the modification of the silane was further enhanced by the interaction between the fiber/matrix and increased the tensile strength of the composite, according to the modification made by the alkali. Furthermore, the thermal instability of the composite has been improved after the silane process [26].

He has indicated that the treatment with silane increases the resistance of the interface according to the results of the jut reinforced polypropylene composites [27].

Examined the effect of silane binding substances in different concentrations applied to jut fabric in the mechanical properties of polyester composites. According to the results of the operation, the modification process with the silane binder substance in the concentration of 0.3%, provides the best interface strength between the jut fiber and polyester, and hence the highest mechanical specifications of the composite material were identified [28].

They used the MAHgPP binder for the surface modification of jut fibers. It was seen that treatment with 0.5% MAHgPP-Toluen solution increased the bending resistance of the composite by 72.3% [29].

Stated that after treatment with maleic acid, the jut-reinforced polypropylene composite absorbed less water [30].

2. GENERAL INFORMATION ABOUT COMPOSITE MATERIALS AND PRODUCTION METHODS

2.1 Composite Materials

2.1.1 Definition of composite materials

Materials formed as a result of the combined materials, on a macro level with the aim of making more than one of the same or different chemical properties that are practically insoluble materials, to make them better or to give them new and better features[31-32].

Therefore, composite materials are defined as materials combined with a macro structure in certain terms and proportions to complement each other's missing aspects with two or more materials that do not have the necessary characteristics that can be used alone.

In our daily life, many natural materials such as rubber, wool and silk are used. These materials, produced in natural ways from plants and animals, are very diverse but limited. These materials are suitable for human and environmental health because they are natural, but they are relatively difficult to find and are not widely used because their processing is expensive. Therefore, in recent years, material research has gained pace to find alternatives to these materials that have better properties and are cheaper. As a result of these studies, especially polymer composite materials have been used from polyethylene for the production of bags and cups, tires, sports equipment, tooth fillings, shoes and clothes, etc.

Composite materials consist of the reinforcing element, matrix material and interfacial phases. The reinforcement element is the element that carries the composite's applied load and provides strength to the structure. The matrix material is meant to keep the structure together, to distribute the load between the reinforcing elements, to prevent the progression of the fracture that may occur during plastic deformation, to delay fracture and the chemical effects of reinforcement elements and enhance the environmental protection conditions. The interfacial phase determines the adhesion between the reinforcement and matrix material.

Strength, impact resistance, fatigue strength, abrasion and corrosion resistance, fracture toughness, aesthetic appearance, resistance to various ambient conditions, depending on the purpose of use from composite materials created from various reinforcement and matrix materials, features such as lightness, rigidity, thermal conductivity and heat resistance can be expected. To provide a combination of such features, the appropriate reinforcement and matrix materials must be selected.

Scientists who work on this issue have used them as additives by synthesizing polymers or copolymers to disseminate their areas of use and to further improve the properties of the materials.

Macroscopic differentiation of structural components of composite materials is possible. The difference between the conventional alloys, which includes multiple phases in composite materials and structures, is due to the micro-degree heterogeneity, although the alloys are macrogenic. Basically, the purpose of creating composite materials is to correct the weaknesses of the materials and to give them superior properties. Composite materials are mainly the products of advanced technology and are materials with high added value and important industrial aspects.

As a result of the rapid developments in material technology that began in the late 1970s, new materials with superior properties have begun to be widely used in engineering applications and in the design of new systems. Nowadays, composite materials are indispensable in various industrial areas due to their economical, high strength and light weight.

The simplest example of composites is concrete used in the construction industry, which consists of cement and sand and is reinforced with steel materials. Another well-known composite material is the oldest building material, which is created by mixing mud and straw and is currently used in rural Turkey. A widely used polymer matrix composite is a fiberglass composite material that uses organic fibers such as anorganic and fiberglass, carbon and aramid [32].

2.2 Areas of Use of Composite Materials

The main areas where composite materials can be used are listed as follows:

1. Processing of traditional materials used in industry (e.g. steel, metals, concrete, plastics, and classical ceramics) with new production, process control and recovery technologies, to lower costs, to give functionality and added values, where composite materials can be produced from these materials. Furthermore, with the creation of composite materials, these traditional materials are integrated with advanced technology applications and are compatible with new materials and performance can be increased.

2. Composite materials can be used in "advanced material" applications, which have high added value, new and advanced features, capable of performing high performance and complex functions. Accordingly, for composite materials, the implementation of advanced production and process control technologies (e.g. "near – net shape" processes, coating techniques, powder metallurgy, new heat treatment techniques) are required.

3. In the field of composite materials, there are long-term studies that have not yet been put into use in industrial terms but have high potential in light of the results of scientific studies and can make technological developments in the future. Examples include carbon-60, low-pressure, low-temperature diamond coatings, intermetallics, carbonitride (CN) synthesis, superconductors, biomimetic materials, nanoparticle materials, and ultra-pure materials.

2.3 Advantages and Disadvantages of Composite Materials

The reason why composite materials are more important than other materials is that in different applications, it is evident that the mechanical properties (tensile, bending, compressive strength, hardness, toughness, etc.), physical properties (electrical conductivity, magnetic properties, etc.) and chemical properties (stability, corrosion resistance, etc.) are better than other materials. In particular, in addition to these features that are important in material selection and design, the material's unit cost, the quantity of material needed, the ease of availability, processing and shaping features are also important in the selection process. The material used during the application is desirable to have properties of the highest degree.

The advantages of composite materials can be sorted as follows.

-Yield strenth,

-Rigidity (modulus of elasticity),

-Fracture toughness (resistance against crack propagation),

-Density (unit volume mass),

-High strength: tensile, bending and compressive strengths of composite materials are much higher than many metal materials. In addition, the forming properties are good, and resistance can be given in the desired direction and desired area during molding. Thus, lighter, more durable and cheaper products can be obtained.

-Corrosion Resistance: Since composites are not damaged by moisture in air, corrosion and most chemical effects, they are safely used in chemical tanks, pipes transporting corrosive materials, boats and marine vehicles, jets and other aerospace vehicles.

-Abrasion Resistance: Composite materials are used in parts of engine components due to their high abrasion resistance.

-Aesthetics: The appearance of composite materials is more beautiful than other materials.

-Lightness: Composite materials are lighter in comparison to other materials because of the polymer in their structure. Therefore, shipping and labor costs are cheaper than other materials.

-Their fatigue lives are longer than other materials.

-Easy formability: large and complex parts, with a single process can be moulded into one piece. This makes it profitable for material and labor.

-Temperature and combustion resistance: Heat-resistance properties of composites created from low-temperature conduction coefficient allow them to be used in conditions that are at high temperatures. Furthermore, with the addition of additives suitable for these materials, this features can be further increased.

-Sound insulation.

-Vibration dampening: Composite materials have the characteristics of natural vibration dampening due to their elasticity and absorbing more impact shocks than metals.

Because of these characteristics, the case of crack formation in composite materials is also less.

Depending on the production method of composite materials, the negative properties of the materials forming the composites can affect the material. For example, if the matrix forming the composite is of fragile structure, this property will affect the heat resistance of the created composite and thus, this material will not withstand very high temperatures.

As it is seen, there are some disadvantages as well as the advantages of composites. These can be sorted as follows:

-Composite materials can contain air particles. This negatively affects the fatigue properties of the material.

-Composite materials show different properties in different directions.

-Precision fabrication of composite materials may be difficult because of the openings formed of the fibers of the same composite specimens caused by, pulling, pressing and cutting processes.

-If the design parameters are not well defined, high manufacturing efficiency cannot be achieved in terms of components forming composite materials.

As can be seen, although composite materials have some disadvantages, they have many advantages compared to other materials. Because of these advantages, composites can solve problems encountered due to the selection of materials in many industrial areas.

2.4 Structure of Composite Materials

Composites generally consist of matrix, reinforcement and additive elements. These materials have different physical properties, and the composite material that is formed together is different from these materials and has superior properties. In general, the reinforcement material takes over the task, while the matrix phase around it supports it and allows it to stand together [31-33]

2.4.1 Matrix material

In composite materials, the matrix has three tasks. These include keeping the fibers together, distributing the load to the fibers and protecting the fibers from environmental influences. When a good matrix material is initially in a low viscosity, fluid structure, it should be able to easily switch to solid form, which can then integrate the fibers in a robust and appropriate way. The matrix material should provide high strength and high hardness to the composite material, but should not degrade performance due to the negativity of a brittle material. The matrix materials that can provide these features may be thermoset or thermoplastic polymer materials.

2.4.2 Thermoplastic matrices

Although the diversity of thermoplastic polymers is very large, very few of them are suitable for use as a matrix. Thermoplastics are softened when heated and re-hardened when cooled. They are used less as matrix materials compared to thermosets, but they provide a safe working environment due to superior fracture toughness, long shelf life as raw material, suitable for recycling and not requiring organic solvents during the hardening process, which are some advantages. Different from thermosets, they can be reshaped by heating after the procedure. Thermoplastics that are solid at room temperature can be stored without the need for an additional cooling process. Thermoplastics also feature high hardness and impact resistance. Some basic properties of thermoplastic and thermoset polymer materials are given in Table 2.1.

Table 2.1: Properties of thermoplastic and thermoset polymer materials [34].

Thermoplastics	Thermosets
Good elasticity but depends on the type	Very poor elasticity
Easily reshaped on heating	Highly intractable crosslink i.e cannot be remoulded
Weak attractive forces between chains	Stronger attractive forces between chains
They are soluble in organic solvents	Not soluble in organic compounds
Super abrasion and dimensional stability	Better flexural and input resistance
They are flexible and not rigid	They are not flexible but rigid because of network structure formed by cross-linking
Softens without chemical change when heated	Undergoes irreversible change which causes it to harden or set

The main reasons why thermoplastics are not preferred as a matrix in composite materials is the high costs and difficulties in production. Operating qualities are low at room temperature, which can lead to loss of time in production. In some cases, the use of organic solvents may be required when forming thermoplastics. This can lead to increased cost and environmental hazards. Thermoplastics can find a usage area at temperatures ranging from 60 ° C to 245 ° C.

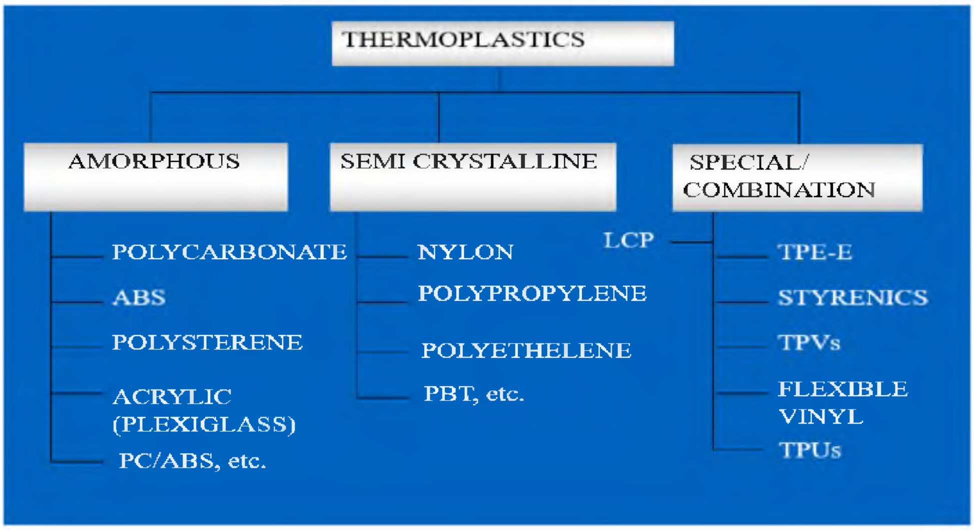


Figure 2.1: Thermoplastic materials according to their structures [35].

Initially, amorphous resins were used as polietersulfon (PES) and polieterimide (PEI) matrix. In subsequent applications, semi-crystalline plastic materials such as polyetheretherketone (PEEK) and polyphenylene sulfide (PPS) have been developed because of resistance to solvents and abrasion resistance, especially in the aviation sector. Unlike other thermoplastics, they have been used in plastics such as polyamide (PAI) and polyimide (PI), which complement polymerization during the curing phase. The most intensive studies were made on polymers used at low temperatures such as polyacrylate (PA), polybutylene terephthalate/polyethylene (PBT/PET) and polypropylene (PP). Besides all these polymers, thermoplastics such as acrylonitrile butadiene styrene (ABS), styrene acrylonitrile (SAN), styrene maleic anhydride (SMA), polysulfone (PSU), polyphenylene ether (PPE) are widely used as a matrix. Figure 2.1 summarizes thermoplastic materials according to their structures.

