Preparation and characterization of natural fibres reinforced polymer composites

By

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CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Signature of the Candidate

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Registration Number: 23
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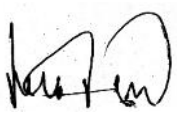
CERTIFICATION

This is to certify that the thesis entitled "**Preparation and Characterization of Natural Fibers Reinforced Polymer Composites**" being submitted by Md. Farhad Ali, Registration No. 23, Session: 2017-2018 (Re: 2022-2023), Department of Applied Chemistry and Chemical Engineering, University of Dhaka, in partial fulfillment of the requirement for the degree of Doctor of Philosophy, is an original study of the author carried out under our joint supervisions. No part of this thesis has been submitted before to any other University or institute for the award of any degree or diploma.

Supervisor



(Dr. A.M Sarwaruddin Chowdhury)

Professor

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Dedicated

To

My Beloved Teachers, Parents and Family

Acknowledgement

All praise is due to the almighty Allah; the most Gracious and the most Merciful.

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ABSTRACT

The ever-increasing quantities of trash produced by the poultry and tannery industries, particularly chicken feathers, cow hairs, and waste leather fibers, pose serious challenges to maintaining a pristine natural environment. Throwing away used chicken feathers is not only wasteful, but also harmful to the environment. However, rising demand for the synthetic polymer is also a major roadblock on the path to sustainability. Polluting the environment and making life more difficult, synthetic polymers are mostly to blame. Waste management and reducing the use of non-biodegradable polymers pose serious obstacles to achieving a clean and sustainable environment. By combining recycled chicken feather fibers (CFF), cow hair fibers (CHF), and leather fibers (LF) with inorganic materials and unsaturated polyester resin (UPR) through a hand lay-up process, this study successfully reduced environmentally hazardous waste from the poultry and tannery industries. The mechanical characteristics of the matrix were improved by including waste fibers at various weight percentages (2, 5, 7, 10, 12, and 15% by weight). These fibers' availability as waste and their reinforcing quality allowed for their usage in the production of low-priced items that reduced pollution to the environment. To improve the composites' mechanical characteristics, many other chemicals, including ZnO, $CaCO_3$, and Al_2O_3, were included into the matrix. The treated chicken feather fiber-based composites gave the better results than that of untreated fiber based composites. When inorganic materials were added as filler in UPR, the prepared composites revealed better results than the neat composites. The composites showed the best overall mechanical properties in the tensile strength (TS), tensile modulus (TM), bending strength (BS) and bending modulus (BM) when 5% of chicken feather and cow hair mixed fiber was used and ZnO was added as filler compared to the other composites. The highest enhancements of TS, TM, BS, and BM were 94%, 159%, 215%, and 528% respectively for optimized composites than those of the control sample UPR. Again, for optimal composite, increments of TS, TM, BS and BM were 3%, 0.68% and 1.95% and 0.16% than those of CFF based composite, 7%, 20%, 2.77% and 0.80% than those of CHF based composite and 39.74%, 11.65%, 27% and 52% than those of LF based composite. FTIR and scanning electron microscopy (SEM) provided strong support for mechanical rather than chemical connection between fiber and UPR. The helical structure of the composites disintegrated in thermogravimetric analysis (TGA), losing its chain-linkage skeleton and peptide fiber bridges, dissolving keratin and collagen into carbon dioxide (CO_2), hydrogen sulphide (H_2S), and hydrogen

cyanide (HCN). The results of water uptake and thickness swelling study for up to 15 days showed good mechanical properties even for potential applications in a humid environment of animal fiber reinforced composites. Degradation values in five media, including compost, soil, brine, and weather for 90 days, suggest that the composites have potential in a variety of settings. The characteristics of composites were considerably enhanced by the use of waste materials. In comparison to chemically treated fiber based composites, gamma modified fiber exhibited superior tensile characteristics. Images of the fiber and fracture surfaces within the composites were taken in order to analyze the mode of failure and learn more about the interfacial adhesion between the fiber and matrix

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Abbreviation

Elaboration

UPR = Unsaturated Polyester Resin

MEKP = Methyl Ethyl Ketone Peroxide

CHF = Cow Hair Fiber

UTCHF = Untreated Cow Hair Fiber

TCHF = Treated Cow Hair Fiber

CFF = Chicken Feather Fiber

TCFF = Treated Chicken Feather Fiber

UTCFF = Untreated Chicken Feather Fiber

LF = Leather Fiber

TLF = Treated Leather Fiber

UTLF = Untreated Leather Fiber

TS = Tensile Strength

TM =Tensile Modulus

Eb = Elongation at Break

BS =Bending Strength

BM = Bending Modulus

cm^2 = Square Centimeter

N/mm^2 = Newton per millimeter square

FTIR = Fourier transform infrared spectroscopy

TGA = Thermogravimetric Analysis

SEM = Scanning Electron Microscopy

CHAPTER 1

CHAPTER 1
INTRODUCTION

In modern civilization, agriculture, the environment, and the economy are all profoundly affected by the use of renewable resources. Biopolymers, which are made from renewable raw materials, are gaining significance as a result of the depletion of fossil fuel reserves and new environmental legislation.

1.1 Overview

The different types of natural fibers are based on where they come from plants, animals, or minerals. It is different from artificial fibers because it is cheap, has a low density, and can be broken down by nature [1]. Many authors and researchers have said that feathers have very good physical and mechanical properties, which is why they can stand up to a lot of mechanical stress and different kinds of chemical and thermal treatments without being permanently damaged. This unusual behavior is thought to be caused by structural proteins, which are mostly made of keratin, that are in the feather fiber. Chicken feathers are a waste product of the chicken business. Straight from a processing plant, "raw" chicken feathers were washed with detergent and dried. After the feathers were cleaned, machines to separate the feathers from the quills worked them. After that, the feathers were separated into two piles: one with usable fiber for future textile production, and the other with large feather and quill scraps [2]. To create nonwoven batting, the fibers from chicken feathers were combined with binder fibers (sheath/core construction). Comparing the battings to comparable goose down and polyester fiber battings, they perform a decent job of holding heat [3]. Every year, chicken processing plants dump billions of kilos of feathers, which is a sizeable quantity of solid waste. Feathers account for a sizable portion of the garbage produced by the chicken business [4]. The maximum weight of a bird's feather is 125 grams, therefore each week, around 3000 tons of feather waste are created worldwide [5]. Getting rid of this large amount of trash is a global environmental problem because it pollutes land and underground water. Proteins make up more than 90% of feathers. Keratin is a structural protein that appears in two forms and is characterized by its fibrous nature, insolubility, and high number of disulfide bonds. Keratin is made up of several amino acids, but cysteine, lysine, proline, and serine make up most of it [6]. Cross-linking occurs between these amino acids through the formation of disulfide or hydrogen bonds. That's how you get fibers that

aren't only durable, but also incredibly strong, lightweight, and soundproof [7] [8]. Bangladesh's commercial chicken farming has grown quickly, and it is one of the country's new and important industries that has been making a growing contribution to the economy. The poultry industry is making a big difference in reducing poverty, poor nutrition, and unemployment. At the same time, chicken farms make many different kinds of waste. The main things that make up this waste are chicken poop, bedding, leftover feed, dead chickens, broken eggs, packing materials, and feathers. Waste from the supplies used to clean and transport birds is also included [9]. According to Grazziotin A [10], a chicken's feathers can account for up to 10% of its whole-body weight. Technology growth in the current era depends on advancements in the realm of materials. Inadequate materials can render even the most well-thought-out structural design ineffective under the combined effects of service loads and the elements. The availability of resources is the ultimate limiting factor in the rate of progress that may be made in any field of study. Composites represent a significant step forward in this effort to develop superior materials [11]. The idea of using composites is not exactly ground-breaking. Composite materials are a common concept in nature. When it comes to materials, scientists, engineers, and researchers are constantly working to improve upon current materials or create entirely new ones. One example of the second group is a composite. In all manufacturing industries, it is important to make parts that are good for the environment, light, and strong. In any manufacturing process, the parts that are made should be light, strong, attractive, cheap, and good for the environment. To make composites stronger and stiffer, fibers are mixed into a resin. Injection molding, compression molding, and resin transfer molding are three different processes for creating composites. Fiber orientation, fiber aspect ratio, form factor, and fibre resin interfacial contact are all contributors to a composite's overall strength. The direction of the fibers can vary depending on how the composites are manufactured [12]. In this study, a natural fiber-reinforced polymer composite is fabricated by combining unsaturated polyester resin (UPR) as the matrix material with chicken feather, cow hair and waste leather fiber as the reinforcement [13]. As a composite reinforcement, CFF, CHF and LF have some interesting qualities, such as being light, insulating well against heat, making good sounds, not scratching easily, repelling water well, and being stiff. Martinez et al. found that the hydrophobic nature of CFF, CHF and LF sclera-protein bio-fibers lets them distribute well inside polymers and stick to them well. They also found that CFF, CHF and LF,-reinforced composites have good thermal stability and low energy loss [14].

Nowadays, most advanced technologies trying to move from non-renewable resources such as. Fossil Fuel, Minerals and metal ores etc. to the renewable resources. They are more likely to employ renewable resources that are easier on the environment in production and industrialization.

Biodegradable and eco-friendly bio composites and bio-polymers are the focus of much research. Now the lifespan of the bio composites and biopolymer materials can be controlled. Recently, this has become an area of interest because it's application and specialties. As it has become a renewed attention for both of the industries and academies for new generation composites and biopolymers, the timely review was presented. There were papers on natural fibers booth the animal and plant fibers reinforced polymer composites which were reviewed by several authors. As the Animal fiber reinforced composites' physical and mechanical properties were presented here, the previous work done on these animal fibers are presented here. Various types of keratinous Animal fibers like. Goat hairs, Cow hairs, Human Hair etc. were used for the research purpose.

The composites were prepared using polyester resin and reinforcing it with cow hair from Zebu breed cattle in Nigeria. The hairs were collected from the tails portion of the cattle and was about 10 cm long. They had treated fibers with NaOH solution. The composites were made in hand lay-up technique at ambient temperature. The fiber loading was 0%, 5%, 10%, 15%, 20% of the total weight. The abrasion Resistance, Hydrophobicity and ultimate tensile strength (UTS) were at their peak at 4% weight. The UTS was 10 MPa, whereas the Young's and flexural moduli were 756 MPa and 5179 MPa, respectively. 35 MPa at 20%wt was the greatest figure for flexural strength. [15] Using cow hair, an organic solid waste, they also created animal fiber-based polyester resin composites that are environmentally beneficial. For the matrix's random dispersion, short fibers were required. NaOH was used to treat some cow hair fibers, which were then chopped to 10 mm length. The composites were created using an open-mould manufacturing approach. The samples underwent two curing processes: the first after manufacture and the second 27 days before to testing. Mechanical properties were found to be superior in the untreated cow hair reinforced composites when compared to both the treated composites and the control sample [16].

The tanneries and leather industries provided the fibres used to create the cow hair studded unsaturated polyester resin composites. Hand lay-up was used to create the composites. Fiber loading was 2,5,7,10,12,15 and 20% of the weight. The mechanical properties like Tensile Strength, Bending Strength, Bending Modulus, Tensile Modulus were measured and FTIR, SEM and water uptake were analysis. The best results were found for 5% fiber loaded composites [17]. The commercial application of animal fiber (human hair) waste is observed in India. The composites were made by using human hair with polypropylene (PP). Two roll mills were used to combine human hair and polypropylene at weights of 5%, 10%, and 15%. When compression moulding, certain conditions had to be met. The hair reinforced polypropylene (PP) composites showed better Impact Strength

and Flexural Strength than the control sample polypropylene [18]. The polymer composites were prepared with the collected cow hair fibers from the tannery wastes and leather industries and Low Density Polyethylene (LDPE). The LDPE was recycled from the water sachets and other plastic wraps which are made of LDPE. Melt combining the scraps and using a hot compression moulding process yielded the composites. Cow hair fibres were treated with 0.2 M H_2O_2, 0.2 M KOH, and 0.2 M NaOH to improve their adhesive qualities. To observe the mechanical and physical properties the fibers loading was varied from 0-50% of the weight with the intervals of 10% weight. Chemically treated fibers added composites showed better results [19].