Thermoplastic polymers are usually used to increase the tensile and bending strengths of the material. Thermoplastics are generally used in the automotive and aircraft industry where high-performance materials are needed. They are mostly produced by injection and extrusion moulding methods. In recent years, they have started to be produced with the GMT (Glass Mat Reinforced Thermoplastics/thermoplastics) method. Reinforced thermoplastics prepared by this method are preferred especially in the automotive sector for cold rolling of plates and their suitability to the recycling process.

2.5 Classification of Composite Materials

Composite materials can be classified in two ways according to the materials that make up their structures and the shape of the building components [31].

1. According to the type of matrix material;

-Plastic composites,

-Metallic composites,

-Ceramic composites.

2. According to the shapes of the building components;

-Particle-based composites,

- Lamellae-based,

-Fiber based composites,

-Filled (cage) composites,

-Layer structured composites.

2.5.1 According to the Materials That Make up Their Structures

2.5.1.1 Plastic composites

Plastic composites are divided into four groups according to their reinforcement elements.

A) Plastic – plastic composites: Reinforcement and matrix element are plastic materials. It serves as a plastic load carrier used as reinforcement in these materials. The plastic used as a matrix is preferred in shock absorbers or plastics which are used according to the desired purpose.

b) Plastic – metal fiber composites: These composites consist of metal fiber reinforced plastics that are widely used in many industries because they are a fairly durable and lightweight product. These composites are obtained by the reinforcement of metal fibers (copper, bronze, aluminum, steel, etc.), polyethylene and polypropylene plastics. Composites formed in this way are particularly very resistant to deformation.

c) Plastic-glass fiber composites: These composites are produced by combining a thermoplastic or thermoset plastic matrix with the appropriate proportions of the reinforcement element consisting of glass fibers. Due to its mechanical and physical properties, glass fibers can be preferred to fibers such as metal, asbestos, synthetic fibers and cotton yarn in many cases. These composites can transmit great forces, but their resistance is small because of the fragile property of the glass. However, if appropriate plastics are selected, the physical and chemical properties of these materials can be improved as desired and in proportion. The most commonly used plastic matrices with glass fiber supplements are polyester.

d) Plastic – foam composites: This type of composite is used as a fiber plastic, and the foam takes on the task of the matrix. Foams can be found in cell structure, low density, porous and natural, most of them are artificially manufactured and are very mild substances. They can be rigid, fragile, soft or elastic according to the cell structure of the foam. Different types of composites can be obtained with the variation of the plastic and foam used.

2.5.1.2. Metal matrix composites

Although most metals and metal alloys provide some properties at high temperatures, they are found in a fragile structure. However, metal matrix composites using metal fibers as reinforcements can have high resistance at high temperature by harmoniously integrating both phases.

Composites with copper and aluminum matrix, wolfram or molybdenum fibers and Al – Cu composites are the best examples that give us this composition [31].These composites economically improve the properties of metal used as a matrix in an economical way. Metal fibers used as reinforcement in such composites can be continuous or in the form of small parts that are uniformly distributed.

2.5.1.3. Ceramic composites

Ceramic composites are obtained from the combinations of metal or non-metal materials. Although the thermal strength of these composites is very good, ceramics have a solid and brittle structure. They also show a very good isolation feature.

We can divide ceramic composites into three main groups:

A) ceramic-ceramic composites: They consist of combining two ceramic phases. Examples include pure tile.

b) Ceramic-glass composites: A glass matrix of quartz fibers, which is a reinforcement element, formed with the dough being placed together with the tile.

c) Ceramic-metal composites: In these multiphase structures, there is a metal phase, a ceramic phase, a pore phase and additional phases of ceramics and metals in complex forms. Examples include diamond cutters made of tungsten carbide and scattered within a cobalt matrix that are used in industry.

2.5.2 By shape of building components

2.5.2.1. Particle-based composites

These are produced by forming a small granular filler for high rigidity and strength. Particle-based composites are materials that are formed by distributing one or two-dimensional macroscopic particles, or very small microscopic particles that are considered zero-dimensional in a matrix. The macroscopic or microscopic dimensions of the particles play an important role in determining the properties of the composite material. Particle reinforced composites, found in the structure are completely randomly dispersed in the matrix, and therefore, are separated from fiber and flake composites because of the isotropic properties of the material. These composites are low cost and high rigidity materials.

The strength of the composite material depends on the hardness of the particles. The most commonly used types are metal particles contained within the plastic matrix. Metal particles provide the thermal and electrical conductivity properties of the material. They are used in the production of aircraft components nowadays due to the hardness and high temperature resistance of the structures containing ceramic particles in the metal matrix. The average embedded particle size is greater than 1 mm and the reinforcing volume ratio is generally not used more than 50%. [33].

2.5.2.2. Lamellae-based composites

The length/diameter ratio is large, and these are high load carrying composite materials. If the concentration of the scales distributed in the matrix is high, they may be in contact with each other. Scales are usually placed with the stacking system to have a planar structure. The durability of this system is good, with a little more cost.

2.5.2.3. Fiber-based composites

These types of composites are obtained by increasing many mechanical properties, with a high-efficiency, very rigid structure, and reinforcing the fibers in certain directions into the matrix material. The material that is reinforced in certain directions is enhanced with properties such as strength, corrosion and abrasion resistance, heat insulation, stiffness and weight. Most materials used especially in engineering fields are produced in this way because they are required to have superior properties. For example, the tensile strength of carbon fibers is 50 times higher than a block of graphite and the stiffness is up to 3 times more [31] Fibers could be, continuous fibers that extend continuously in the structure, long fibers, discontinuous fibers, or fibers obtained by cutting [31]. Figure 2.2 presents the classification of composite materials according to the shape of the reinforcement element.

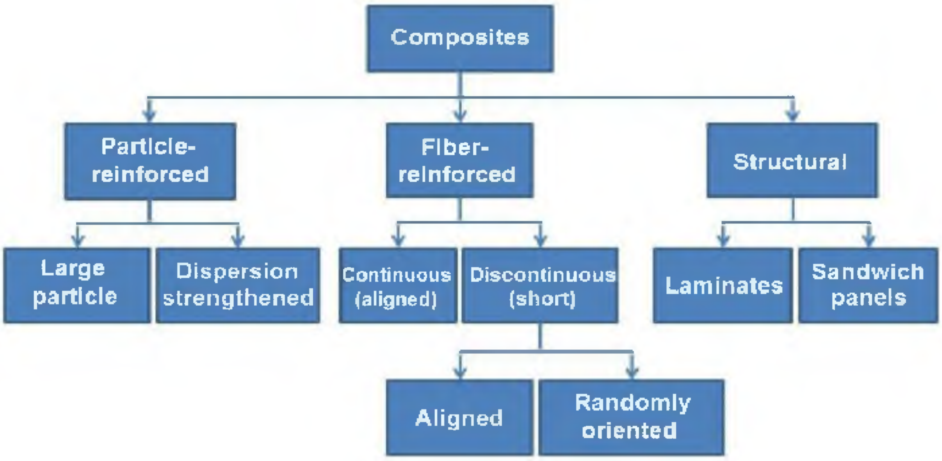


Figure 2.2: Classification of composite materials according to the shape of the reinforcement element [36].

The most important factors affecting the engineering performance of fiber-matrix composites are the shape, length, orientation of the fibers, mechanical properties of the matrix, and fiber-matrix intermediate surface properties [31]. Although the fibers are generally circular, they can be less often rectangular, hexagonal, polygonal and hollow circular cross-section. Although these sections have good properties, such as high strength, the cost, the ease of use makes the circular cross-section superior. Although the design possibilities in continuous fibers are more limited compared to uneven fibers, these fibers offer ease of operation. The orientation of continuous fibers gives better results than discontinuities ones, but the use of non-permanent fibers gives more practical results. Some types of fibers used in these composites include the following [32].

-Carbon (graphite) fibers,

-PAN (Polyacrylonitrile and pitch origin)

-Aramid (aromatic polyamide) fiber, (trade name; Kevlar-DuPont)

-Boron fiber

-Oxide fiber

-High density polyethylene fiber

-Polyamide fibers

-Polyester fiber

-Natural organic fibers

2.5.2.4. Filler composites

In these composite materials, the matrix is a three-dimensional continuous material and is filled with three-dimensional filler. The matrix skeleton can be in various geometrical forms, in the form of smooth honeycomb, cells or porous structures, which are lined up in the form of grids. These structures include metallic, organic or ceramic-based fillers. In order to ensure the optimum properties of composites to be produced, components that are insoluble and non-chemical reactive must be selected.

2.5.2.5 Layer structured composites

They consist of a combination of at least two layers with different characteristics. It allows the production of many composites in various properties. Corrosion resistance can be improved by coating weak metals with high resistance metals or plastic materials. Soft metals can be combined with tougher materials to enhance hardness and abrasion resistance, combining single layers with different fiber orientations, as well as versatile load carrying capability.

2.6 Natural Fibers

2.6.1 Introduction

The advantages of composite materials and their availability in various engineering applications have resulted in increased research and production rates in this area. The increase in production rate and dissemination have also contributed to the need for cheaper raw materials. In addition, products that complete their lifespan must be destroyed or recycled. However, composites created with matrix materials such as glass, carbon, aramid and epoxy, polyester and polyurethane are strongly bonded to each other, which makes them difficult and expensive to recycle. These reinforcement materials are harmful to human health during production, use expensive raw materials, and have recycling difficulties. These have led to the search for creating alternatives that are cheap, environmentally friendly and harmless to health. In this context, the reinforcement of polymer matrix materials with natural fibers such as flax, hemp, jute, ramie and sisal has reached an important point today.

2.6.2 Vegetable fibers

Natural fibers are composite materials by their nature serving as a microfibrillar reinforcement element in the lignin and hemicellulosic matrix. Hydrogen bridges and other bonds in the chemical structure of the fiber give the fiber strength and rigidity [2].

Plant based fibers are basically, bast (such as bast or sap) fibers (flax, hemp, jute, ramie, kenaf), seed fibers (cotton, kapok), leaf fibers (sisal, abaca, pineapple, henequen) and fruit fibers (coconut). Among them, the best fibers are sagging fibers. These fibers consist of long elemental fiber bundles. The length of the elemental fibers varies according to the plant variety. They have diameters from 5µm to 15µm, and thicknesses between 15µm and 35 µm. The elemental fiber bundle consisting of 12 and 48 fibers is referred to as technical fibers. They are gathered together in the pectin and hemicellulose matrix. Structural properties of elemental fibers are formed by means of cellulose [37]. Figures 2.3 and 2.4 show the internal structure of cellulose based plants and fiber cell microstructure, respectively.

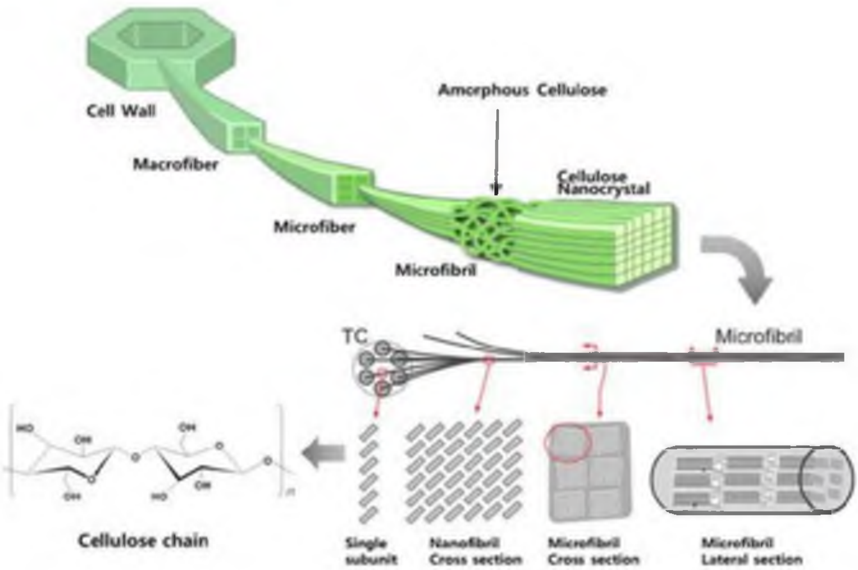


Figure 2.3: Internal structure of cellulose based plants [38].

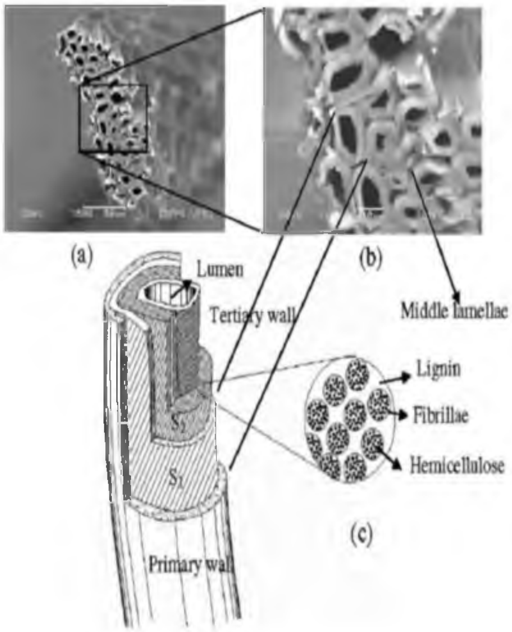


Figure 2.4: Fiber cell microstructure [39].

Table 2.2: Measurements of some natural fibers [40].

Fibre				
	Length (mm)		Diameter (mm)	
	Min-Max	Average	Min-Max	Average
Flax	8-69	32	0.008-0.031	0.019
Jute	0.75-6	2.5	0.005-0.025	0.018
Ramie	60-250	120	0.017-0.064	0.040
Hemp	5-55	25	0.013-0.041	0.024
Sisal	0.8-7.5	3	0.007-0.047	0.021
Coir	0.3-1	0.7	0.010-0.024	0.020
Cotton	10-50	25	0.014-0.021	0.019

Eco-friendly herbal fibers such as flax, hemp, ramie, kenaf, sisal, henequen and jute used in polymer matrix composites constitute an alternative to glass fiber. Natural fibers cause less concern during production in terms of health and safety. In addition, they offer mechanical properties comparable to synthetic fibers with low densities and low costs [41]. However, synthetic fibers can be produced as standard with the desired characteristics, whereas natural fibers cannot always be grown in standard properties depending on factors such as production location, soil structure, and climatic conditions.

This is one of the disadvantages of natural fiber reinforced composites. Some dimensions of some plant based fibers and chemical compositions of different natural fibers are presented in Tables 2.2 and 2.3 [40;42].

Table 2.3: Chemical composition of different natural fibers [42].

Fiber	Cellulose (%)	Hemicelulose (%)	Lignin (%)	Waxes (%)
Sugarcane bagasse	45	30	24	1
Bamboo	26–43	30	21–31	-
Flax	71	18.6–20.6	22	1.5
Kenaf	72	20.3	9	-
Jute	61–71	14–20	12–13	0.5
Hemp	68	15	10	0.8
Ramie	68.6–76.2	13–16	0.6–0.7	0.3
Sisal	65	12	9.9	2
Coir	32–43	0.15–0.25	40–45	-
Pineapple leaf fiber	81	-	12.7	-
Curaua	73.6	9.9	7.5	-

All plant based fibers have different surface morphologies, mechanical and physical properties. Plant based fibers with some complex surface morphologies exhibit different adhesion properties on the polymer-fiber intermediate surface. Therefore, they are not suitable for use in every type of fiber composites. In addition, the sizes of the herbal fibers vary according to growth and climatic conditions. Most natural fibers are lignocellulosic, but they also contain hemicellulose, pectin, fat, silica, paraffin and other water-soluble components. The knowledge of the concentration of these components is vital during the production of natural fiber reinforced composites. Cellulose is a semi-crystalline polysacidity, while hemicellulose is a highly branched amorphous polymer. The paraffin content must be at minimum level [43] in order to have a high adhesion between the fiber matrix. Table 2.4 presents the physical-mechanical properties of vegetable fibers and synthetic fibers.

Table 2.4: Physical-mechanical properties of natural fibers and synthetic fibers [44].

Type	Fiber	Density (g/cm³)	Tensile Strength (MPa)	Elastic Modulus (GPa)	Elongation at Break (%)
GRASS	Bagasse	1.2-1.25	20-290	17-27.1	1.1
	Bamboo	0.6-11	140-230	11-17	-
WOOD	Hard Wood	0.3-0.88	51-210.7	5.2-15.6	-
	Soft Wood	0.3-1.5	45.5-1000	3.6-40.0	4.4
FRUIT	Coir	1.15-1.45	106-593	1.27-6.0	15.0-59.9
	Oil palm	0.7-1.55	100-400	1.0-9.0	8-25
BAST (STEM)	Jute	1.3-1.46	393-800	10-30	1.5-10.0
	Flax	1.4-1.5	345-1500	27.6-80	1.2-3.2
	Hemp	1.47-1.48	550-900	70	1.6-4.0
	Kenaf	1.2-1.45	295-930	53	1.6-6.9
	Kudzu	-	130-418	-	-
	Nettle		650	38	1.7
	Ramie	1.45-1.5	220-938	24.5-128	1.2-3.8
LEAF	Abaca	1.5	400-980	3-12	3-10
	Banana	1.35-	355-500	12-33.8	5.9-53
	Henequen	1.2-1.4	430-580	10.1-16.3	3.0-4.7
	Pineapple	0.8-1.6	170-1672	82	1.0-3.0
	Sisal	1.33-1.5	400-700	9.0-38.0	2.0-14
SEED	Cotton	1.5-1.6	287-597	5.5-12.6	3.0-10.0
	Kapok	0.38	93.3	-	-
SYNTHETIC	Carbon	1.4	4000	23-240	1.4-1.8
	E-glass	2.5	2000-3500	70.0	0.5-3.0
	S-glass	2.5	4570	86.0	2.8
	Aramide	1.4	3000-3150	63-70	2.5-3.7

Bast Fibres	**Seed fibers**	**Leaf fibers**	**Fruit Fibers**
Flax	Cotton	Sisal	Coconut
Jute	Kapok	Abaca	
Hemp			
Ramie			
Kenaf			

The types of vegetable fibers can be distinguished according to the type of fiber. As this thesis uses jute fibers as reinforcement elements, information about their properties will be given.

2.7 Jute

The most inexpensive jute plant in the natural fibers is a plant of approximately 100 species in the Corchorus family [45]. The commercial-grown varieties are Corchorus Olitorius, a lighter Corchorus Capsularis and softer and stronger, known as white jute. They are also called gold fibers because they maintain their natural luster even after the jute fibers have been processed. The length of these plants can be between 2 m and 4 m [46].

Figure 2.5: Jute Fibres [47].

It is the most produced plant in the world after cotton. India is the homeland of this plant that grows in tropical climes. 80% of worldwide production is carried out in India, Pakistan and Bangladesh . One reason why production is so much in these areas is that labor is very cheap. In addition to these regions, it has begun to be cultivated in China and Malaysia. In addition, the genus Corchorus Olitorius is cultivated in Mediterranean countries. It is produced in the states of Texas and South Carolina. The plant, which is quite difficult to collect, becomes an adult in about three months. It should be collected when blossoming. The crop that coincides with the seed period is heavy, but its fibers are thickened and hardened. The collected jute plant is thrown into ponds in bales and the forest plants are covered with animal manure. In dirty and airless water, jute shells are decayed. At the end of the digestion, the fibers are separated from the shells by hand. The fibers are then laid for drying [46]. The length of the fibers obtained is 18-25 cm. When first obtained, the light yellow fibers turn into light brown over time. The fiber obtained from the hemp is brighter. Subsequent operations are carried out by machines in factories. The fibers are cleaned and wrapped as a rope. The flexibility of jute fibers is minimal. As with other cellulosic fibers, moisture absorbency is high. Its strength is lower than linen and hemp. Most of the jute produced in the world is used for making sacks, cloth, rope and string [48]. Figure 2.6 shows a photo of harvested jute bundles.

Figure 2.6: Jute Stem [49].

2.8 Reinforcement Material

In composite materials, fibers or particles in different geometries are used for reinforcement. Criteria to be considered in the selection of fiber in the production of composite materials include [50].

-Lightness (Specific gravity),

-Strength and modulus (tensile and compression),

-Fatigue Strength,

-Fatigue break mechanism (the material is brittle or ductile),

-Thermal and electrical conductivity,

-Economical

The reinforcement material is responsible for the mechanical strength of the composite material, and its durability enhancing effect often begins to be observed when the volume within the composite exceeds 10% [51]. Carbon, glass, aramid, boric oxide, high density polyethylene, polyamide and polyester composite materials are widely used in the production of synthetic fiber types. Saggy fibers such as jute, flax and hemp are natural fiber types that are widely used in composite applications [32]. As part of this thesis, jute fabric is used as a reinforcement element and the characteristics of the jute fiber will be explained in the future pages.

The jute fiber is a thick, strong and rigid fiber derived from the jute plant grown in tropical areas [52]. In old periods, a large part of the jute fiber produced was string from spinning, and was transformed into low added products such as sacks and carpet backs. In recent years, technical textiles (packaging, heat and sound insulation materials, filters, geotextiles etc.), vehicle floor coverings, and the use of jute fibers in high-value areas such as plastic composites has increased.

vehicle floor coverings, and the use of jute fibers in high-value areas such as plastic composites has increased.

The advantages of the jute fiber are as follows [53]:

-Being a natural substance harmless to the environment during use,

-Biological because it can be broken down by microorganisms in nature after the end of its lifetime, thus not causing environmental pollution,

-Producing abundant quantities and being cheap,

-High specific strength and modulus values,

-Low intensity,

-High dimensional stability and resistance to friction,

-No waste material remains when burned and destroyed, and the resulting harmful compound is very small,

-Does no damage to machine parts,

-The sound absorption feature is very good due to its spaced structure.

The disadvantages of the jute fiber are:

-High sensitivity to moisture,

-Low mold strength [52].

-at temperatures above 190 °c, most of its mechanical properties reduce [54].

Jute has a lignocellulosic structure as many other natural fibers. Jute fibers consist of a small amount of pectin, fats and dirt with cellulose, hemicellulose and lignin. Jute fiber consists of approximately 60-70% cellulose, 12-13% lignin, 13-20% hemicellulose and a small amount of pectin, oil and dirt. The properties of the jute fibers vary according to the physical and chemical properties of these components, the ratio in the fiber and the placement style (microfibrillar angle) within the fiber. The ratios of the components depend on the maturity level of the fiber and the plant properties. The jute fiber is very layered in structure [55]. Figure 2.7 shows the multilayer structure of the jute fiber.

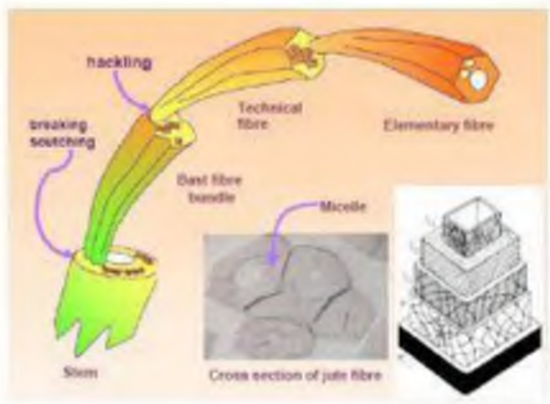


Figure 2.7: Multilayer structure of the jute fiber [55].