Tannery industries discharge a vast amount of solid waste which are polluting the environment, this hazardous leather waste disposal contaminate the waste lands [20]. Recycling of this solid wastes may save the environment because of the toxicity of solid waste, it should be managed properly [21]. Leather disposition is a very severe issue because the chromium used in the trimming process can change valence under particular and temperature circumstances, changing from trivalent chromium(Cr+3) to hexavalent chromium(Cr+6) , a very poisonous and carcinogenic metal [22]. As a result, releasing a large volume of leather of garbage in the atmosphere might contaminate water bodies and land, the importance of environment friendly composite materials are going all the time. This study aims to employ leather fiver in conjunction with polymer. So that the newly formed composite material can be used in various engineering purposes. Unsaturated Polyester Resins (UPR). As the matrix for this investigation with wet blue leather trimming dust and buffing dust as reinforcement components. The 0.25 M NaOH was used to chemically treat the reinforcing fibers. Mechanical properties of leather fiber/polymer composites were studied by measuring their tensile strength, tensile modulus, abrasion resistance, elongation at break, tear strength, shore hardness and using scanning electron micrograph analysis. The results of the characterization show that these composites might be utilize to replace traditional construction equipment sheet, O ring and insulation materials. Leather waste can be used as filter polymer composites to make useable industrial products. The biodegradable nature of this composites is the prime need for green environment and these composites can be the alternative of synthetic polymer composites. So, the utilization of leather fibers (buffing dust and trimming dust) lowers manufacturing costs of the composites as well as reduces environmental pollution.

Innovative methods have been created for underdeveloped countries in order to use animal fibers as a raw material to generate high-value products at competitive prices. Waste leather fibers are currently used to manufacture products that have an impact on the environment, such as gelatin and glue, but

chicken feathers and cattle hair are not in our country. The animal fiber reinforced composites have a high potential for increased utilization and a wide range of applications. Composite materials based on animal fiber can be used to replace a variety of plastic items made of nondegradable polymer. The stability and expansion of our economy can benefit greatly from the use of composites made from animal fibers. Moulding, furniture, windows, doors, bathtubs, partition boards, storage tanks, toys, etc. may all benefit from its usage.

1.2 Objectives

The study's overarching goal is to enhance the mechanical qualities of composites made from waste leather, chicken feather, and cow hair using an unsaturated polyester resin matrix. These composites would be environmentally benign, lightweight, and aesthetically pleasing. To achieve this goal, animal fibers will be chemically and physically modified, and inorganic elements will be included as filler.

The goal of the project is to reuse waste from the leather business in the composite sector and prevent environmental pollution by employing trash from the poultry and tannery industries. Bangladesh is a developing nation, therefore industry and urbanization often need to be balanced with environmental goals. The preparation of low-cost, lightweight, high-strength goods for a range of applications is another goal of this study. Examining the viability of employing animal fibers as reinforcement on thermoset matrix UPR is the other purpose of this research.

The goal of this research was to encourage the use of animal-based natural fibers in place of synthetic ones for making composites out of unsaturated polyester resin. This was necessary because thermosetting plastics like polyester have brittle fractures, and there is increased interest in using sustainable, eco-friendly materials that were once thought of as garbage. The study was done in an effort to lessen the environmental problems that cow hair creates while also promoting the usage of cow hair in engineering applications. The objective of this study was to construct reinforced polyester composites from fibers of treated waste leather, feathers from chickens, and cow hair while also analyzing the mechanical properties of the composites, including their water absorption, swelling under test conditions, and degradation in various media, among others. Several technical techniques, including IR (infrared spectroscopy), SEM (scanning electron microscopy), and Thermogravimetric Analysis (TGA), were employed to analyze the composites.

There are five chapters in the thesis. This thesis' second chapter will analyze the pertinent literature on animal fibers and animal fiber composites, with a focus on chicken feather, cow hair, waste leather, and their composites.

CHAPTER 2

CHAPTER 2

Literature Review

The majority of organic fiber that exists naturally originates from either plants or animals. With the exception of wool and silk, most appealing natural textile fibers are created by plants. All plant fibers are composed of cellulose, as opposed to the proteins found in fibers derived from animals. Natural animal fibers are a better choice for use in composite materials since they are often stronger and stiffer than their plant counterparts.

2.1 Animal fiber

Natural fibers (such as cellulose, mineral, or animal fibers) or synthetic fibers manufactured by humans are both used as reinforcement materials (glass, carbon and polymer). The emphasis in this case is on artificial glass fibers, which make up the majority of the massive, affordable buildings. After plant or vegetable fibers, animal fibers are the most often used natural fibers. They typically contain proteins and are possible composite reinforcements. This fiber can be found in animals such as sheep, goats, lamas, rabbits, musk oxen, and sheep. Silk, feathers, and hair can also be found in a variety of places.

2.2 Comparison of natural fibers

Rope, thread, clothing, rugs, and other textiles and décor have all been crafted from cellulose fibers for centuries or perhaps millennia. Wood fibers are the most widely used kind of cellulose due to their widespread application in the paper and pulp industries. But other fiber types are increasingly used. Table 2.2 mentions the utilization of additional fiber kinds.

Table 2.1 outlines the origins and examples of natural fiber [23].

Source of fiber	Example
Grasses and Reed	The stems of plants with monocotyledons like bamboo as well as sugar cane are rich sources of these fibers.
Leaf fiber	Most monocotyledonous plants, such as sisal, henequen, and abaca, contain fibers that run longitudinally through the leaves.
Blast fiber	The phloem, or inner bark, of the stems of dicotyledonous plants is where these fibers are located. Kenaf, flax, hemp, and jute are all examples of such plants.
Seed and fruit hairs	These fibers, which primarily come from seed hairs and flosses, include cotton as well as coconut.
Wood fiber	The xylem of both gymnosperm (softwood) and angiosperm (hardwood) trees contains these fibers. Spruce, pine, and maple are all great examples.

Table 2.2 Commercially important fiber sources [23].

Fiber Source	Species	World Production (10^3 tonnes)	Origin
Wood	(>10,000 species)	1,750,000	Stem
Cotton lint	*Gossypium sp*.	18,450	Fruit
Bamboo	(>1250 species)	10,000	Stem
Jute	*Corchorus sp.*	2,300	Stem
Kenaf	*Hibiscus Cannabinus*	970	Stem
Flax	*LinumUsitatissimum*	830	Stem
Sisal	*Agave Sisilana*	378	Leaf
Coir	*CocosNucifera*	100	Fruit
Ramie	*Boehmeria Nivea*	100	Stem

Abaca	*Musa Textiles*	70	Leaf
Sunn hemp	*CrorolariaJuncea*	70	Stem
Roselle	*Hibiscus Sabdariffa*	250	Stem
Hemp	*Cannabis Sativa*	214	Stem

Several physical parameters determine whether cellulose fiber is suitable for use in composites. Some of the most important factors that must be considered are the fiber's dimensions, defects, variability, crystallinity, and structure. The selection of a fiber for composite reinforcement is mostly driven by its mechanical qualities. Using a reinforcing fiber with greater strength is essential for producing a high-quality composite.

For a composite to be strong, nevertheless, excellent fiber dispersion, optimal fiber orientation, and proper matrix-fiber bonding are also essential. The sole factor that affects composite strength is fiber strength. Another element that might affect fiber choice is the cost of the cellulose fiber. Prices for fiber frequently shift dramatically and are influenced by a variety of variables, including supply and demand, quality, and currency exchange rates. Table 2.3 provides a comparison of the relative costs of several fibers. Although the price of cellulose fiber in bulk is far less than that of glass and carbon, it still needs to be processed in order to be utilized in composites. In spite of this, cellulose fiber still seems to be less expensive than synthetic fibers.

Table 2.3 Cost of natural plant fibers [23].

Fiber Type Price	$US/Kg
Bamboo	0.5 -1. 0
Jute	0.3-0.7
Flux	0.4 -0.8
Hemp	0.5 – 1,5
Wood	0.2 – 0.4
Sisal	0.4 – 1.0
Carbon	10 – 200

Glass	1.5 – 3.2

According to Table 2.4's data, jute, hemp, and bamboo fibers are the strongest among all of them, with the highest Young's modulus values. These qualities make fibers that are utilized as reinforcement in composite materials appealing. Although certain synthetic fibers have higher Young's modulus values than others, their lack of cost-effectiveness and biodegradability make them undesirable in particular industries.

In this research, bamboo was employed to strengthen a composite material. Because of its rapid growth, high mechanical strength, and ease of processing, bamboo is a renewable resource with many practical applications. It inhabits the tropics and subtropics of Asia, Africa, and Latin America.

Table 2.4 Properties of natural fiber in relation to those of E-glass [23].

					fiber					
Properties	E-glass	Hemp	Jute	Ramie	Coir	Sisal	Flax	Cotton	Kenaf	Bamboo
Density, g/cm^3	2.55	1.48	1.46	1.5	1.25	1.33	1.4	1.51	-	1.4
Tensile strength, (MPa)	2400	550-900	600-1100	500	220	600-700	800-1500	400	930	500-740
Young's modulus, (GPa)	69	50-70	10-30	44	6	38	60-80	12	-	30-50
Specific stiffness, (MN.m/kg)	27	34-47	7-21	29	5	29	43-57	8	-	-
Elongation at failure, (%)	3	1.6	1.8	2	15-25	2-3	1.2-1.6	3-10	-	2-5

Ply-wood was created in the 1940s, and bamboo and wood were quickly applied to the construction of girders, walls, pillars, rafter frames, bamboo mixed structures, and interior decorations. Three

situations exist where modern bamboo structures can be used, each with different requirements: Low-cost practical structures, temporary constructions, such as

a structure used for rest or exposition, as well as a luxurious villa, a tearoom, etc. Yet with better growth methods, bamboo has the potential for substantially larger fiber production, which might lead to cheaper costs [24]. Bamboo, when compared to other fiber, also has the benefit of having a high level of disease and pest resistance. It may also be planted in dense plantings to prevent weeds from developing in between the plants. Because bamboo cannot be grown using pesticides or herbicides, it has a major advantage over other fibers in many nations where herbicide usage is heavily regulated [25].

Fiber is the main component of a substance made up of fibers and other components. They provide a significant contribution to the volume of the composite. Reinforcing fibers can only withstand tensile strains. The matrix in fiber-reinforced composites allows the fiber to contribute the majority of the composite's strength and stiffness. Chicken feather fiber is widely available in our country and makes excellent composites. Feather fibers are a byproduct of poultry. Waste feathers from poultry processing plants add to solid waste issues [26]. Feathers are keratin structures that are hierarchically branched. They are one of the most intricate keratin structures discovered in vertebrates. Every year, millions of tons of chicken feathers are discarded globally. Creating and discarding feathers in Asia, especially India, adds to urban pollution. Because of this, feathers are used in consumer items. CFF's fibers may strengthen composites. CFF is constantly accessible; therefore, it may be used in less-strengthening consumer composites. Composites with CFF are cheaper. Fiber-reinforced polyester composites are used in India. These items are handcrafted nationwide. Rich nations create most feathers from meat processing. Indian habits cause massive feather production. This dispersed chicken feather supply works nicely with India's fiber composite facilities. The hard-to-remove feathers have various uses. New data shows feather meal can transmit illness [27]. Therefore, feather fiber is utilized increasingly. US, Europe, and Australia need 60% biodegradable automobile interiors. Natural fibers offer another benefit. Biodegradable feather fibers are superior to synthetics. India has feathers. Unlike natural fibers, it is accessible year-round. Small Indian production units employ bucket-and-brush manual lay-up. This paper examines if chicken feather fiber may strengthen polyester composites. The quill is the feather's central shaft. Quills have barbs. From barbs, barbules, and hook lets. All feather sections, including the quill, are comprised of keratin. The sequence of amino acids in feather keratin distinguishes quills from barbs [28,29]. Quill and barb are composed of -keratin (sheet) (helix). Barb and 8 barbule operate and appear differently from quill.

The rigid, thin quill that appears like a sheet is not fiber. The barb, barbule, and hook let's are all soft fibers. CFF is an ideal composite fibre since it is self-adherent, has a high tensile strength, and maintains a consistent diameter. Of the 95 amino acids in keratin, 40% love water and 60% detest it [30]. Experts say 50/50. Both resins that love and hate water can be used with feather fiber. Feathers have been used for a very long time. [31,32]. Due to the quantity of poultry farms that generate meat, processing factories have a lot of chicken feathers. Eggs and meat are chickens' main uses. Layers can live 500 days before being murdered. Broilers are reared for 55 to 60 days before being slaughtered. Layers' feathers are mature, robust, and older. Younger broiler feathers are delicate and sensitive. Chickens have long, stiff flying feathers like other birds (shorter and softer). Broiler chicks have over 80% down or after feathers, whereas layers have less than 60%. Fibers must have strong tensile strength, a consistent diameter, and an aspect ratio of 50 or higher. Feather fiber almost meets all four needs [33]. CFF may be used as a renewable raw material to supplement existing supplies since it is accessible and simple to work with. Unlike glass fibre, CFF does not pose health risks to workers. Glass fiber has a density that is just half that of chicken barb. Fillers, insulators, as well as filters can all benefit from the usage of feather barbs to reduce weight, but composites cannot. Chickens shed their feathers at an alarming rate [34, 35]. Feather waste may be aerobically digested to help the economy as well as the environment. In addition to producing methane with digested waste for fertilizer [36,37], it is also effective in eliminating viruses from feather waste. Recently, researchers have looked into pretreatments that use chemicals, enzymes, and other biological processes to make feathers more digestible [38,39]. 80 to 95% of feather keratin may be broken down using calcium hydroxide at 150 °C [40].

In many nations, the waste feather generated by the poultry industry is a significant source of solid waste [41, 42]. Cow hair and cut waste leather also significantly contribute to pollution. The protein keratin, an insoluble substance with a high degree of resilience, makes up around 90% of the weight of the fiber found in feathers and quills. Keratin also plays a crucial role in the formation of animal hair, hooves, and horns [43, 44]. Keratins comprise scaffolding proteins that organize the cytoplasm of cells of the epithelium into a latticework of intermediate filaments. Their functional responsibilities include cell development, hair cycle, tissue remodeling, wound healing, and structural maintenance of cells and tissues (Sinclair, 2007). Over 90 amino acids go into the formation of keratin, but the primary ones are cystine, lysine, proline, and serine [45, 46]. Collagen is a fibrous protein that is the main building block of leather. There are 21 different types of amino acids that work together to make polypeptide bonds to form collagen. The strength, lightness, and excellent thermal and insulating characteristics of fibers are due to the cross-linking of these amino

acids with one another to form disulfide or hydrogen bonds [47, 48]. Chicken feather fibers have a tiny (5 micron) diameter and excellent adsorption qualities [49]. By Marc Andre Meyers et al. [50], the structure and mechanical characteristics of proteins have been explored.

In this study, UPR composites made of animal fibers were created, and their characteristics were assessed. Some writers have looked into the properties of natural fiber reinforced composites based on plants and animals [51–55]. Natural fibers have many desirable properties for composites, but they also have a number of limitations, including a high moisture sorption, poor dimensional stability, low heat resistance, isotropic fiber resistance, and compositional unpredictability. Natural fibers must have a high adhesion to be used as reinforcement in composite materials since the fiber-matrix interface determines the macroscopic mechanical properties. To improve adhesion, physical and chemical treatments are used to maximize this contact. For instance, reactive chemical coatings in the fibers result in chemical. For instance, chemical linkages between the matrix and the fibers are created by reactive chemical coatings in the fibers.

2.3 Leather Buffing Dust

The manufacturing of chrome-tanned leather results in the generation of a significant amount of solid waste, a significant portion of which is comprised of leather buffing dust, which is a fine powder consisting of any remaining collagen fibrils after milling and buffing procedures. As one of the most difficult types of tannery waste to manage, it is disposed of using practises that involve landfills and incinerators at the present time. Several investigations have been conducted in the scientific literature concerning its application in the formulation of composites. As a filler for a variety of polymeric matrices, chrome-tanned buffing dust has been used to produce leather-like composites with possible applications including handbags, wallets, key chain holders, and purses, as well as footwear items including shoe bottoms, insoles, heels, and other similar components. This essay compiles the findings of a number of investigations on composites produced from buffing dust derived from the leather industry that have been carried out by researchers. Data from past research activities that made use of a variety of polymer matrices may also be used to give information on the characteristics of composites. Fiber-reinforced composites made with buffing dust help avoid landfills, conserve energy, stop the depletion of virgin raw materials, produce low-cost composites with improved mechanical properties that can be used for multifunctional applications, and offer a solution to the environmental issues connected to the leather industry's waste management [56]. In

addition, these composites help produce low-cost composites with improved mechanical properties that can be used for multifunctional applications.

Figure 2.1 (a) Morphology of Buffing Dust [57].

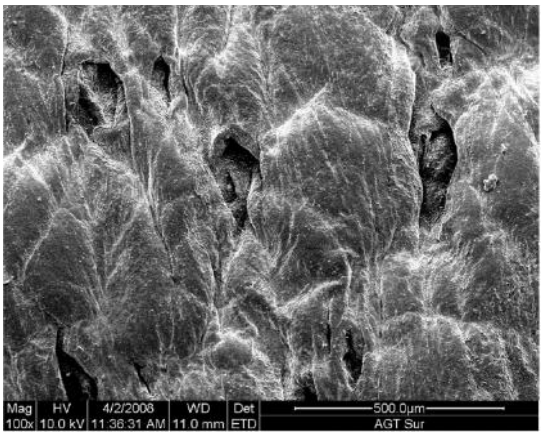


Figure 2.1 (b) SEM for raw leather surface [58].

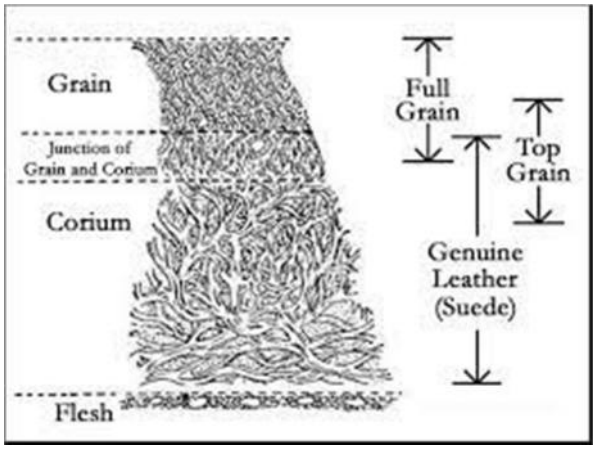


Figure 2.2 (a) Leather cross section [59].

Chemical Composition of skins:

- The main constituents of freshly-flayed animal hide/skin are:
  - (i) water 64%
  - (ii) proteins 33%
  - (iii) Fats 2%
  - (iv) mineral substances 0.5%
  - (v) Other substances 0.5%

Figure 2.2 (b) Chemical composition of skin

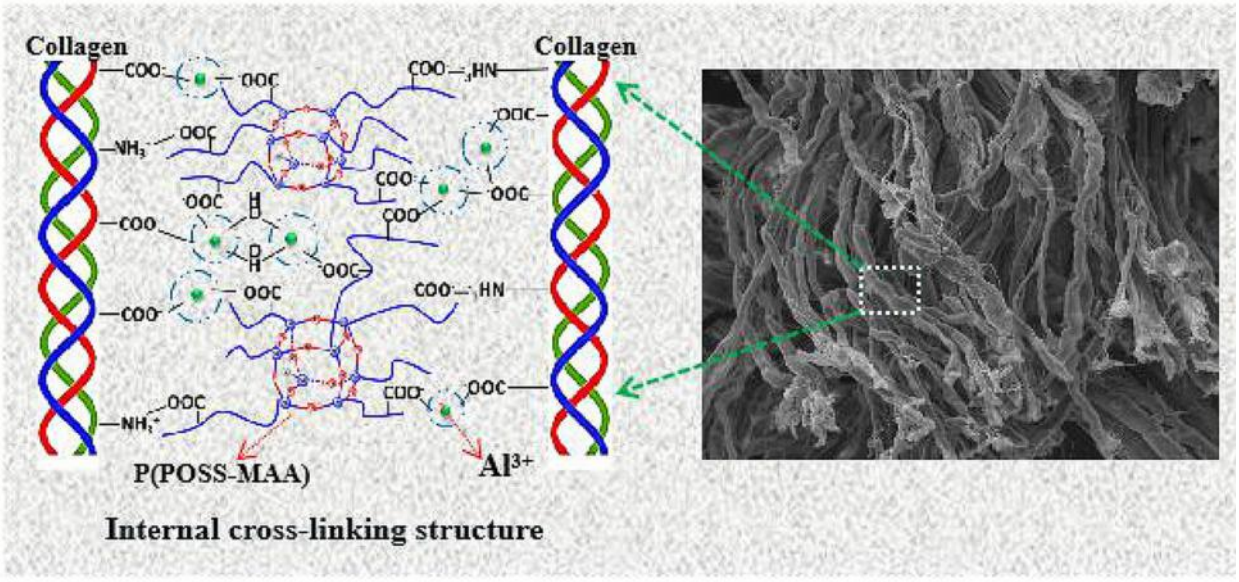


Figure 2.3 Internal cross-linking structure of collagen [60].

2.3.1 Cow Hair

In the books, the leathery hide appearing on the mammals like horses, pigs, and cattle is taken as hair. We call the hair on animal body fur because they only grow to a certain point. The hair that grows to a certain point is usually taken by us as fur whereas the hair that keeps on growing is called “hair”. Cows have hair even though they do not grow after a certain point and offer exceptional coverage. Let alone cows, some other mammals like horses and pigs are also blessed with hair. Fur and hair are the two different terms we use for the same thing, the only difference is that fur does not grow further after reaching a certain point whereas, hair keeps on growing. Fur or hair are needed by the animals for thermoregulation, protection, camouflaging, and sensory purposes. A cow's hair and hide make up the rubber on car tires. Other parts of the cow are used for other purposes. This material is used to make carpets, clothing, and even the binding agent for highways, which is made from beef byproducts. It is also used in the manufacture of dynamite. Boron, barium, calcium, copper, iron, lead, potassium, magnesium, manganese, phosphorus, silicon, silver, sodium, and zinc are some of the elements that were discovered in the ash. Other elements found in the ash include sodium and zinc. The ash that was collected from several of the white hair samples did not contain any potassium.

Figure 2.4 Photographic view of cow hair fiber [61]

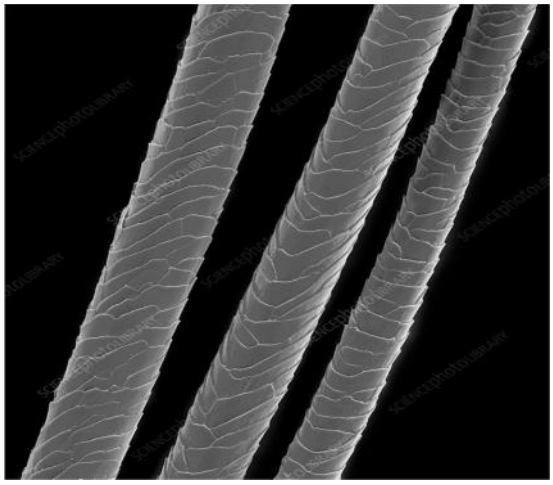


Figure 2.5 Scanning electron micrograph (SEM) Cow (cattle) hair [62]

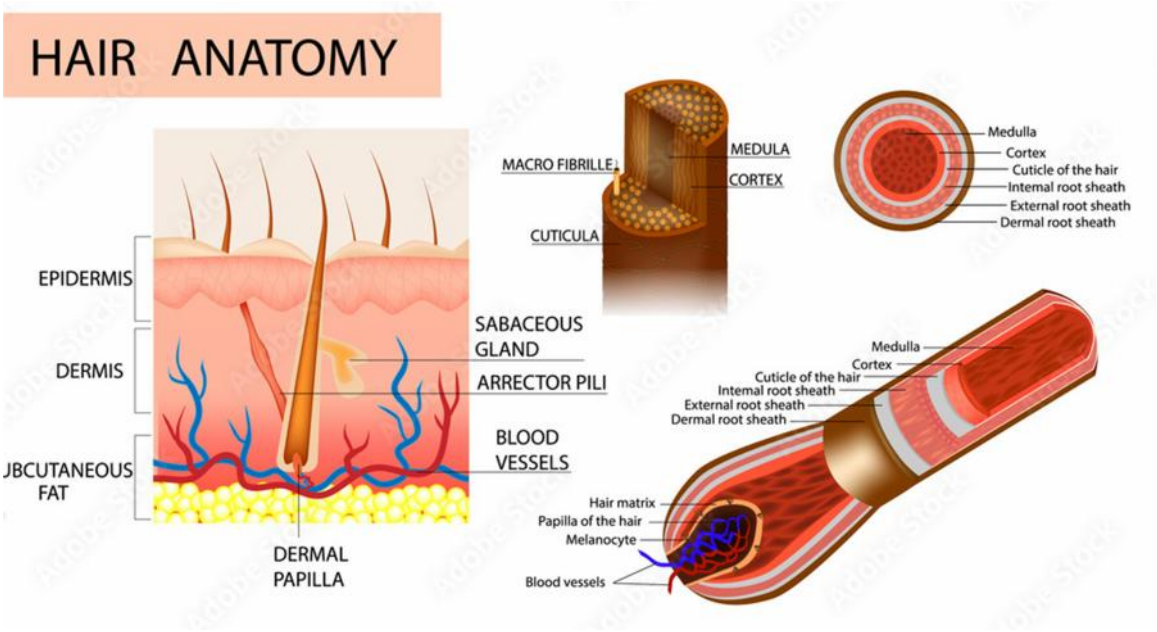


Figure 2.6 Anatomical illustration of hair bulb and hair follicle [63]

2.3.2 Chicken Feather

A chicken's body is covered with four different types of feathers: down feathers, contour feathers, semiplumes, and filoplumes. Each is arranged differently and serves a certain objective.