2.8.1. Fib-matrix interface

Fiber, matrix and fiber-matrix interface are the most important components that determine the mechanical and environmental strength requirements in textile supported composites. The main element that carries the load in a composite structure is the fibers. The resin is responsible for the transmission of the load between the fibers and the homogeneous distribution throughout the composite structure. The point of occurrence of this load transfer between fiber and resin is the fiber-matrix interface. The adhesion between the fiber and the matrix should be good, so that the load applied to the composite can be directly distributed to the fibers without focusing on the matrix or the interface. If the structure mismatch between fiber and resin is not resolved, a healthy merge cannot be achieved, so the mechanical properties of the composite material can be lower than expected. This problem is even more pronounced between the natural fibers in the polar structure and the polymers in the non-polar structure [56-57]. To resolve this problem, the properties of natural fibers and polymers are approximated by using different interface modification methods. Basically, these methods are based on the basis of hybrophobling natural fiber and/or hydrophilating the matrix material. Thus, the adhesion between the fiber and the matrix is increased and the surface energies of the fiber and polymer matrix are approximated to each other. Many methods have been developed to improve the interface of natural fiber-reinforced composites and to reduce moisture absorption [58].

In past studies, alkaline processes for fiber modification, processes with silane based harmonizers, processes with benzoyl peroxide, processes with permanganate, and hot water processes are used to increase adhesion on the intermediate surface [59-60]. In the scope of this thesis, jute fabrics were treated with NaOH in the modification of the fiber-matrix interface. In addition, maleic anhydride-based harmonizers are used for the modification of the fiber-matrix interface.

2.8.2. Process with sodium hydroxide

The alkaline process is based on treating lignocellulosic-based reinforcement fibers in different temperatures or time with sodium hydroxide (NaOH), usually at various concentrations.

Lignocellulosic fibers are polar-characterized due to hydroxyl groups (cellulose) found in their structures. Impurities such as pectin, lignin, and wax in fibers and high quantities of hydroxyl groups prevent these fibers from connecting to the matrix polymer, weakening the interface and negatively effecting the mechanical properties of polymer-based composite material. Some of these substances on the surface of the cellulose fibers are eliminated by alkaline processing and a large number of open cellulose tips that can interact with the polymer on the fiber surface are formed. The free energy of the fiber surface increases with alkali processing. It also develops mechanical connections in the fiber/polymer interface by roughening the fiber surface [61]. The alkaline process affects the cellulose fibrillation, lowering the polymerization degree of cellulosum, directly affecting the amount of lignin and hemicellulose separated from the fiber [62].

2.8.3 Maleic anhydrite vaccinated polyolefins

Maleic anhydride vaccinated polymers are the most commonly used harmonizing agents. Basically, these harmonizers consist of two main elements. The first part of these parts is polyolefin, which is probably composed of YYPE or PP, and the task is to connect to the polymer matrix, and the other part is maleic anhydrate that is probably the covalent bond with the lignocellulosic fiber and sometimes the ionic or hydrogen bonds it creates. This binding occurs in melting processing temperatures [63]. If a covalent connective formation occurs, the maleic anhydride forms a cellulosic ester with hydroxyl groups found in cellulose and a free acid, which is then bonded to the polymer chain through the pulp-binding agent. Maleic anhydride grafted polyolefins are generally harmonizing agents containing a maleic anhydride group with a ratio of 1 – 6% as a result of vaccinating the maleic anhydrate on the polymer structure. Maleic anhydride vaccinated polyolefins establish covalent bonds with hydroxyl groups of cellulosic fibers in the extrusion temperatures, thereby strongly linking the fibers to the polymer matrix. The modified cellulose fiber structure that is formed as a result of this esterification exhibits a much better distribution in the polymer matrix than non-modified cellulosa [64].

2.9 Manufacturing Methods of Mixed Materials with a Polymer Matrix

Various ways are used in the manufacture of mixed materials with a polymer matrix. The geometric shape, size, resin type and properties of the part to be moulded, reinforcement shape, and the characteristics expected from the material are the main factors affecting the choice of manufacturing method. There are many methods for the production of polymer-based mixed materials in the desired specifications and format. The selection criteria for manufacturing methods are shown in Table 2.5 as follows:

Table 2.5: Manufacturing methods of mixed materials with a polymer matrix [65].

Technique	Characteristics	Examples
Sheet molding	Fast, flexible, 1-2" fiber	SMC automotive body panels
Injection molding	Fast, high volume very short fibers, thermoplastics	Gears, fan blades
Resin transfer molding	Fast, complex parts, good control of fiber orientation	Automotive structural panels
Prepreg tape lay-up	Slow, laborious, reliable, expensive (speed improved by automation)	Aerospace structures
Pultrusion	Continuous, constant cross-section parts	I-beams, columns
Filament winding	Moderate speed, complex geometries, hollow parts	Aircraft fuselage, pipes, drive shafts
Thermal forming (future)	Reinforced thermoplastic matrices; fast, easy repair, joining	All of above

SOURCE: Office of Technology Assessment, 1988.

2.9.1 Extrusion method

Between the period of 1940-1950, the development and production of synthetic-based polymers formed a sector by its own for their processing. The polymer processing industry has also developed rapidly because manufacturing of polymers and their processing are related to each other. The polymer processing industry is the industry branch that makes the polymers obtained by chemical processing to be the final product required, being subjected to thermal and mechanical processes. The extrusion process has had a major role in the development of the polymer processing industry. The most prominent feature of the extrusion process is a cylindrical casing and rotating screws, which is the most important polymer processing technique today. Approximately 60% of polymers are processed by this method and become the final product [66].

The word "extrude" in Latin is formed by combining the words "ex" (Out) and "Trude" (push). The extruder can be thought of as a machine that is pushing out a material as it suggests. The screw extruder makes the solid polymer melt efficiently and continuously and sends it to the outlet under pressure by pumping high viscosity molten solution. There is no significant change in the chemical properties of the polymer at the end of the extrusionprocess [66]

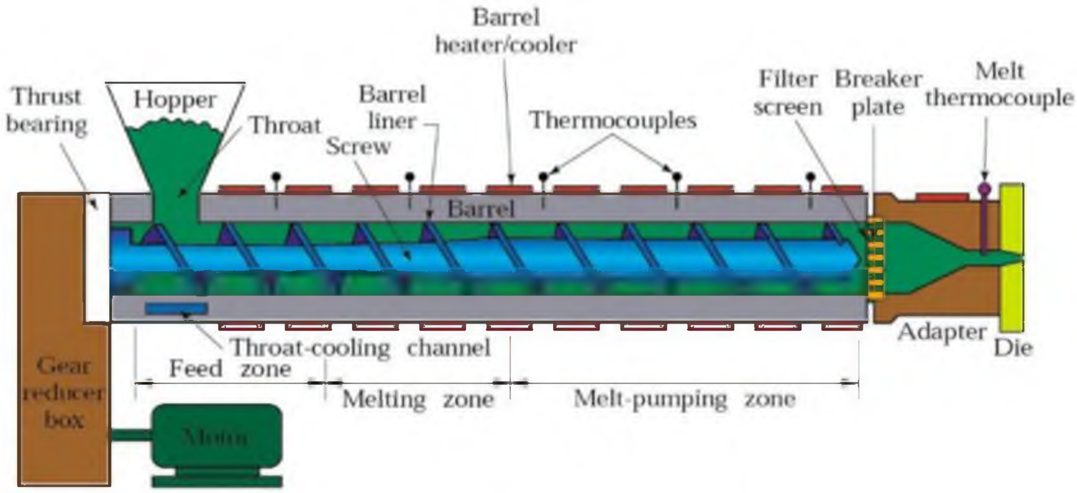


Figure 2.8: Extrusion Machine Process Phases [67].

As shown in Figure 2.8 the extrusion machine, as in the injection molding machine, powder or granular resin is continuously sent from a feed funnel to a heating cylinder (hive), which is pushed forward with the help of the infinite screw found here. As it progresses in the cylinder it heats up, softens and melts because of the heat it receives from the cylinder wall and the internal friction caused by the slide. When it reaches the end of the cylinder, a certain amount is stored and forced to pass through a mold that is connected to the end of the machine and designated the section shape of the product, thereby obtaining the shape of the cavity of the mold [68].

The processing of polymers is done with melting and plastic extrusion. If the polymer is fed into the extruded molten solution, there is a melt extrusion. Extruders of this shape have a single region. This is the molten transport zone. The extruded plastic is the extrusion process by melting the solid polymer. Once the polymer is acquired, it is made rigid and stored or processed in other facilities for fiber production. This extrusion process is called plasticizer extrusion [69].

Solid polymers to be processed are produced in granules, powders or small grains. To help the efficient processing of the polymer, auxiliary substances such as antioxidants, plasticizers, pigments and lubricants can also be extracted from the granular feeding chamber to the extruder. Since these auxiliary substances affect and modify the physical properties of the polymer to be processed in the extruder affecting the hydrodynamic and thermodynamic properties, their effects on the polymer are neglected in the theoretical analysis of the extruder [69].

The performance of the extruder largely depends on the screw design and operating conditions. Basic geometric variables of the screw: the number and geometry of screws, depth change along the duct depth, and the extruder can be shown as the radial opening between the screw and the hive. Screw and sleeve material is steel and can be hardened against abrasion [69].

Figure 2.9: Extruder screws with different designs [70].

In single screw extruders, the melting and pressure zones can be longer depending on the polymer material and the desired output characteristics, whereas in extruders where two or more screws are used together, the number of sections is more than one (e.g. two melting zones, two pressure zones). Important variables that must be checked during the extruder process can be shown as screw speed, screw temperature and output pressure. The screw speed depends on the size and manufacturing capacity of the extruder [69]. Figure 2.9 shows the extruder screws with different designs.

The main factor that determines the limit of the manufacturing speed is that the polymer can be processed in a quality manner. The desired temperature and pressure values are obtained at the output and the thermal homogeneous of the polymer are the parameters indicating the quality of the polymer processed. In extruders running at high speeds or in extruders with large screw diameters, it is difficult to fully dissolve the polymer in the extruder and obtain a homogeneous structure. In large screw diameter extruders, a slower working speed and a longer screw are required to ensure adequate melting due to the large volume of melting. For fast-running extruders, longer screws are required for adequate melting. The polymers produced in extruders running at a speed of 1000-2000 rpm in experiments have less quality than those employed at low speed [68].

The basic process variables in extruders are screw speed and temperature variation. The basic construction parameters are screw length (L) and diameter (D), and the ratio of each other (L/D) determines the extruder characteristic. L/D largely determines the output of the extruder, the polymer output time, and the appropriate cylinder surface for heat transfer to the polymers. Screw geometry is important when designing the extruder [68].

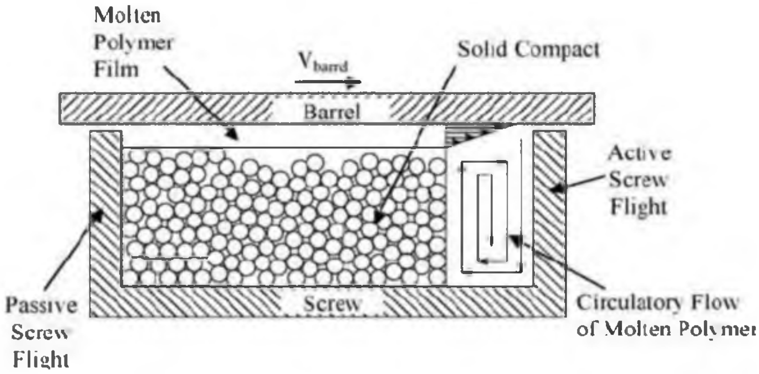


Figure 2.10: The melting mechanism for single screw extruders [70].

The transition from the transport zone to the pressure zone occurs gradually due to the heating and melting of the chip or granular solid polymer in contact with the heated hive and molten polymers. When the polymer is in contact with the heater element hive, it is seen that it is formed by a thin film layer and acts as a lubricant between the hive and the screw. It starts to create a melt pool towards the back of the screw duct, which is reversed to the displacement movement of the melting polymer screws. The material in the pool gradually increases the volume depending on the temperature increase and the screw movement, and it becomes completely molten in the screw ducts close to the pressure zone by confining the solid polymer [68]. Figure 2.10 shows the melting mechanism for single screw extruders.

3. MATERIAL AND METHOD

3.1 Material

In this study, it is aimed to evaluate the thermoplastic process wastes with natural fiber wastes. For this purpose, the potential uses of the "jute" as a natural consolidation agent and the properties of the PP/jute composite material to provide high strength and modulus of PP raw material, which is a dust waste of the production of polypropylene (PP) granules is examined. Jute is a plant based fiber native to India containing amorphous microfibrils, spontaneously decomposes in soil, is cellulose based (70%), with hemicellulose (20%) and lignin (13%). In this study, jute sack edge wastes supplied from the Ege Çuval (Sack) company are examined. Figure 3.1 summarizes the steps of the production process and experimental strudies.