The contour feathers of a chicken are the first feathers you notice. The largest feathers on a chicken, they give the animal its shape and serve as its first line of defense against the elements. They coat the chicken's exterior.

Down feathers are another name for plumules. They are fluffy instead of smooth because they lack the hooks that attach barbs to one another. Because down feathers are primarily used as insulation for capturing air for warmth, they are most noticeable on young chicks. The down feathers are located closer to the body in mature hens.

Filoplume and bristles, two tiny feathers, are less apparent but nevertheless serve a purpose. The tip of a filoplume has a few barbs, giving it a hairy look. They do have sensory receptors at their base,

albeit their precise use is not entirely known. The tiny feathers that cover a chicken's eyes, nose, and mouth are known as bristles. They safeguard certain locations by excluding dust and other particles.

Chickens keep warm in the winter by fluffing up their downy feathers which traps tiny pockets of air warmed up by their own body heat. That warm air is held close to the body which prevents cold air from touching their skin.

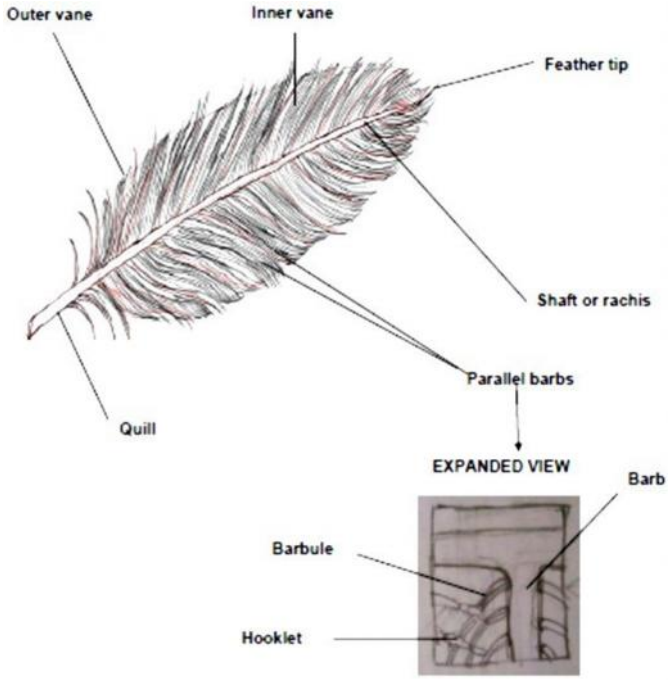


Figure 2.7 Parts of a chicken feather [64].

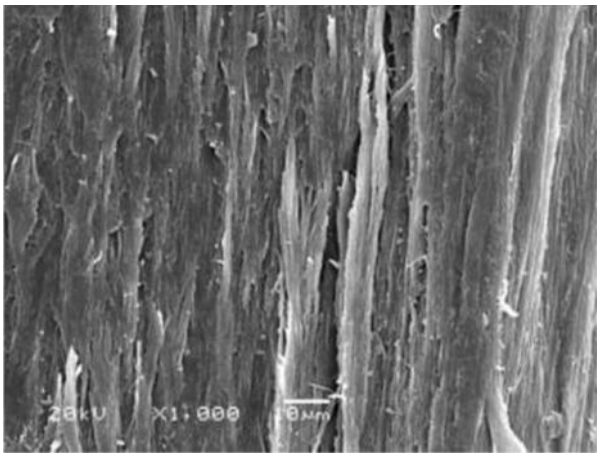


Figure 2.8 SEM for raw chicken feather surface [65].

2.4 Fiber constituents

80–90% of the keratin found in chicken feathers. In its disulfide bonds, crosslinking between neighboring links, and amino acid structure, basic keratin includes a high concentration of nitrogen and sulfur [66].

In contrast to the final analyses, which revealed carbon (64.47%), nitrogen (10.41%), oxygen (22.34%), and sulfur (2.64%), with a closer look the following compositions were revealed by analyzing chicken feathers: crude protein (82.36%), crude fiber (2.15%), crude lipid (0.83%), ash (1.49%), NFE (1.02%), and moisture content (12.33%) [67].

While minerals and lipids are present in minute amounts in cow hair, keratin makes up the majority of it [68]. The disulfide bond between neighboring cysteine residues enhances cortical keratin during the keratinization stage in cow hair, making it challenging for cow hair to easily breakdown.

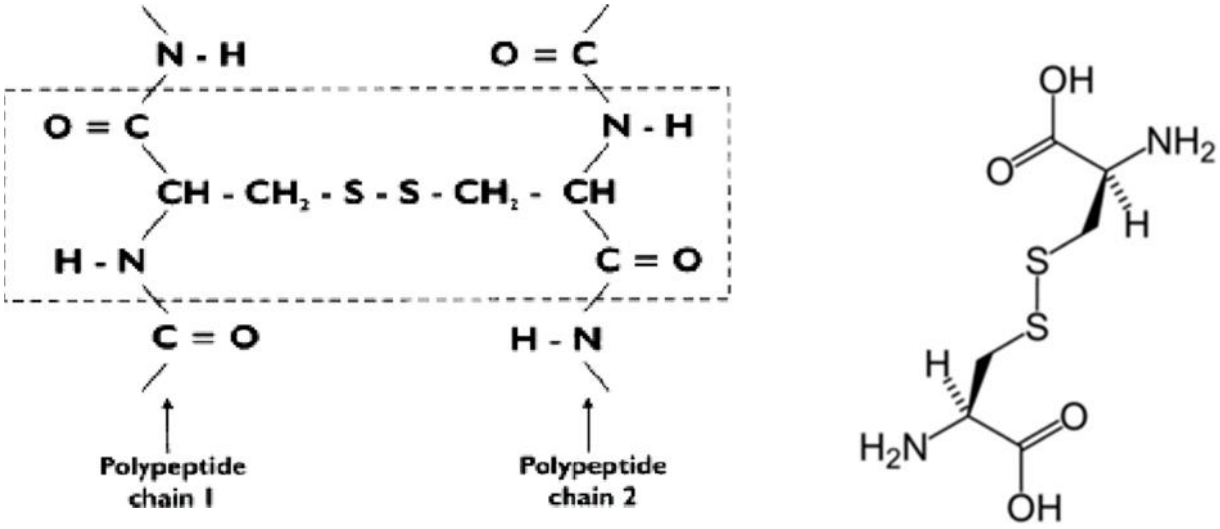
Water, protein, fatty substances, and certain mineral salts make up fresh hides. The protein is crucial for the production of leather. This protein can carry many types: Collagen- on tanning gives leather.

2.4.1 Keratin

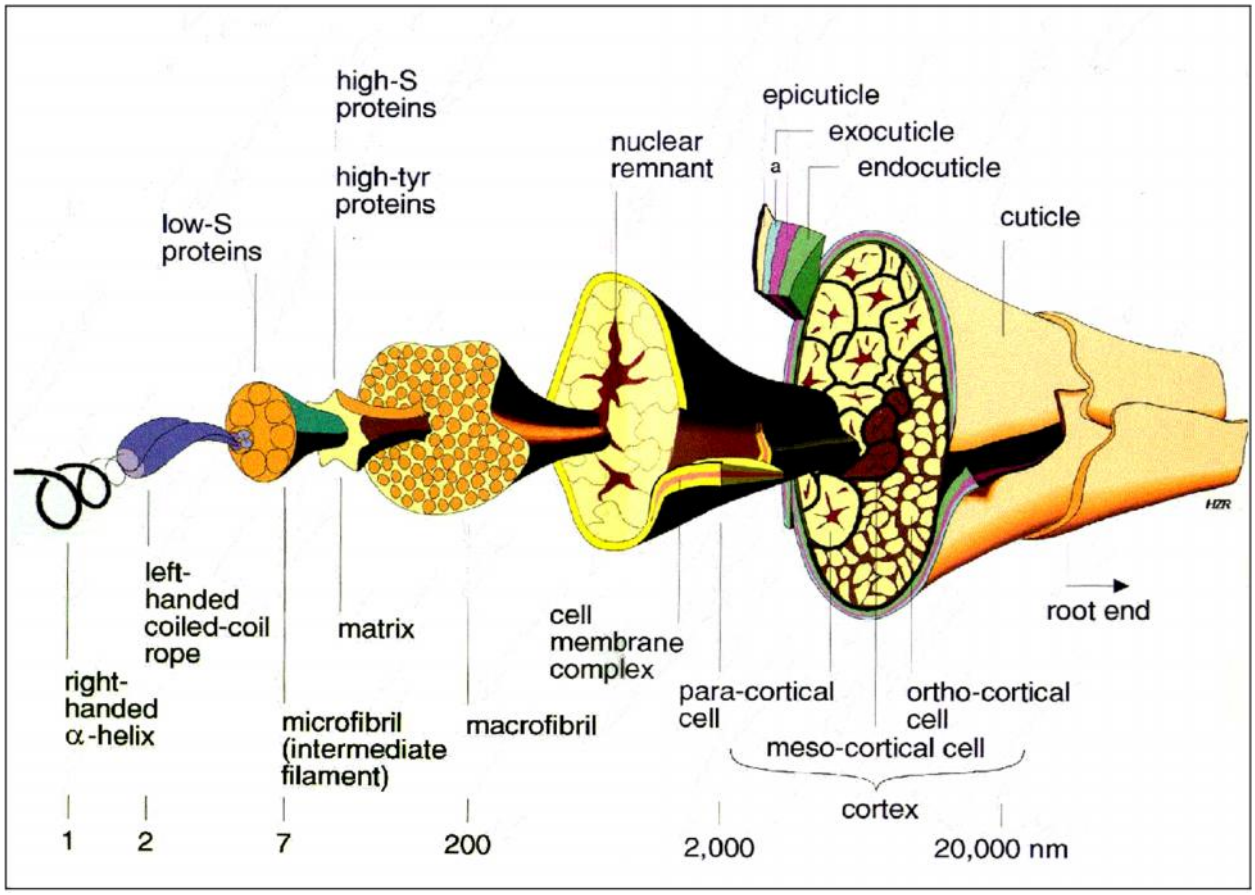
The scleroprotein family that comprises structural fibrous proteins includes keratin. Vertebrates have the alpha-keratin (-keratin) type. The outermost layer of skin, as well as the scales, hair, nails, feathers, horns, claws, and hooves of vertebrates, are all mostly made of this substance. Epithelial cells are additionally shielded by keratin from harm or stress. Keratin is challenging to dissolve both in chemical and aqueous solutions. Reptiles, birds, amphibians, and mammals all have stiff, unmineralized epidermal appendages made of bundles of keratin monomers that form intermediate filaments. Excessive keratinization contributes to the fortification of several tissues, like the osteoderm of armadillos and the horns of cattle and rhinos. Chitin is the only other biological substance that can come close to matching the resilience of keratinized tissue. All vertebrates have primordial, softer forms of keratin, but only sauropsids (reptiles and birds) have tougher, developed versions. 18 amino acids make up keratin. Cysteine, cystine, serine, glutamic acid, glycine, threonine, arginine, valine, leucine, and isoleucine are the amino acids that are found in the highest

concentrations. The protein that is present in the largest amount in hair is alpha keratin, which is fibrous and low in sulfur.

Feather keratin fibers possess outstanding mechanical properties, are lightweight, repel water, can absorb sound, retain warmth and cost-efficient. Inorganic solvents cannot dissolve them, and they are non-abrasive, ecologically safe, biodegradable, and renewable. Chicken feather keratin fibers are the perfect material to use as a high reinforcement of structure in polymer composites because of these properties [69].



(a)



(b)

Figure 2.9 (a) Chemical structure of Keratin , (b) morphological and chemical structure & property relationships for alpha-keratins in bleached hair [70].

their properties (Robbins, 2002)

Cuticle Layer	Cystine Content (%)	Details
Epicuticle	~12	18-MEA lipid layer attached to outer epicuticle contributes to lubricity of the hair
A-layer	~30	Highly crosslinked
Exoxuticle	~15	Mechanically tough
Endocuticle	~3	Chemically resilient
Inner Layer		
Cell Membrane Complex (CMC)	~2	Lamellar structure consists of inner β-layer, δ-layer, and outer β-layer

Table 2.5. Amino acid content in keratin fiber from chicken feather [71].