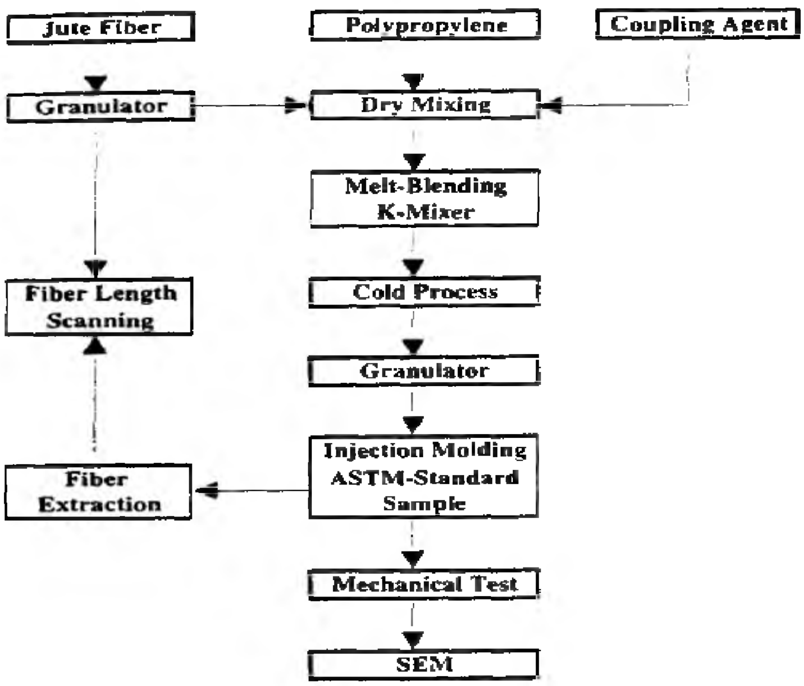


Figure 3.1: Schematic representation of production process ranking and experimental studies [71].

Jute of (10-Cross-stitch : 311 grams/yard^2) were evaluated. Following manufacture, the jute sack edges that emerged as waste were separated into 15-18 mm long yarns and the formation of jute fibers was provided by blowing compressed air. The oil on the surface of the jute fibers, the oily layers of the wax, were cleaned in the laboratory environment in a solution of 2% NaOH (23 ºC, 50% RH) for 2h, then placed in an incubator at a temperature of 50 ºC for 24 h for drying. In order to achieve maximum adhesion on the PP and jute interface, jute fibers which were dried in the previous stage were kept for 2h in 0.3% silane (Dow Corning, Product code Z-6030) solution. The PP/jute mixture materials were compounded in a double screw extruder at 190 ºC temperature. Standard tensile specimens were produced from the PP/jute mixture granules from the injection molding machine at a temperature of 180 ºC. Their physical and mechanical properties were examined.

3.2 Chemical Used

3.2.1 Properties of materials used in the production of composite materials

3.2.1.1 Jute fabric

The jute sack edge wastes (10-cross-stitch: 311 grams/yard^2) obtained from Ege Sack company were evaluated. Jute sack edges, which emerged as waste after garment manufacture, are divided into 15-18 mm long yarns. Figure 3.2 shows the jute wastes used in the study.

Figure 3.2: Jute wastes used as a natural reinforcement agent.

3.2.1.2 Maleic anhydrite (PL1010)

PoLinker PL1010 resin is a grafted coupling agent based on polypropylene which combines functional groups by using reactive extrusion. PL1010 resin can improve the polarity of the plastic to increase the compatibility between different materials. Table 3.1 presents the properties of the MA-G-PP technical data sheet used in the experimental study and Table 3.2 gives the technical characteristics of the silane used during sample preparation.

Table 3.1: The properties of the MA-g-PP technical data sheet used in the experimental study[73].

PROPERTIES	Test Method	Unit	Value
THERMAL			
Vicat Softening Point	ASTM D1525	°C	95
PHYSICAL			
Specific Gravity	ASTM D792	-	0.902
Melt Flow Rate (190°C/2.16Kg)	ASTM D1238	g/10min	80
Hardness	ASTM D785	R-scale	97
MAH Graft level	Polyalloy Method		Medium

3.2.1.3 Silane (XIAMETER OFS-6020)

Table 3.2: The technical characteristics of the silane used during sample preparation[74].

Property	Unit	Result
Appearance		Clear liquid
Flash point – closed cup	°C (°F)	85 (185)
Specific gravity at 25°C (77°F)		1.03
Refractive index		1.445
Neutral equivalents	g/eq	115
Color		Light straw
Viscosity	mm^2/s	5

3.2.1.4 Polypropylene

Polypropylene is a highly durable polymer that is resistant to chemicals. The boiling point is soluble at high temperatures in high aliphatic and aromatic hydrocarbides. When temperature, heat, and mechanical loading are too much, the cross-chain breaks and the polymer becomes more fragile. Its nonpolar and hydrophobic structure limits the amount of hydrophilic additives that will be used. Polypropylene is used in the construction of auto battery vessels, screw caps, some yogurt and margarine containers, and plastic films. It is also used for packaging of syrup and fruit juices that need to be packaged when hot. It creates 13.2% of all plastics. Table 3.3 gives some mechanical properties of polypropylene.

Table 3.3: Mechanical properties of polypropylene [74].

Property	Polypropylene
Unit weight (gr/cm^3)	0.9-0.91
Reaction with water	Hydrophobic
Tensile strength (MPa)	300-400
Elongation at break (%)	100-600
Melting point (◦C)	175
Thermal conductivity (W/m/K)	0.12
Length (mm)	6

3.3 Experimental Study

Figure 3.3, shows the natural consolidation agent used in the project, the jute edge wastes provided from the Ege Sack company.

Figure 3.3: Length of waste fiber.

Figure 3.4, shows the lengths of the The Ege Sack company's jute edge waste which were between 10-12 cm. (10-Cross stitch: 311 grams/yard^2)

Figure 3.4: The Ege Sack company's jute edge waste.

Jute sack edges from waste following garment manufacture has been clipped with the help of scissors, Figure 3.5.

Figure 3.5: Clipped waste jute.

Two kilograms of jute edge wastes were obtained, which were15-18 mm in length and they were divided into strands Figure 3.6.

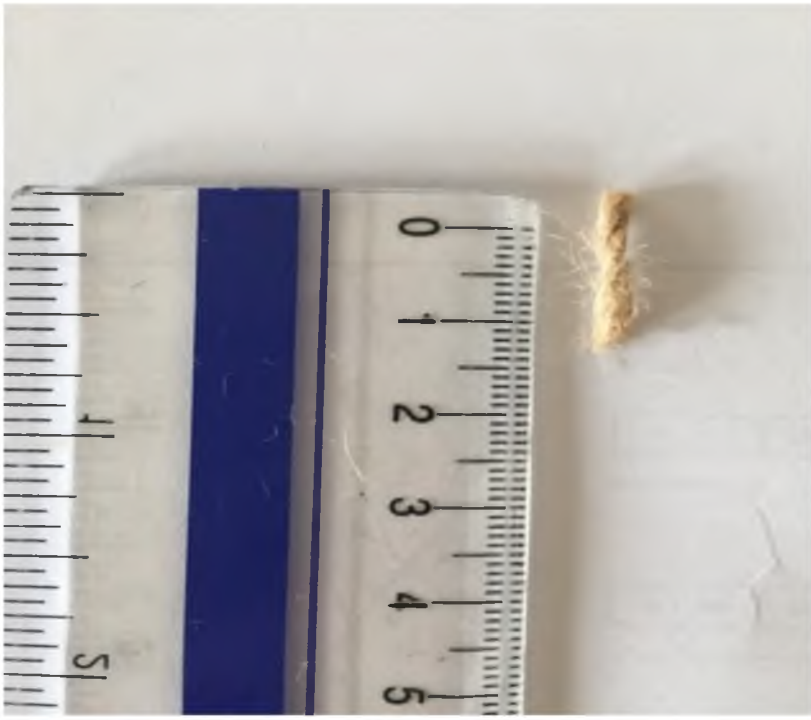


Figure 3.6: Clipped waste jute length.

Two pieces of plastic containers of 70 L volume were used in the pre-cleaning process of our natural fiber waste, Figure 3.7

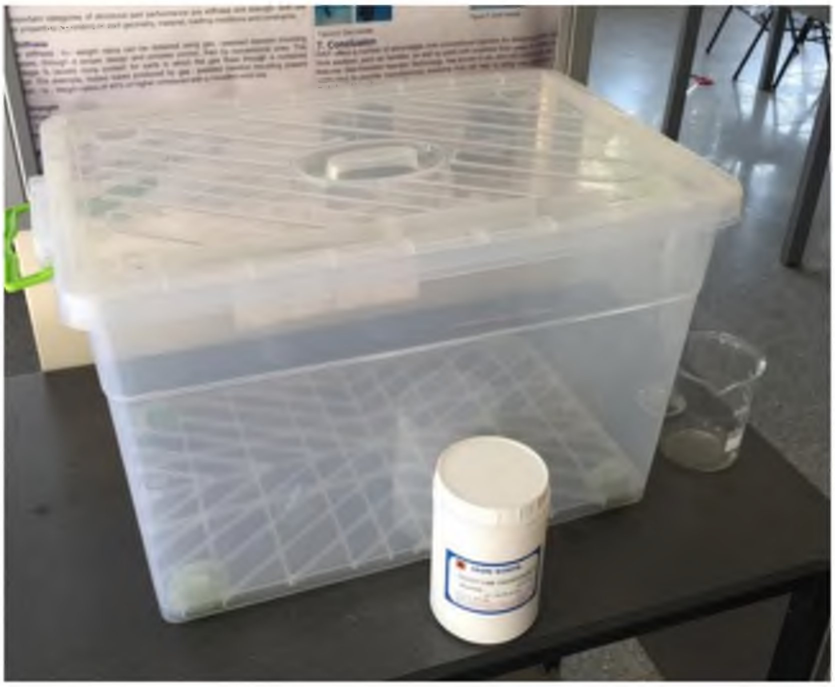


Figure 3.7: Plastic container used for pre-cleaning.

A total weight of 2 kilograms of jute waste were produced after the clippings emptied into the plastic containers, Figure 3.8.

Figure 3.8: Cropped jutes poured into plastic container.

As seen in Figure 3.9, 50 liters of water was poured onto the cropped jutes and kept for 2 hours in 2% NaOH solution.

Figure 3.9: The cropped jutes kept for 2 hours in 2% NaOH solution.

As seen in Figure 3.10 Jutes were kept for 2 hours in the NaOH solution for cleaning and then the jutes were removed and held for 24 hours at room temperature.

Figure 3.10: The jutes removed and held for 24 hours at room temperature.

After the jutes were ventilated, they were loaded into the feed unit of an injection molding machine, and subjected to a drying process of 3 days 8 hours at 50 degrees, Figure 3.11.

Figure 3.11: The jutes subjected to a drying process of 3 days 8 hours at 50 degrees.

The finished jutes were put in a sack and stacked up and waited until the next process, Figure 3.12.

Figure 3.12: The finished jutes put in a sack.

As seen in Figure 3.13, in order to cover the surface of the fiber after washing and the drying process, 100 gr silane with coupling agent feature from the Dow Corning company (Z6020 coded) was procured.

Figure 3.13: Silane (XIAMETER OFS-6020).

Jutes were placed in 34 lt of pure water with a 0.3% silane (100 g) and held in the solution for 2 hours, Figure 3.14.

Figure 3.14: The cropped jutes kept for 2 hours in %0,3 silane(100 gr) solution.

The jutes undergoing a surface coating process were kept at room temperature for one day for ventilation, Figure 3.15.

Figure 3.15: The jutes were kept at room temperature for one day.

The damp jutes were placed in a sack before entering the drying oven, Figure.3.16.

Figure 3.16: The damp jutes placed in a sack.

As seen in Figure 3.17, the surface-coated jutes were ventilated for one day and then placed in a sack. The jutes were dried for 3 days and 15 hours at 60 degrees in the drying oven at the Turkish Standards Institute.

Figure 3.17: The jutes that were dried.

As given in Figure 3.18, the weight of the dried jutes has been measured.

Figure 3.18: The jutes' measured weight.

Dried jutes are put into a plastic box before being made into fibers, Figure 3.19.

Figure 3.19: Dried jutes are put into a plastic box.

As given in Fig. 3.20, in order for the dried jutes to be made into fibers;

-The lid of the plastic box is closed, then the air inlet and outlet locations have been identified to ensure vacuuming.

-In the process of fiber making, the air outlet is closed with a sponge to prevent the jutes from exiting out.

-A compressed air gun is used when making jute fibers.

Figure 3.20: Compressed air gun used to make jute fiber.

Figure 3.21 shows the natural fiber wastes being cleaned with a solution of NaOH after clipping. They are coated with silane before completion of the drying process, and made into fibers and prepared before entering the extruder.

Figure 3.21: the drying process, and made into jute fibers and prepared before entering the extruder.

3.4 Tensile Sample Preparation Procedures

As seen in Fig. 3.22 PP/jute mixture materials are melted by feeding into the double screw extruder belonging to Uçar Plastic company. The extruded screw speed is set at 40 rpm and operating temperature between 180-190 ºC.

Figure 3.22: Extruder machine used in Uçar Plastic Company.

Table 3.4 shows the codes and mixing ratios of the PP/jute mixture sample codes that are used for comparison in mechanical tests.

Table 3.4: Sample codes and descriptions of the different ratios produced in the experimental study.

Sample Type	Specification
J0	PP original raw material (dust)
J1	PP %2,5 JUTE REINFORCED
J2	PP %5 JUTE REINFORCED
J3	PP %10 JUTE REINFORCED
J4	PP %15 JUTE REINFORCED
J5	PP %20 JUTE REINFORCED
MH418	PP(Petkim)
GF5	PP %20 GLASS FİBER REINFORCED PP

The samples are coded according to the jute ratio added to the polypropylene (MFI, tensile test, density, SEM analysis) in the experimental studies. The values of the resulting results are specified in tables and graphs according to these codes.

Figure 3.23 shows jute and PP in different proportions and with added % 5 MA-g-PP. The mixtures created are first put into the sack and then blended in the mixer approximately 5 minutes.

Figure 3.23: Jute, pp and %5 MA-g-PP added mixture in sack.

Figure 3.24 shows the natural fibers mixed in the mixer, polypropylene and %5 MA-g-PP material that we added in the extruder from the feed.

Figure 3.24: The mixture added in the extruder from the feed.

After the samples from the extruder were cooled in cold water, the plastic crushing machine was advanced, Figure 3.25

Figure 3.25: The mixture from the extruder delivered to the crushing machine.

The mixture extracted from the extruder is made of PP/jute material granules by directly entering into the plastic crushing machine, Figure 3.26.

Figure 3.26: Crushing machine.

Figure 3.27 shows the production of tensile specimens, which was carried out at the injection molding machine in the Polymer Technology Laboratory at Ege University Vocational School.

Figure 3.27: Injection molding machine.

The PP/jute mixture which we have prepared the mixture and made granules in the cutting machine is put into a plastic box, Figure 3.28

Figure 3.28: The PP/jute mixture made granules put in plastic box.

Fig. 3.29 shows the granules in the feed point of the Injection molding machine have been transferred inwards. The granules that were melted under a temperature of 180 degrees form pulling rods from the mold.

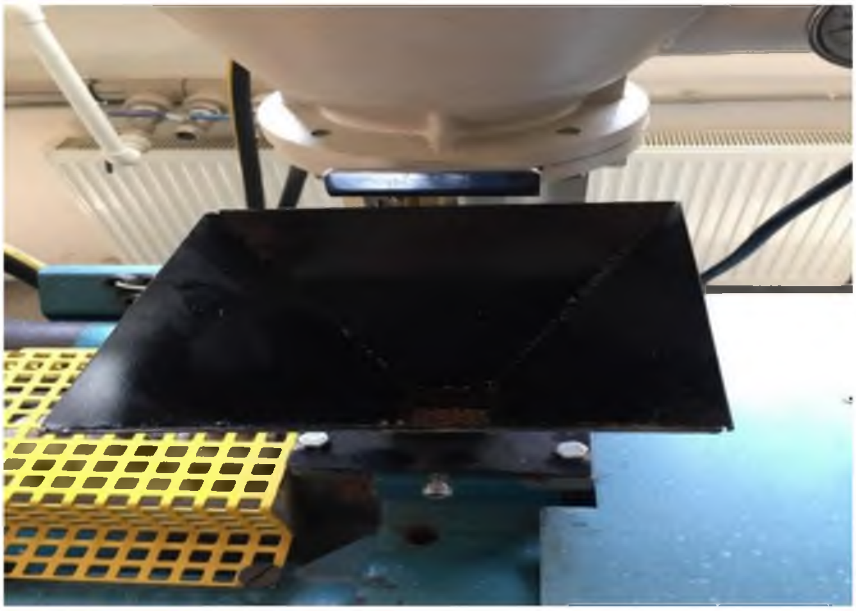


Figure 3.29: Feeding point of injection molding machine.

Fig. 3.30 PP/jute mixture tensile specimens were carried out under 180 °C temperature by conveying granules from the feed point of the injection molding machine. From left to right (J0, J1, J2, J3, J4, J5, MH418, GF5) photos of tensile sample bars with different mixing ratios are given.

Figure 3.30: Tensile samples.

4. RESULTS AND DISCUSSION

4.1 Tensile Testing

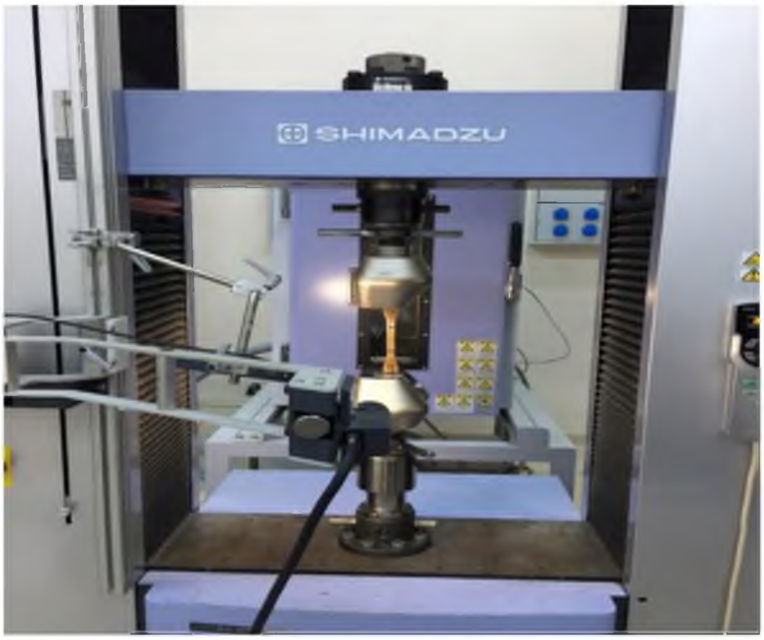


Figure 4.1: Shimadzu AG-100 tensile test device.

Tensile test was carried out in the Shimadzu AG-100 Tensile testing device (Figure 4.1) in the Mechanical Engineering Department of Composite Laboratory of Dokuz Eylül University. Tests were conducted according to the ASTM D3039 standard. The tests were performed with specimens fixed to the jaws and pulled with a speed of 50 mm/s. When reading the extension and force data from the device, precise extension values can be obtained by the video extensometer.

Figure 4.2: Computer output of the tensile test device.

The extensometer device measures the amount of extension for the region specified during the tensile test by accurately tracking the pixel through the camera. Before starting the test, the modulus of elasticity can be obtained by automatically calculating the stress and length values. Figure 4.2 shows the computer output of the tensile test

4.2 MFI Test

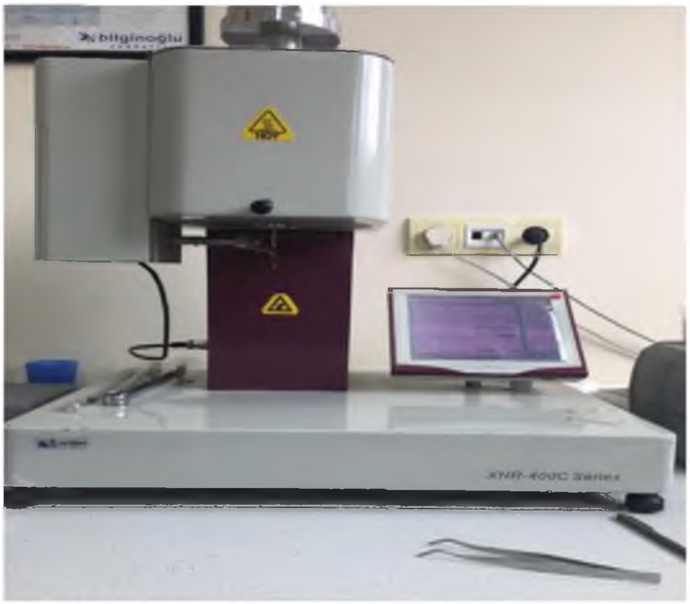


Figure 4.3: JJ TEST XNR-400C brand melting index measuring instrument.

In the study, the effects of 2.5%, 5%, 10%, 15%, 20% jute-additive pp specimens on fluidity properties were also examined. The specimens' melting index measurements according to the ASTM 1238-04c standard were carried out using the JJ TEST XNR-400C brand melting index measuring instrument located at Ege University Polymer Laboratory. As the analysis temperature, both heaters were set to 190 °C. The piston weighing 1.9 kg was used to ensure the flow of the melted material. Three measurements were made and averages for each specimen were taken. Figure 4.3 JJ TEST XNR-400C shows the brand melting index measuring instrument.

According to the results obtained in the MFI measurements, it was observed that there was less fluidity of the PP material with a % 20 jute additive than the pp of 2.5% and with an increased reinforcement ratio. As a reason for the pure PP material, the growth of the bonds in the polymer material is broken and the flow is ensured more comfortably. Fig. 4.4 shows The image of the output point of the melted material from the melting index measurement tool.

Figure 4.4: The image of the output point of the melted material from the melting index measurement tool.

4.3 SEM Analysis and Interpretation of Images

All kinds of additives and phase changes that can be made in biotechnological specimens including materials, contact structures of metal-metal, conductive-semiconductor, semiconductor-semiconductor layers, contact structures of crystal structures, mixture and alloy structures, can be examined with a scanning electron microscope (SEM). Also surface and cross sections of dust, ceramics and other materials can be used for morphological analysis with high magnification ratios. Image formation in scanning electron microscope (SEM) is done by the focus of high-voltage accelerated electrons on the specimen, the effects of various interventions between electron and sample atoms during the scanning of this electron bundle on the sample surface are suitable for and transmitted to the screen by passing through the signal amplifiers.

In order to better understand the effects of the recycling process on the mechanical properties of mixed materials, SEM (scanner electron microscope) images of fracture surface, cross section and transverse surfaces were obtained. By these images, a more reliable understanding of the interaction and adhesion of fibers and yarns with PP were obtained. Figures 4.5 and 4.6 show the SEM image of 20% glass fiber reinforced PP and 20% jute-added PP, respectively.