Functional Groups	Amino acid	% Contents
Positively charged	Arginine	4.30
Negatively charged	Aspartic acid	6.00
	Glutamine	7.62
Hygroscopic	Theronine	4.00
	Serine	16.0
Hydrophobic	Tyrosine	1.00
	Leucine	2.62
	Isoleucine	3.32
	Valine	1.61
	Cystine	8.85
	Alanine	3.44
	Phenylalanine	0.86
	Methionine	1.02
Special	Proline	12.0
	Asparagine	4.00

2.4.2 Collagen

The most prevalent protein in leather is collagen. Connective tissue is created using its structure, which resembles fibers. This kind of tissue, which as its name suggests links other tissues, is a crucial part of bone, skin, muscles, tendons, alongside cartilage. It aids in building supple, robust tissues that can endure strain.

In diet, collagen is only naturally present in connective tissue-containing animal flesh, such as meat and fish. However, a range of meals, both animal and plant-based, include components for our systems to make collagen.

As we get older, our bodies naturally produce less collagen, but excessive sun exposure, smoking, drinking too much alcohol, and not getting enough sleep and exercise cause collagen production to decline the fastest. Collagen in the inner skin layers transforms with age, going from a well-

organized network containing fibers to a disorganized maze [72]. Environmental exposures can weaken and thin collagen fibers, which results in wrinkles on the skin's surface.

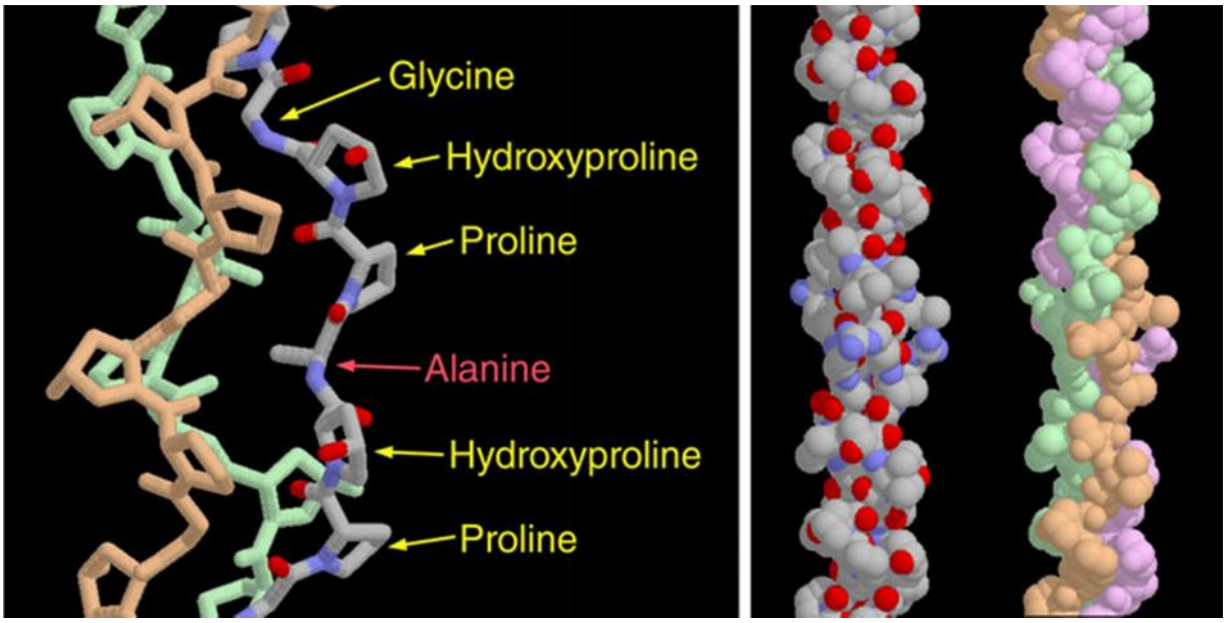


Fig. 2.10 Collagen Triple Helix [72, 72]

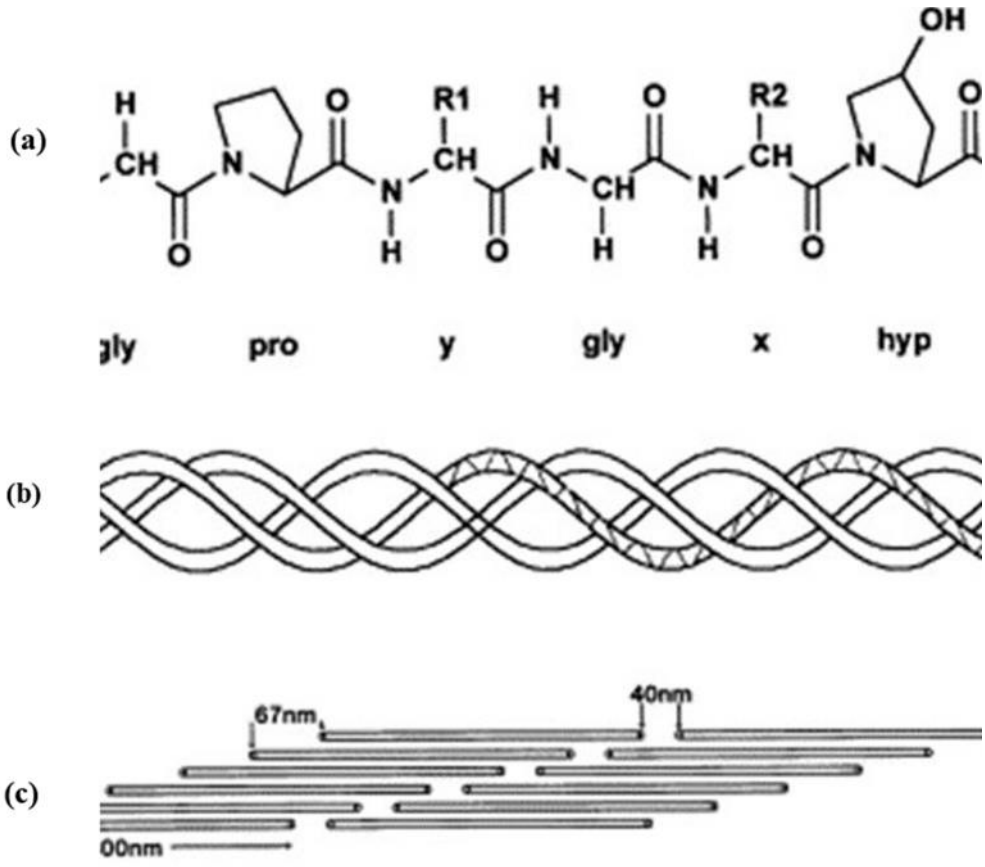
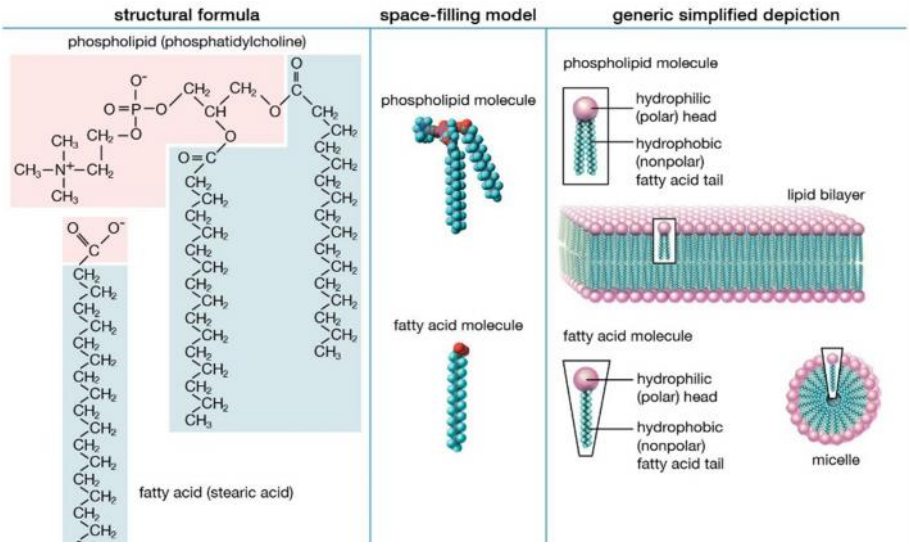


Fig. 2.11 chemical structure. (a) Sequence of amino acids -primary structure, (b) left-handed helix -secondary structure; right-handed triple-helix -tertiary structure and (c) staggered -quaternary structure [73].

2.4.3 lipids

Lipids are organic compounds made of oxygen, carbon, and hydrogen atoms. They are the fundamental constituents of living cells and are used to form and function. Fatty, waxy, or oily molecules are referred to as lipids. They are soluble in solvents that are organic but insoluble in solvents that are polar, like water. Lipids consist of: Triglycerides, or fats and oils Phospholipids. Lipids are fatty or oily nonpolar molecules that are kept in the body's adipose tissue. A diverse class of substances known as lipids is mostly made up of hydrocarbon chains. Lipids are organic compounds that are high in energy and supply that energy for several living activities. Major types include fats and oils, waxes, phospholipids, and steroids. The characteristics of lipids are that they are hydrophobic, made of hydrocarbon chains, are good stores of energy for cells, and can be saturated or unsaturated. In the endoplasmic reticulum, a process known as lipogenesis produces fatty acids from acetyl-CoA in order to convert excess carbohydrates in the diet into triglycerides. Two typical lipids' structures and characteristics. Phosphatidylcholine, a phospholipid, and stearic acid, a fatty acid, both include chemical groups that create polar "heads" and nonpolar "tails." The nonpolar tails are hydrophobic, or insoluble in water, compared to the polar heads, which are hydrophilic. The hydrophilic ends of the lipid molecules in this composition are directed toward the watery medium, while the hydrophobic ends are sheltered from the water, resulting in aggregation formations such as micelles and lipid bilayers.



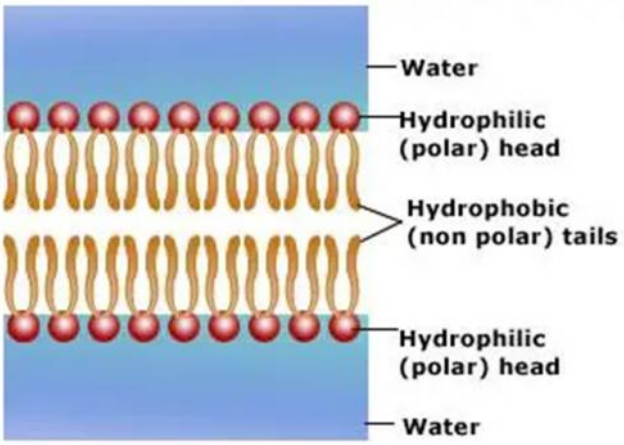


Fig: 2.12 Structure of Lipids [74]

2.5 Literature review on chicken feather, cow hair and leather fiber

2.5.1 Review on chicken feather

Millions of tons of chicken feathers are created each and every year as a byproduct all over the world since there is such a high demand for poultry products [75,76]. The majority of these flakes are burned or disposed of as trash, with just a small portion being used in insulation and down products [77]. Chicken feathers contain more than 85 % of crude protein, valuable components, 70% of amino

acids, vitamins and other growth factors [78]. The use of these materials in many products, including feed [79], fertilizer [80], biofilm [81], and others, has attracted the attention of researchers. This is because chicken feathers have a high mechanical stability and are not readily degraded by conventional proteolytic enzymes. Nevertheless, due to a lack of practical recycling techniques, chicken feathers have been categorized as garbage [82]. The 7% of the live bird's weight that is made up of feathers, which are high in the protein keratin, creates a significant bulk that may be turned into a profitable meal. Feather meal is a fantastic source of fugitive protein. According to recent studies, chicken feathers may be useful as a protein supplement for persons trying to increase or maintain lean body mass.

Several researchers conducted experimental studies on the characteristics of hybrid composites that were reinforced with jute and chicken feather fiber (CFF) [83]. The form of the surface of the fracture and its failure under various stress situations were investigated using SEM. Finally, the combination of specimens were characterized by applying TOPSIS, a multiple criterion selection approach.

Zhan et al. statistically examined the mechanical characteristics of feather barbs. The Gaussian distribution of the strain at CFF break has a mean value that is 6.93%. Tensile modulus and average tensile strength for CFFs were 35901090 N/mm^2 and 20374 N/ mm^2, respectively. The tensile strength and tensile modulus of several varieties of feathers were found to vary significantly. Weibull distribution was used to describe the CFF failure, using scale parameter values of 178.7 N/ mm^2 and shape parameter values of 2.32. Overall, the examination of the CFFs' applicability in composite materials was aided by their well-studied mechanical features [84].