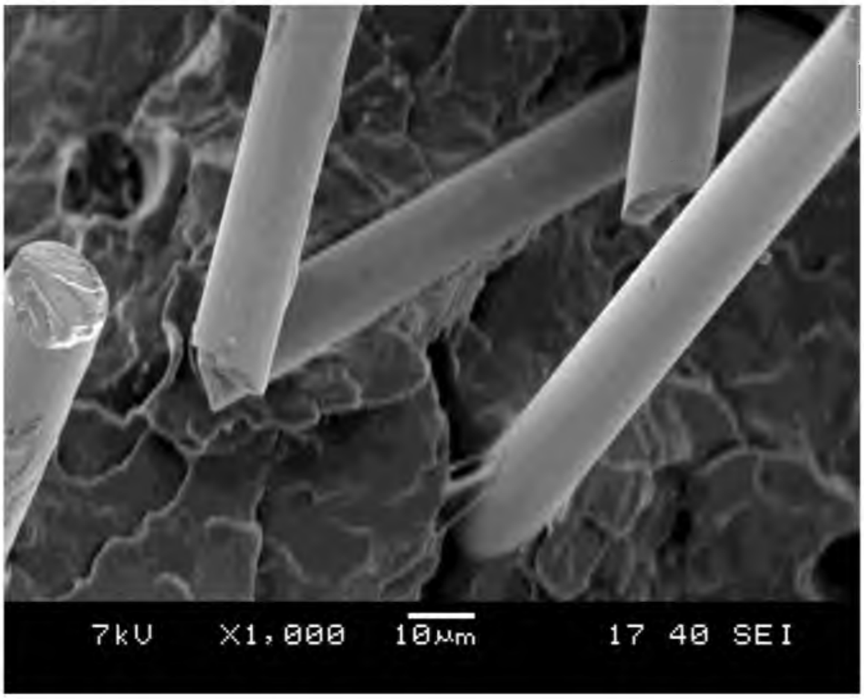


Figure 4.5: 20% Glass Fiber Reinforced PP.

Figure 4.6: 20% Jute-Added PP.

In the continuous jute reinforced polypropylene matrix test samples were produced with a thickness of 4 mm, the damaged surfaces of specimens were examined as a result of tensile tests in detail with the scanning electron microscope (SEM). The SEM images of the samples containing the woven fabric structure that comprises the composite specimens, which are subjected to tensile testing and composed of test result refractive surfaces, are investigated according to the contribution ratio of the jute.

One of the most important factors in the CFRC materials used in this study is the ability to wet the reinforcement material by the matrix materials. It is very important to observe this situation. The inability of a reinforcement material to be dampened by the matrix relates directly to the mechanical values of the structure. For this reason, the most important consideration in the selection of materials during the first design periods of the composite construction work is the compatibility and processability of the matrix and the reinforcement.

To observe this situation, SEM is the preferred imaging tool. Of the composite material used in the studies, the wetness between matrix-reinforcement was looked at. It is observed that the matrix can soak the reinforcement as the photos show the shapes.

Figures 4.7, 4.8 and 4.9 give SEM images of 2.5% Jute added PP, 5% Jute added PP and 10% Jute added PP, respectively.

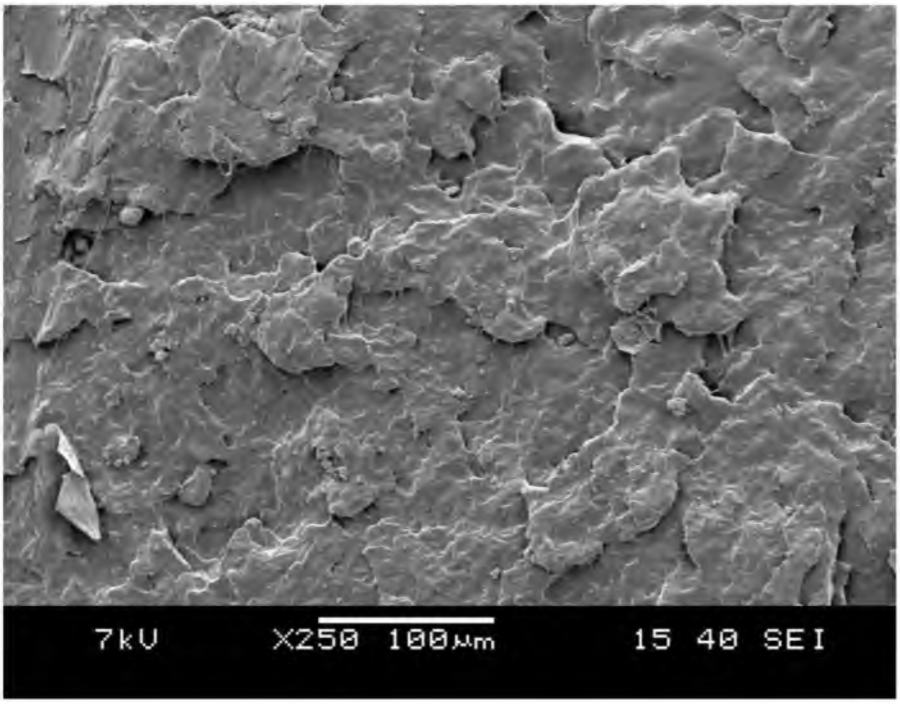


Figure 4.7: 2.5% Jute added PP.

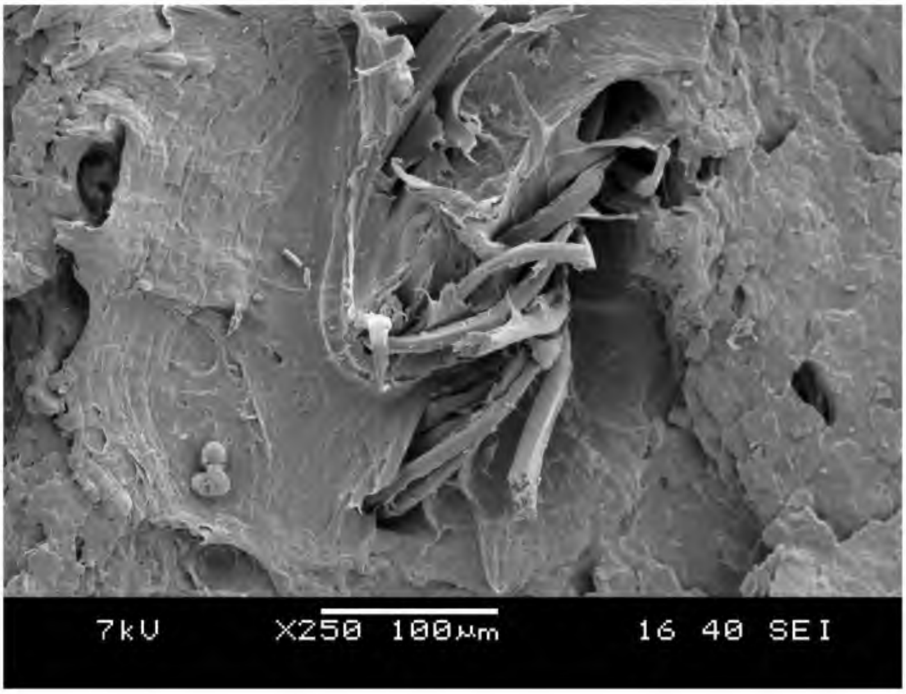


Figure 4.8: 5% Jute added PP.

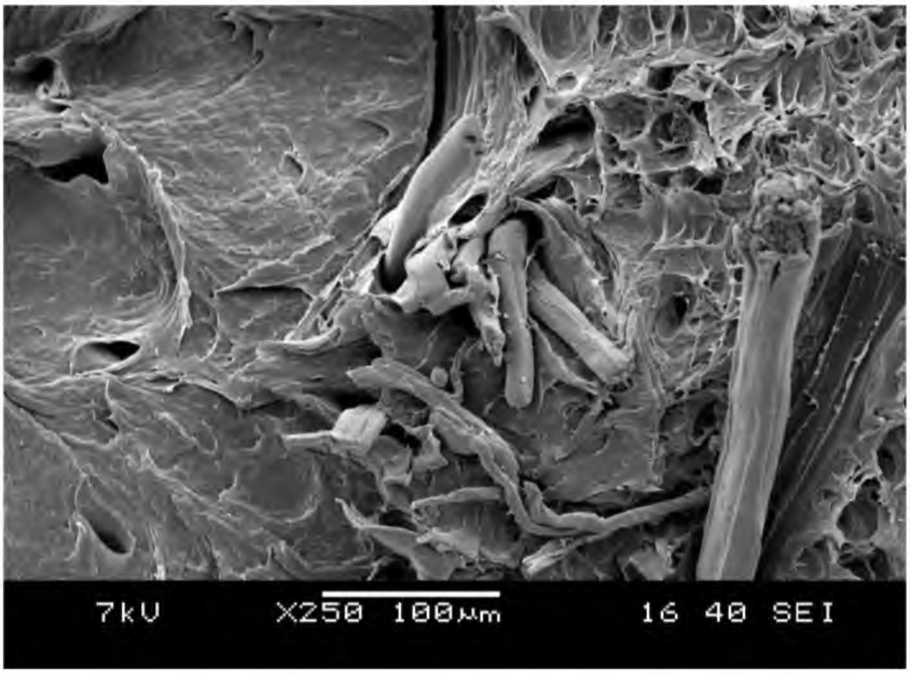


Figure 4.9: 10% Jute added PP.

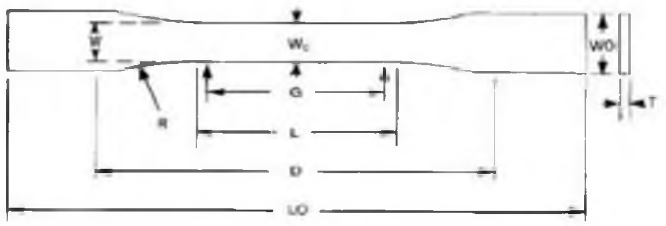
4.3.1 Interpretation of the microstructure according to sem images

As examined from the SEM images, a homogeneous dispersion is achieved at the lowest jute rate. The homogeneous structure is lost with increased jute ratio and jute fibers in the form of the structure become apparent. The same homogeneity at every point of the mixture cannot be delivered, following 5% jute addition is not fully formed by the polypropylene with the direction of the fibers and the controllability is low during production. When the material is examined after the tensile test, gaps in the internal structure have occurred. The jute was not dissolved in PP, which caused a decrease in both strength and MFI values.

4.4 Mechanical Test Results and Interpretation

4.4.1 Tensile testing

Tensile testing of materials was carried out using a Shimadzu AG-100 tensile test instrument in accordance with the ASTM D638-08 standard. Specimen dimensions were determined according to the relevant standard "Type 1" due to the values of the specimen thicknesses at 7 mm and below. In the tests, at least 5 samples were tested for each type of material. The average of the five tests are taken. Together with the force-extension data, the elasticity module values of the materials were also obtained. The tensile tests were carried out at room temperature and set to 50 mm/min as the extension rate. Figure 4.10 gives the tensile test specimen shape and dimensions.



Specimen Dimensions for Thickness, T, mm [in.][A]

Dimensions (see drawings)	7 [0.28] Type I	Tolerances
W—Width of narrow section[E,F]	13 [0.50]	±0.5 [±0.02][B,C]
L—Length of narrow section	57 [2.25]	±0.5 [±0.02][C]
WO—Width overall, min[G]	19 [0.75]	+ 6.4 [+ 0.25]
WO—Width overall, min[G]	...	
LO—Length overall, min[H]	165 [6.5]	no max [no max]
G—Gage length[I]	50 [2.00]	±0.25 [±0.010][C]
G—Gage length[I]	...	±0.13 [±0.005]
D—Distance between grips	115 [4.5]	±5 [±0.2]
R—Radius of fillet	76 [3.00]	±1 [±0.04][C]
RO—Outer radius (Type IV)	...	±1 [±0.04]

Figure 4.10: Tensile test specimen shape and dimensions.

In the study, raw (non-reinforced) low density polypropylene and volumetric materials were produced by 2.5%, 5%, 10% , 15% and 20% jute. Figure 4.11 shows the specimens used in tensile testing

Figure 4.11: Specimens used in tensile testing.

Jute-PP specimens with different proportions of granules from the injection molding machine were prepared by feeding the above-mentioned measurement sizes. In Table 4.1 the maximum force values as a result of tensile testing are given, with the average value added at the right hand side of the table.

Table 4.1: Maximum force values as a result of tensile testing.