In order to utilize and assess the mechanical qualities of these materials as well as fiber strengthened vinyl ester and polyester composites, Uzun et al. performed research on chicken quills and chicken feather fiber-stitched polymeric composites. The chicken feather fibers (CFF) were washed, put through tests, and had their physical characteristics, such as linear density and tensile behavior, investigated before being used to create the composites. The unidirectional composites reinforced with chicken feather fibers (CFF) were produced by using vinyl ester and polyester resins, along with three different loadings of reinforcing fibers (2.5%, 6% and 10% by weight). In order to evaluate the control composite (containing 0% carbon fiber) and the CFF reinforced composite, tensile testing, flexural testing, and Charpy impact testing were carried out. It was demonstrated that despite the fact that the tensile and flexural performances of CFF reinforced composites are inferior to those of the

control composites, the impact characteristics of the CFF reinforced composites are notably superior. The 10% CFF reinforced polyester composite had an impact resistance of 4.56 kg/ mm^2, which was three times greater than the control composite's (1.85 kg/mm^2) impact resistance. Additionally, the composite had a Charpy impact value of 4.42 kg/mm^2, which was 25% higher than the control vinyl ester composites (3.31 kg/mm^2). Because of its better impact behavior, the CFF reinforced composite has potential uses. They demonstrated that due to its low cost, exceptional qualities, and environmental friendliness, chicken waste can be processed and employed in any technical applications [85].

Unsaturated polyester resin may be used to treat discarded chicken feathers to make usable and biodegradable polymer composites without sacrificing the feather fibers' natural properties, according to recent studies. Recently, scientists, particularly those from poor nations, have reconsidered the economic significance of feather fibers. They are now able to create new industrial uses for feather fibers, such as reinforcement for the creation of polymer composite materials [86,87]

Aspen fiber was combined with chicken feather fibers (CFF) in increments of 2.5%, 5% or 25% ranging from 0-95%, using 5% phenol formaldehyde resin as an adhesive, Winandy et al. constructed medium density fiberboard (MDF) panels. It was also examined how well the panels resisted mechanical, physical, and deterioration forces. Compared to control panels made entirely of wood, the strength and stiffness of MDF-CFF composites declined as CFF percentage increased. On the other hand, MDF-CFF panels showed only average protection against decay fungus but a considerably increased resistance to water-soak absorption. This advantage was probably brought about by the hydrophobic keratin found in CFF. The CFF levels required to reduce thickness swelling and enhance water-resistance need to be determined by more study [88].

Chicken feather fibers (CFFs) and glass fibers were used to reinforce epoxy polymer composites, and Zhanet al. created and examined these composites' physical characteristics. CFFs or hybrid fiber composites (glass fiber combined with CFFs) lowered the density of the material by up to 30–40% when compared with glass fiber reinforced composites. Storage moduli and flexural strengths of CFF composites are approximately 3500 N/mm^2 and 50–80 N/mm^2, respectively. Despite having a higher percentage of bio-based materials than CFF composites, the hybrid fiber composite performs mechanically better. This study provided an example of a cutting-edge CFF use [89].

Recent research by Farhad et al. focused on ecologically hazardous waste chicken feather fibers (CFF) & metal inorganic components that were combined with unsaturated polyester resin (UPR) to create usable composites. Consider CFF as a disposable resource and its potential to serve as

reinforcement allowed for the preparation of inexpensive goods that ultimately produced less environmental pollution. For the purpose of enhancing the mechanical characteristics of the composites, several substances like ZnO, $CaCO_3$, as well as Al_2O_3 have been included to the matrix. They found that the ZnO and UPR-treated chicken feather fiber-based composites had relatively strong tensile-strength (TS), percentage of elongation at break (EB), tensile-modulus (TM), bending-strength (BS) and bending-modulus (BM) properties when compared to the other composites. These are all measures of the composite's ability to withstand tension. In comparison to the control sample UPR polymer composites, the increases in the ideal composite's TM, TS, BM, and BS are 34.19%, 69.78%, 40%, and 56.75% respectively. For up to 15 days, they analyzed the composites' water uptake characteristics in order to understand how the materials absorbed water. FT-IR was used for the functional group analysis. Scanning electron microscopy (SEM) imaging was used to investigate the adhesion studies between the fiber and matrix. There is good fiber matrix adherence. The composites thermal stability temperature was determined by conducting thermogravimetric analysis (TGA) at temperatures up to 600°C. To determine composite disintegration in four stages, including brine degradation, compost degradation, soil degradation and weather degradation, they conducted degradation experiments for 90 days. The characteristics of composite materials were significantly enhanced by the inclusion of garbage [90].

Tetracycline elimination was studied by Hu et al. utilizing multilayered graphene-phase biochar (MGB) made from leftover chicken feathers. They used a two-stage carbonization and KOH-activation process to create MGB. SEM, TEM, FT-IR, Raman spectra, Zeta potential, elemental analysis, and scanning and transmission electron microscopy (SEM, TEM) were used to describe MGB. On the surface of MGB, they displayed numerous chemical functional groups. The MGB was distinguished by a BET surface area of 1838 m2/g. When MGB was utilized in the adsorption of TCs, an extremely high removal efficiency (up to 99.65%) and a quick equilibrium (within 30 s) were attained. Temperature had an impact on the adsorption processes, and at a temperature of 30°C, MGB displayed the greatest ability to adsorb with a capacity of 388.33 mg/g. The Langmuir and Elovich models, respectively, did a good job of describing the data for adsorption isotherms and kinetics. The chemical monolayer adsorption may be crucial to this procedure. Additionally, the MGB adsorption was tolerant to a wide pH range, high ionic strength, and even the presence of co-existing anions. Regeneration tests showed that even after four cycles, the removal effectiveness was remained satisfactory (96.61%). These findings have significant ramifications for how animal waste-derived adsorbents will be used going forward to clean wastewater that contains antibiotic residues [91].

2.5.2 Review on chicken feather

Oladele et al. Fiber created reinforced polyester composites by adding fibers of cow hair from the tail portion, of cattle known as Zebu breed cattle in Nigeria to polyester resin. Hand lay-up procedures were used to create the composites, which were then tested after curing at room temperature. Open molds were used to distribute the 10 mm-long NaOH-treated fibers at random inside a polyester matrix. Tensile, abrasion, flexural and water absorption properties of polyester composites reinforced with cow hair fiber (CHF) were studied. Mechanical (tensile, flexural), abrasion resistance, and water absorption are some of the features of fiber reinforced composites that have improved the greatest in comparison to the unreinforced polyester material. Optimal combinations of characteristics were found in certain fiber fractions, and inferences were derived about the origins of these values for each metric. At 4% CHF content, the Young's modulus was 756 MPa and the flexural modulus was 5179 MPa, and the UTS was around 10 MPa. The material was also abrasion resistant and hydrophobic. Best flexural strength at peak was 35 MPa at 20 weight percent CHF content [92].

In order to create the degradable and low-cost keratin-based spray-able mulch film (KSMF), Wenxin et al. hydrolyzed abandoned bovine hair using Pulping spent liquor. The keratin hydrolysate they produced was then mixed with polyacrylamide (PAM), polyvinyl alcohol (PVOH), glycerol (GL) and N,N-methylene bis (acrylamide). The KSMF was created with nutrients including N, P, K, S, Ca, and Si that are necessary for plant development, and its water absorption rate in deionized water was 380%. After being buried for 50 days under dirt, it degraded by 23.1%. To apply KSMF onto the soil, it was necessary to dilute it first, but once diluted, it was easy to use by spraying it onto soil surface and physically create a barrier that helped to preserve heat and lessen water evaporation. In addition to preventing "white pollution" and accomplishing waste recycling, throughout the crop’s growth cycle, the KSMF underwent significant degradation and penetrated into the soil, transforming into a top-notch organic fertilizer with excellent biomass, expanding its potential for use in sustainable contemporary agriculture [93].

Waste that contains keratin (such as hair, wool, feathers, and other materials) can be recycled, developed, and used in new ways to address difficulties with energy scarcity and environmental degradation. The removal of keratin and the production of valuable products based on it are the only ways to address the pollution causes by waste that contain keratin. Keratin-based biofilms are

becoming increasingly popular because of their exceptional features such example as excellent biocompatibility, quick decomposition or high biodegradability, suitable adsorption and a wide range of renewable sources, among other things. The production of biofilms based on keratin from garbage containing keratin is essential for renewable able development since they are a wonderful replacement for many different uses today. In this paper, four crucial methods of extraction of keratin—thermal hydrolysis, using ultrasonic technology, using solvent system that are eco-friendly and microbial decomposition—are portrayed and to attain clean production while preserving the functional properties of natural keratin to the maximum extent possible, which requires scrutinizing its traits. Then, utilizing a number of methods, including solvent casting, freeze-drying, electro-spinning, template self-assembly and soft lithography, the production of keratin-based biofilms is demonstrated. Next, keratin-based biofilms' functional properties and prospective uses are investigated. Future research goals linked to keratin-based biofilms are also recommended. Given their vast potential in fields as diverse as biomedical materials, optoelectronic devices, and metal ion detection, it is safe to say that the high-value transformation of waste materials including keratin into regenerated keratin-based biofilms is crucial to the advancement of sustainable development. This research seeks to offer some fundamental insights into the creation and use of keratin-based biofilms [94].

Heterogeneous materials with one or more solid phases are called composite materials. Making composite materials affordably has been the ideal challenge in recent years. As a result, we have developed a natural fiber composite that combines goat hair, epoxy, and graphene as a primary source of improved mechanical properties. Five layers of goat hair placed between layers of epoxy matrix make up the fabrication of natural composite. The mechanical characteristics of these composites, including their tensile strength, interlaminar shear, flexural strength, and impact strength, are under investigation. The mechanical properties of the six composite groups are analyzed, and the results are given [95].

Scientists today are very interested in developing eco-friendly materials. Materials made from natural fibers are renewable, biodegradable, as well as secure for the environment. Compared to inorganic fibers, these organic composites offer additional benefits, including low cost, reduced density, and ease of availability in nature. Compared to traditional processes, the production of natural fiber composites is simple. Various sectors have started to focus on eco-friendly materials to replace hazardous products as a result of environmental awareness and increased worry about the

greenhouse effect. The animals' (goats' and cows') short fiber is utilized to make epoxy-based composites. Chemicals are used to treat these fibers. Filler is ash from groundnut shells. Mechanical properties are evaluated by testing their impact and compressive strengths, surface roughness, and hardness. It is shown that the interfacial connection between the two phases enhances the mechanical behavior of the composites. C3 composites, in general, have a greater mechanical behavior than other composites. Scanning electron microscopy (SEM) is being used to learn more about the composites' microstructure. It has been shown that including groundnut shell ash into a composite not only serves as a filler but also enhances the interfacial bonding inside the material [96].

A biological fiber with a known microstructure is human hair. It has numerous distinctive qualities, including high tensile strength, thermal insulation, a special chemical make-up, elastic recovery, and a scaly surface, among others. However, because of its delayed disintegration, it causes several environmental issues. Even if there are currently a few options for using it, hair is still regarded as a biological waste. Due to this, an attempt is made in the current study to investigate the feasibility of creating a class of polymer composites reinforced with short human hair fibers. By using a straightforward hand lay-up process, epoxy composites with various hair fiber content (0, 2, 4, 6 and 8 wt%) are created. By performing tests in accordance with ASTM standards, mechanical parameters such as tensile, flexural, and compressive strengths were assessed. The composite's tensile and flexural strengths greatly increased with the addition of fiber content, whereas the compressive strength only slightly increased. These samples were subjected to scanning electron microscopy in order to examine the microstructural characteristics [97].

As a waste product from the leather industry, cow hair is commonly stored in large quantities as refuse, which has harmful consequences for the environment. In this study, foam concrete made from iron tailings was strengthened mechanically using cow hair as a reinforcing fiber. Foam concrete's apparent density, compressive strength, and flexural strength were studied in relation to the amount of cow hair fiber utilized, utilizing a number of different characterization techniques. The roundness, average pore size, and porosity of the samples with varying amounts of cow hair fiber were examined with Image-Pro Plus. Evidence suggests that adding a suitable amount of cow hair fiber to foam concrete can assist ensure that the pore size and distribution remain constant throughout the test piece by forming a stable network structure in three dimensions. The foam concrete's compressive strength was 11.19 MPa and its flexural strength was 3.58 MPa when the fiber concentration was 0.2 wt%. Compressive strength, flexural strength, and fracture resistance were all improved as a result of using foam concrete. The current action contributed to the development of a circular and

environmentally friendly economy, which was in keeping with the strategic objective of making use of solid waste and recycling resources [98].