SAMPLE TYPE		TENSILE TEST RESULTS MAXIMUM FORCE(N)					AVERAGE(N) VALUE
J0	PP RAW MATERIAL	888,618	911,919	871,436	910,315	870,616	890,580
J1	%2,5 J-PP-MAPP	844,113	950,448	981,331	976,753	897,233	929,975
J2	%5 J-PP-MAPP	998,004	942,771	922,601	903,193	901,763	933,666
J3	%10 J-PP-MAPP	875,489	831,397	809,987	862,217	795,778	834,973
J4	%15 J-PP-MAPP	846,179	727,558	788,895	843,064	849,072	810,953
J5	%20 J-PP-MAPP	897,408	913,366	936,366	869,465	868,082	896,937
MH418	PP(PETKIM)	631,221	627,534	628,430	630,312	629,412	629,381
GF5	%20 GF-PP	1829,82	1935,51	1869,04	1880,314	1877,610	1878,458

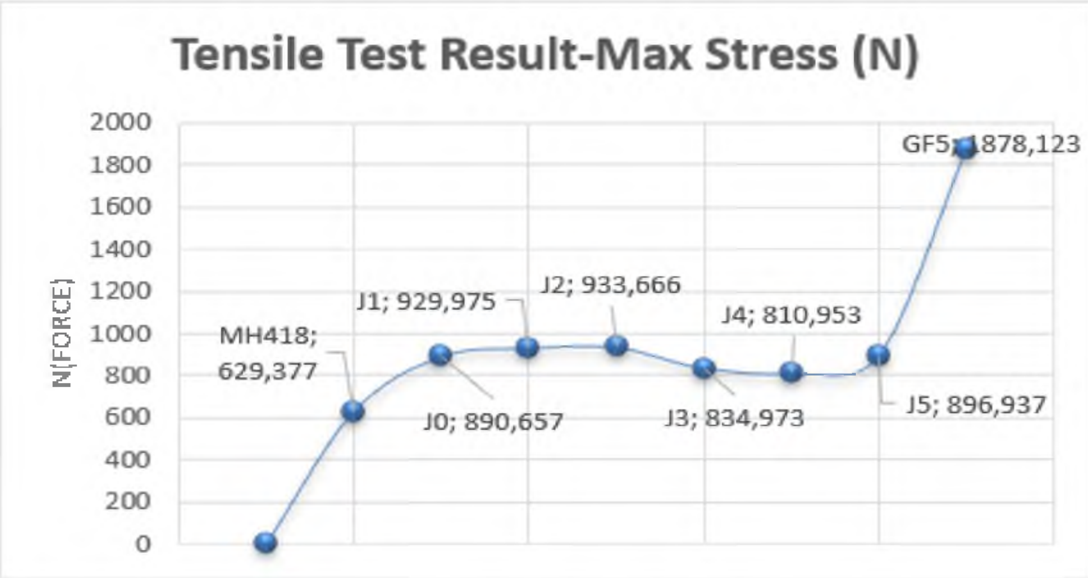
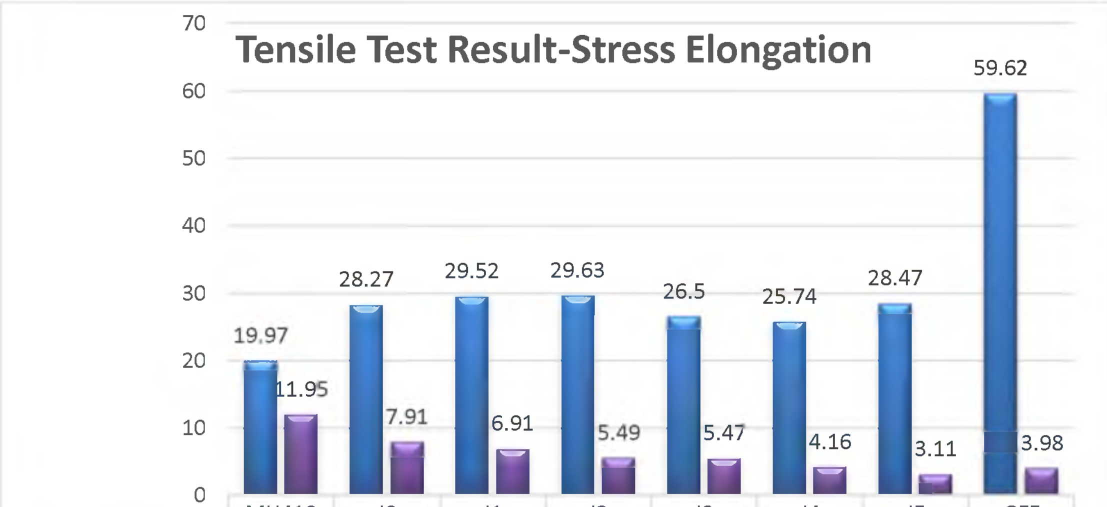


Figure 4.12: Tensile Test Results.



	MH418	J0	J1	J2	J3	J4	J5	GF5
Max Stress N/mm²	19.97	28.27	29.52	29.63	26.5	25.74	28.47	59.62
Max Elongation(%)	11.95	7.91	6.91	5.49	5.47	4.16	3.11	3.98

Figure 4.13: Tensile Test Result Charts.

4.4.2 MFI testing

The tensile strength of the control specimen without a natural reinforcement agent (jute) was 28.3 MPa, this value has increased to 29.6 MPa in PP/jute composite material containing 5% jute, while the extension value of fracture decreased from 7.9% (control) to 5.5%. In the study carried out, it was determined that jute was effective in the increase of tensile strength of PP material, but it reduced its elasticity. These results are summarized in Figures 4.12 and 4.13.

Table 4.2: MFI test results.

SAMPLE TYPE		**MFI Values of Samples**			
		FIRST WEIGHING(30s)	**SECOND WEIGHING(30s)**	**THIRD WEIGHING(30s)**	AVERAGE **(g/ 10 min)**
J0	PP RAW` MATERIAL	0,324	0,331	0,3255	0,3268
J1	%2,5 J-PP-MAPP	0,4043	0,405	0,4008	0,4033
J2	%5 J-PP-MAPP	0,5119	0,5043	0,5037	0,5066
J3	%10 J-PP-MAPP	0,4328	0,453	0,485	0,4569
J4	%15 J-PP-MAPP	0,322	0,3126	0,3059	0,3135
J5	%10 J-PP-MAPP	0,1591	0,1521	0,1571	0,1561
MH418	PP	0,1571	0,160	0,170	0,1605
GF5	%20 GF-PP	0,074	0,071	0,072	0,072

Table 4.2 has been presented which shows the MFI test results. As a result of the analysis of the PP and jute wastes in the experimental studies, an increase of % 5 in the value of the MFI was observed for the added jute-PP mixture. However, when % 10 jute was added, and in parallel to the tensile test results, a decrease parallel to the increased fiber ratio was observed in the MFI value. Although not very pronounced, reduction were observed in the modulus of elasticity and extension values. The reason for these two conditions is that the radicals formed during the reprocessing of the material cause cross-

linking or branch in the chains and hence cause the hardening of the material. Figure 4.14 the MFI test results are summarized.

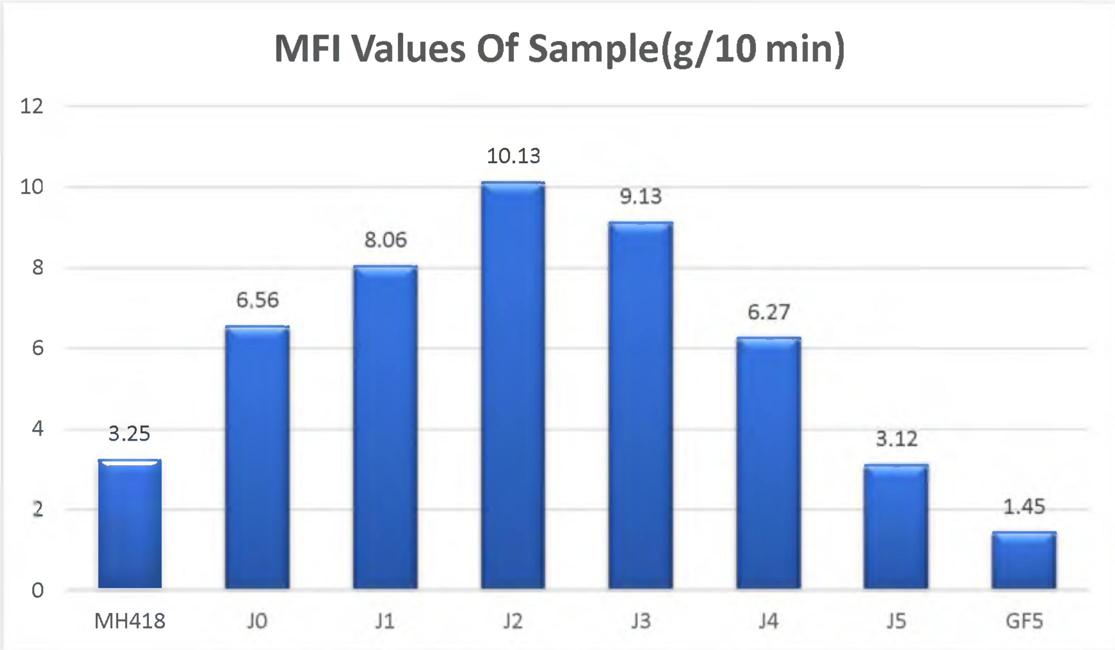


Figure 4.14: MFI Test Results Chart.

4.4.3 Density Testing

Table 4.3: Density Test Results.

DENSITY TEST RESULTS				
SPECIMEN	**FIRST MEASURE**	**SECOND MEASURE**	**THIRD MEASURE**	**FOURTH MEASURE**
GF20	0,9540			
J0	0,8947	0,8939	0,8828	0,8832
J1	0,9017	0,8577	0,8872	0,9037
J2	0,9089	0,8833	0,9033	0,8692
J3	0,8003	0,8035	0,8281	0,8342
J4	UNMEASURED <0,7800			
J5	UNMEASURED <0,7800			

Density test results are presented in Table 4.3. According to the results of the mixture density test, the sample density of the natural reinforcement agent of J0 was 0.8832, for the 2.5% jute additive pp mixture the density value was 0.9037, for % 5 jute additive pp the density value was 0.8692, and density value of 0.8342 was observed for the% 10 jute-PP mixture. The density values measured in % 15 and % 20 J-PP mixture remained below the lower limit of 0.7800 and the desired values were not reached.

5. CONCLUSION

The PP/jute mixture materials were placed into a double screw extruder at a temperature of 190 ºC. After obtaining PP/jute mixture granules, standard tensile test specimens were produced at 180 ºC temperature in the injection molding machine and the physical and mechanical properties of composite material were examined. The tensile strength (28.3 MPa) of the control specimen without the natural consolidation agent (jute) was seen to increase with the PP/jute composite material containing % 5 jute, to 29.6 MPa and the elasticity value of fracture decreased from 7.9 mm (control) to 5.5 mm. In the study carried out, it was determined that jute was effective in the increase of the tensile strength of PP material, but it reduced its elasticity and it was confirmed that jute has the potential for use in composite production as a natural reinforcing agent.

According to tensile test results, tensile strength values for % 10, % 15 and % 20 jute/PP mixture decreased in tensile strength, when compared to the % 5 jute/PP material, by % 10.5, % 13.1 and % 3 respectively. The extension values were observed to have decreased from 5.5 mm at % 5 jute/PP, to 5.47 mm, 4.16 mm and 3.11 mm, in order of % 10, % 15 and % 20 jute/PP mixture, respectively. It was seen that the desired tensile strength values, with fibers added above the % 5 jute ratio were partially reached. The reason for this can be explained as, thermoplastic material production in today's technology using the double screw extruder addition method of the mixture is difficult to control and the desired proportion of polymer and fiber waste to be fed to the extruder was not done precisely. Therefore, it can be said that the desired homogeneous structure in the material cannot be fully provided.

According to the results of the MFI test, an increase in the MFI value was achieved by % 5 jute additive to the jute-PP mixture. However, by adding 10% jute, the test was observed to decrease in parallel to the increasing fiber ratio of the MFI value in parallel to the tensile strength of composite.

In SEM analysis, a homogeneous dispersion is achieved at the lowest jute rate. With increased jute ratio, the homogeneous structure has been lost and the fibers have changed direction, so the fiber is not obtained in the desired strength and the polymer and fiber cannot be connected to the desired level. Therefore, it is seen that in the material interior structure the desired homogeneous distribution was not available.

However, with the appropriate production method and improvements in the process, the results obtained by a systematic feeding method are thought to be better.

It is thought that widespread use of the jute, especially as a plant based fiber with appropriate production conditions, will contribute to the cost advantage and the removal of environmental problems.

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