Since a lot of cow hair ends up in the trash because of the leather industry, it's important to find a way to recycle it so it doesn't add to pollution. According to the results of this investigation, which used cow hair waste as the carbon precursor, N_2 is the best gas for making biochar. Bio-chars made by direct pyrolysis, KOH activation, and the MgO template approach were compared and contrasted for their individual qualities. The highest specific surface area found through characterization is 1753.075 m^2/g. The keratin was cleaned up after being extracted from the cow hair. The MgO template method was then utilized to create biochar, yielding a sponge with a highly ordered structure. It's possible that wastewater containing direct blue dye might be removed using biochar made from discarded cow's hair. It has a strong regeneration efficiency and an adsorption capacity of 1477 mg/g after 10 hours. This work offers a novel source for manufacturing carbon compounds for the treatment of dye wastewater while effectively using hair debris that contains keratin [99].

This article presents a research investigation into innovative functional materials that draw inspiration from the structural properties of hair. Wasted cow hair was treated with acid and hydrogen peroxide before being dried and powdered to make hair powder (HP) for this experiment. HP and acrylic resin (poly (acrylic acid) (PAA) were combined to create a sound-insulating film (SIF). On the basis of the SIF's operation, the formation conditions—including the HP weight percent, film-forming temperature, and solvent—were studied. Investigated and compared with already available items were the sound-insulating properties. The SIF performed better than a polyurethane (PU)-foam-based board of the same thickness, but it was comparable to that of an asphalt- or rubber-based board in the 20–20,000 Hz sound wave [100].

Because they are readily available and offer special qualities for use in polymer applications, natural fibers have recently attracted scientific interest in reinforcing polymers. According to preliminary investigations, slaughterhouse operators in Nigeria are burning cow hair (CH), sheep hair (SH), and human hair (HH) without regard for the environment or the health of people. This has raised concerns among the public. The study's goal of finding eco-friendly uses for these discards makes it crucial. If correctly employed, the hair fibers used in this study might benefit the economy of any country in which they were produced. Using an injection molding machine, we created composites with varying weight percentage concentrations of Polypropylene (PP), human, sheep, and cow tail hair fibers (0, 2, 4, 6, and 8 w% respectively). The average dimensions of untreated and treated PP composites were measured, along with their densities. The composites were also evaluated for their

hardness, impact resistance, and ultimate tensile strength. Sheep hair, on average, has a larger diameter than human hair, hence it is considered to be superior. Cow tail hair has the highest average density, followed by human hair, and then sheep hair, in descending order of hair fiber length. Compared to unreinforced PP, the human hair/PP composite showed the greatest improvement in ultimate tensile strength and modulus, flexural strength, and modulus after being loaded with 8% fiber. The best elongation at break was found in a cow tail hair/PP composite with a 2% fiber loading. Human hair/PP composites at 4% fiber loading showed the highest yield for impact strength, whereas cow tail hair composites at 2% fiber loading showed the highest yield for the hardness test. Except for the air entrapment in the picture of cow tail hair, the surface scanning electronic microscope (SEM) images of composites did not reveal any serious manufacturing flaws. Additionally, the research found no evidence of voids or fiber breaking in the photos. At 8% maximum loading, SEM pictures of the PP-composites interface revealed a respectably strong fiber adherence to the polymer matrix. For environmental sustainability and to enhance material qualities for diverse uses, this study is advised [101].

2.5.3 Review on leather fiber

This is the first study on the plasticization of atactic polystyrene (PS) using waste chrome-tanned Indian leather buffing dust. Up until this point, no efficient reuse of leftover leather polishing dust has been documented. After initial characterization, this waste material was dissolved in solvated polystyrene. Surface hardness of the resulting composites made from them using the solution cast process drastically decreases up to a certain level of modifier content before increasing. The optimal degree of surfactant addition during the dispersion of buffing dust decreases surface hardness even further. In this system, sodium lauryl sulphate (LS), a more traditional compatibilizer, has been found to be inferior to para-toluene sulphonic acid (PTSA). Without sacrificing strength, the breaking strain has risen considerably from 0.2% in raw polystyrene to 25% in the PTSA-compatible system. Additionally, the compatibleized composites exhibit clear "yield behavior" when stretched. The breaking strength has increased as a result, and is now much higher than it was for the virgin polymer. The glass transition temperature (Tg) has been effectively decreased by the plasticization of the composites; the composite containing PTSA had the lowest value, probably as a result of the creation of greater free space surrounding the stiff polystyrene particles as a result of its effective ability to adsorb smaller dust particles. The composites are more thermally stable than virgin

polymer, according to a research on accelerated thermal deterioration. This may be because the waste contains chromium, which serves as heat sinks [102].

Flexible composite sheets are produced using a simple solution casting method, utilizing discarded buffing dust and cotton waste from post-consumer sources. Various mixing ratios of natural rubber latex (NRL) were utilized as a binder ingredient. FTIR was used to verify the chemical connection between cotton fiber and buffing dust. TGA and DTA experiments were used to demonstrate the composites' thermal stability in their as-prepared state. By using FESEM analysis, the surface tropology of manufactured composites was investigated. In comparison to pure buffing dust, produced composites were shown to have improved gas barrier qualities based on the findings of oxygen gas transmission rates. The generated composites with the ideal NRL content increased in tensile strength, elongation, hardness, and density by 58%, 48%, 35%, and 21%, respectively, as compared to pure buffing dust sheets. Therefore, the packaging and interior design industries would benefit from using these simple, affordable, and flexible composite sheets [103].

The leather business produces large amounts of chrome-tanned waste, which is bad for the environment. In acrylonitrile butadiene rubber, waste leather was used as a filler, both before and after ammonia solution and sodium format treatment. Various formulas (untreated, treated with ammonia solution, and sodium format) are used to create waste acrylonitrile butadiene rubber/leather composites. Many of the produced composites' qualities, including their rheometric ones, are noticeably improved after being loaded with treated leather waste. The composite's tensile strength, modulus at 100% elongation, hardness, and Young's modulus all increased thanks to the addition of the treated leather. Incorporating treated or untreated leather wastes into toluene enhanced the crosslinking density, which decreased the equilibrium of swelling. Composites, including treated and untreated leather, exhibit considerable improvements in thermal stability as well as ageing coefficient [104].

The global leather industry is well recognized for its high levels of pollution, including contaminated water and soil. A common waste product from the leather industry that is discarded nearby and utilized for land fill is dyed trimming. This article looks at and reports on the recycling of such industrial trash for producing valuable items by replacing leather. Flexible composite sheets were produced using solely dyed trimmings as well as natural fibers in a variety of blend ratios. Natural fibers were derived from cotton and jute waste. Maximum tensile strength and breaking loads were demonstrated by the composite sheets at mix ratios of 50:50 between colored trims and natural fibers. According to American Society for Testing and Materials and Indian Standard procedures, the

ultimate tensile strength, elongation, double fold, bursting strength, density, and water and oil absorption properties of the composite sheets were assessed. To analyze the final products, Fourier transform infrared spectroscopy, thermo-gravimetric analysis, and scanning electron microscopy were employed for characterization purposes —the composite sheets—and the raw materials—the colored trims and jute and cotton fibers. Dye trimmings were analyzed using energy-dispersive X-ray technology, with the results showing that the untreated samples contained 2.54% chromium while the NaOH-treated samples did not. With the increase in flexibility, the natural fiber considerably enhances the mechanical strength and thermal characteristics of the blended composite sheets. These flexible sheets can replace leather in the production of clothing and other items since they are stronger physically than leather [105].

In order to lessen pollution from the leather sector, a composite leather-buffing dust was created in this study. The necessary quantity of buffing, wheat flour, binder, etc. was mixed and then poured into a 210297 mm timber frame to create the batch-wise composite sheet. The sheet was first dried in the sun and then in the oven. Tensile strength, elongation at break, Thermogravimetric Analysis (TGA), and Fourier Transform Infrared (FTIR) Spectroscopy were all evaluated for the constructed composite. The composite that was created has a tensile strength of 2.95MPa. According to the TGA data, buffing dust was less stable than composite. The leather goods sector may employ the composite buffing dust as a means to control solid waste in tanneries [106].

In this investigation, clay was mixed with vegetable trimmings and fleshings at weight ratios of 1, 3, 5, and 10% to create bricks. Using the applicable Turkish or ASTM standards, the bricks' bulk density, thermal conductivity, and strength were assessed. The addition of fleshings and vegetable shaving wastes to bricks decreased their density, thermal conductivity, and compressive strength. Higher inclusion levels made the decline more pronounced. For both wastes, 5% utilization was the ideal threshold. However, after meeting with the Society of Brick builders, testing has started using solid wastes to produce the porosity that brick builders typically achieve with sawdust. [107].

Investigating the creation of valuable products from various leather waste types was the major goal of the current study. A fixed bed reactor was used to pyrolyze buffing dust, shavings, with vegetable-tanned shavings from a leather tannery at 450 and 600 °C in a N_2 environment. Pyrolysis resulted in the creation of gas, oil, ammonium carbonate, as well as carbonaceous waste. Investigations were conducted to determine how temperature and the kind of leather waste utilized influenced the distribution of pyrolysis products. Buffing dust yielded the most oil (approximately 23%), whereas other garbage produced yields of just 9%. Results from column chromatography and elemental

analysis showed that pyrolysis oils may be processed again to produce fuel or chemical feedstock. Carboneous residue (chars) yields ranged from 37.5% to 48.5%, with a calorific value of 4300 to 6000 kcal kg1 that may be put to use as solid fuel. Activated carbon was made by reacting these chars with carbon dioxide. The activated carbon made from chromium-tanned shavings had the highest surface area (799.5 m2 g1). As an adsorbent, activated carbons made from chromium-tanned leather were used to get rid of dyes in water [108].

In the study there was focused on making of leather composites using solid leather waste, different plant fibers namely enset (Ensete ventricosum), hibiscus (Hibiscus cannabinus), jute (Corchorus trilocularis L), palm (Phoenix dactylifera) and sisal (Agave sisalana) and two polymer resins i.e., Resin Binder (RB) and Poly Urethane Binder (PUB) in various proportions. The tensile strength of composites consisting of leather fiber combined with hibiscus, sisal, and palm fibers as well as resin binder is higher than that of the corresponding controls. This demonstrated the resin binder's outstanding compatibility with both leather and plant-based fibers. Sisal-based composites in this study demonstrated greater tensile strength values when compared to other composites. The study's products' composite character was visible in SEM images. Through FTIR analyses, the functional groups of cellulose, binders, and collagen protein were discovered. Composite sheets made from jute (LF-JS), palm (LF-PS) and sisal (LF-SS) all had higher melting points than the control in the DSC analysis, whereas samples made from enset (LF-ES) and hibiscus (LF-HS) had lower melting temperatures. Based on these results, any composite sheet meeting the specifications might be used to manufacture things like lightweight purses, imitation roofs, mouse pads, key chains, wallet components, and furniture [109].

Many applications and disposal options for chrome shavings have been suggested, but they haven't been adopted or used in the industries owing to practicality issues and other limitations. Still, chrome shavings are not being used to their full potential. They have only really been utilized to recover protein hydrolysate and use it again in different applications. The majority of the chrome that the investigator collected was used for tanning. They did not, however, see a significant commercial recovery on an industrial level. Due to practicality and financial limitations, other uses for chrome shavings did not find significant usage and were not adopted by the industry. Traditional leather boards, such as those used as insoles and packaging materials, were produced.[110].

The experimenter provided the concept for this study's practical application of residential plastic trash and leather waste from industry. In this work, the manufacture and characterisation of a composite made from waste HDPE and wet blue leather waste were described. At 180 0C and 15

rpm, a two-roll mill is used to combine the two wastes. Compression molding was used to improve surface smoothness after milling composite mixes at a temperature of 190° C and less than 40 tons of pressure. After molding, ASTM standards for testing mechanical properties required that specimens be punched out. Tensile strength, rip strength, flexural stability, and hardness tests were performed on the final product, which had a thickness of around 3 mm. It gave people the chance to use their garbage, which reduces environmental contamination. Numerous applications and disposal strategies for chrome shavings have been proposed, but they haven't been adopted or considered by the industries owing to practicality issues and other limitations. Even yet, there was a lack of use for the chrome shavings. The majority of the chrome that the investigator collected was used for tanning. They did not, however, see a significant commercial recovery on an industrial level. Due to practicality and financial limitations, other uses for chrome shavings did not find significant usage and were not adopted by the industry. Traditionally, leather was used to make boards. [111].

2.6 Literature review on FTIR

One of the most used methods for determining chemical structures and identifying substances in biological samples is infrared spectroscopy. Chemical composition can be inferred from the absorbed energy of infrared light, which causes the stretch and deformation vibrations of certain molecular bonds (C-H, O-H, N-H, etc.). The FTIR spectrum of plant tissues acts as a fingerprint of the primary organic components such as carbohydrates, proteins, lipids, lignin, and different aromatic or other abundant compounds. The study of wood using FTIR has a long history. Attenuated total reflection (ATR) spectroscopy, a development of FT-IR spectroscopy, eliminates the need for any further sample pre-treatment, hence advancing the technique. This means it has the potential to be a high-throughput procedure. Research on the effects of fungi on wood and the identification of fungi in wood have all made use of FTIR spectra, as reported by Rumana et al. (2008). Animal species were also identified using infrared spectroscopy. The chemistry of animal fibers has also been characterized using FTIR spectra. Due to the impact of chemical treatment, there were peaks that represented animal fibers that shifted [112]. Sharma used FTIR to investigate microcrystalline chicken feather [113]. Fig. 4.13 provides a typical spectrum of bamboo fiber. Functional groups, molecular structure, and rigidity of substances are all determined by FTIR. Various peaks are seen in the infrared spectrum because radiation was absorbed in different ways by various functional groups. A certain compound is accountable for a specific wavelength, which has complete control on the

composition and structure of the chemical. Infrared radiation exhibits stretching vibration and bending vibration, two different forms of vibration. The connected atoms' distance from one another shifts as the stretching vibration progresses, but their plane of alignment remains unchanged. There are two distinct types of stretching vibration. Both symmetric and asymmetric stretches exist. In contrast to symmetric stretching, asymmetric stretching often has a greater wave number. Molecules vibrated in relation to their axes during bending vibration Scissoring vibration and rocking vibration are two different forms of bending vibration. While rocking tends to cause molecules to move in the same direction, scissor vibration has the propensity to bring them closer together. Because of this, scissoring has a substantially greater wave number than rocking. This explains why rocking has a substantially smaller wave number compared to scissor motion. The vibration relationship is described in detail below.

$\nu_{assy} \rightarrow \nu_{sym} \rightarrow \nu_{bend}$

The following variables affect wave number.

i) Various bond vibrations

ii)Coupled bond vibrations,

(iii) Fermi resonance, (iv) inductive effects,

(v) hybridization,

(vi) mesomeric effect,

(vii) hydrogen bonding effect

(viii) ring size effect

Different vibrations of bonds

Wave number is altered by the dipole moment in the same sample and bonding. C-H symmetric and asymmetric vibrations occur at 2872 cm^{-1} and 720-1450 cm^{-1}, respectively, in the methyl radical (-CH3). Wave number is influenced by various vibrations.

Coupled vibration effect

The C-H bond in every molecule has a single wave number, or symmetric vibration, in the spectrum. On the other hand, they showed symmetric and asymmetric wave numbers when another C-H bond was present. This is known as coupled vibration.

Inductive effect

The wave number of an IR-active chemical can change if a nearly-functional molecule shifts. The inductive effect describes the modification to the wave number that results from a change in the functional group. Positive inductive effects (in which donor atoms replace the H atom in the functional, resulting in a lower wave number IR absorption band) and negative inductive effects (in which the bond length is reduced when an electron source or acceptor is present) are the two different types of inductive effects. Therefore, larger wave numbers will be used to study the IR absorption band.

Hybridization

Because the s orbital is more prevalent, the molecule's bond length is longer. As a result, the IR absorption band appears at longer wavelengths.

Resonance Effect

Increases in bond length can be seen when the effect of resonance is present. As a result, the infrared absorption spectrum appears at longer wavelengths.

Hydrogen bonding effect

Any molecule may form two different types of hydrogen bonds: intermolecular hydrogen bonds and intramolecular hydrogen bonds. The IR spectra was discovered to have a lower wave number for hydrogen bonding. IR wavelengths are between 400 and 650 cm^{-1}. There are two major geographic divisions for this wave number;

i) Finger print vibration region and ii) Functional group region

2.7 Literature review on modification

Gamma radiation

Natural fibers may be found in the forestry and agriculture industries. They are widely available, affordable, and regenerable materials. These may be used in both private and professional settings. Natural fibers are increasingly often used as reinforcement in pulp, textiles, insulating materials, eco-friendly composites made of polymer matrix, and other items. The synthesis of polymeric materials that are sustainable and provide the least danger to the environment has also received attention as a result of rising health and environmental concerns. Because of its various benefits, such as being biodegradable low cost, ease of availability, low density, and absence of abrasiveness, natural fibers are employed as reinforcement in bio-composite [114, 115]. 1,4-D glycoside linkage makes up natural fiber, which easily absorbs moisture from the environment. Bamboo is made up of 67% holocellulose, which includes 24% lignin, 60% -cellulose, and 16% hemicelluloses. The primary building block of cellulose macromolecules is a hydro-d-glucose, which has three hydroxyl groups per glucose ring. These hydroxyl groups (-OH) combine with additional glucose rings and -OH groups from the moisture to produce intramolecular hydrogen bonds. Hydrophilicity is a drawback of

cellulose, as is its high moisture content, which may go up to 12.33%. This is caused by the presence of hydroxyl groups inside the cellulose architecture. In order to make composites with improved mechanical and environmental performance, hydrophobicity of the fiber is required. Hydrophobic natural fiber with a hydrophobic polymer matrix lead to poor mechanical characteristics in composites. Concerns about the dimension stability of the fiber composite cannot be dismissed since moisture absorption can cause fiber swelling. Numerous efforts have been made to solve this issue, including physical and chemical treatments that changed the fiber's surface structure and surface energy. Adequate adhesion among the surfaces can be achieved by improved wetting as well as chemical bonding of the natural fiber in addition to polymer matrix. Numerous studies have been conducted to enhance the characteristics by physical treatment [116,117]. Gamma radiation was used as a physical treatment on animal fiber composites as a result. Animal fiber composites become more durable when exposed to gamma radiation at various dosages.

Gamma radiation is a potent kind of ionizing radiation and has a significant impact on materials made of polymers. Ionization and excitation are produced by the high energy radiation action on organic polymers. The polymer undergoes breakage or scission, when the polymer molecules are either split into smaller pieces or cross-linked, based on the radiation dosage and the kind of polymer molecules. Free radicals were created when animal fiber composites were exposed to radiation. Chemical bonds that break later result in fragments of big polymer molecules. Free molecules cause the chemical link to break as a result. The big polymer molecules are broken down into pieces by chemical bonding. The resulting free radicals may react to affect the polymer's chemical structure and the molecules' physical characteristics. Free molecules cause the chemical link to break as a result. The big polymer molecules are broken down into pieces by chemical bonding. The resulting free radicals may react to affect the polymer's chemical structure and the molecules' physical characteristics. Additionally, the molecules may be connected together to form larger molecules through a process known as cross-linking. When composites made of fibers were subjected to gamma radiation, the tensile strength as well as Young's modulus increased with radiation doses and then decreased after achieving a maximum value at a particular dosage. The inter-cross-linking between the nearby fiber molecules that takes place during gamma exposure may be the cause of the gains in mechanical characteristics with increasing doses of gamma radiation Mechanical characteristics declined with increasing gamma radiation pre-treatment doses, which may be related to the breakdown of protein backbone by ionizing radiation at higher gamma doses. As a result of the primary bond breaking in the protein component during degradation, the final cell strength is reduced [118].

2.8 Literature review on thermal study

Thermogravimetry allows for precise regulation of heating conditions, such as a consistent heating rate and a large temperature range. This research requires a small sample size. Moisture and volatiles are known degraders of composites, and their concentrations may be quantified.

Thermogravimetric data includes the number of thermal breakdown stages, the material's weight loss at each step, the threshold temperature, and other information. The TG and DTG (differential thermogravimetric) curves both reveal details on the kind and circumstances of the material's breakdown. Thermogravimetry may be used to learn how cellulose fiber's pyrolytic behavior is affected by its crystallinity, orientation, and crosslinking. It has been shown that there are primarily two types of reactions involved in the heat degradation of cellulose. A slow deterioration that comprises depolymerization, hydrolysis, oxidation, dehydration, and decarboxylation takes place at low temperatures between 1200°C to 250°C. Rapid volatilization occurs at higher temperatures, along with the production of levoglucosan and a burnt product. Decomposition causes a significant drop in the degree of polymerization and a loss of fiber strength. Initial chain breaking at the crystalline/amorphous boundary causes a substantial reduction in molecular weight.

The composition of chicken feathers as determined by proximate analysis included crude fat (0.83%), crude fiber (2.15%), crude protein (82.36%), ash (1.49%), NFE (1.02%), and moisture content (12.33%). [119]. the primary part of hair, which contains the long keratin chains that give hair its elasticity, suppleness, and resilience. A lipid- and protein-rich intercellular cement holds the cortex's cells together. Each cell is made up of bundles that are directed in the direction of the hair's length. These bundles, known as macro fibrils, are composed of microfibrils, which are composed of protofibrils. Keratin, a fibrous and helical protein that is part of the makeup of the skin and all phanera (hair, nails, etc.), makes up 95% of the protein that makes up hair. There are 18 amino acids that make up hair, including proline, threonine, leucine, and arginine. Keratin is especially rich in cysteine (a kind of sulfur amino acid), which forms disulfide bridges between molecules to give the structure its stiffness and strength. The body contains more than a quarter of its protein as collagen, which is also present in significant amounts in tendon, cartilage, and bone in addition to being the most prevalent animal protein. About 33% of the protein in fresh, untreated hide or skin is protein, of which 29% is collagen [120]. The sample's thermal properties are influenced by variations in the ratios of keratin, collagen, and lipid in animal fiber.

Like other natural fibers, bamboo is hygroscopic and has a propensity to achieve equilibrium with the relative humidity of the surrounding air, either by absorbing moisture from or releasing it into the air [121].

When the interior structure of a rachis chicken feather was investigated, it was discovered that it consisted of 5–20 m micro cells. These design features highlight the rachis' small weight and effective insulating capabilities. The rachis substance exhibits a high degree of hygroscopy, according to research [122]. Cow hairs are hygroscopic, which means they can take up moisture from the air. Wet hair shafts are stretched throughout the drying process, causing them to assume the desired shape, such as straight or curly [123]. Due to its porous nature and high hygroscopicity, leather tends to collect moisture from the air during shipment, storage, and packaging. The porous surface of leather renders it extremely vulnerable to mildew growth in humid conditions when exposed to the air during processing. When exposed to hot and humid weather conditions, they are extremely likely to swell/warp and shrink, respectively. However, this characteristic is negative in terms of dimension stability for applications like composite. Due to the presence of hydroxyl or comparable oxygenated groups in the cell wall polymer, natural fibers absorb moisture through H-bonding.

2.9 Literature review on Water-Uptake study

T. P. Sathishkumar et. al. [124] found that organic strand-reinforced polymer composite substance proposed a broad area of characteristics in engineering applications. As compared to raw strand the chemically handled strands have high thermal properties, chemical properties, and mechanical characteristics. Natural strands treated with different chemical concentrations advances the interfacial holding in the middle of the matrix and fiber whichever upgrade thermal properties or mechanical properties. Treated fiber composites diminished water assimilation.

S. K. Ramamoorthy et. al. [125] In research found that hybrid natural strand composite was processed by joining distinct strand reinforcements, and water assimilation and mechanical characteristics were examined. The compression molding approach utilized to make composite overlays (laminates) against organic-based resin i.e. acrylate epoxidized soybean oil also organic jute strand of non-woven as well as woven type, the non-woven reproduced cellulose mat i.e. Lyocell and viscous, or also woven glass strand. composite overlays dried at pressure 40 bars and temperature 160 - 170 , accompanying strand volume 40wt%. They researched the impact of pre-treatment among the re-produced cellulose strand utilizing 4% NaOH sol. As an outcome, the tensile, as well as flexural characteristics of an organic strand, reinforced composite largely influenced by the impact of water, yet it was enhanced impressively by hybridization with the glass and lyocell strand.

V. Gager et. al. [126] explores the development of hygromechanical characteristics of flax/PP nonwoven composite in extensive scope with natural relative humidity circumstances starting with 10-98% relative humidity. Impact of the micro-scale structure against different porosity composition (5%,30%,50%) to study on hygroscopic and mechanical behavior contrasted with glass/PP composites like baseline. As an outcome, there is no critical variation in moist content as well as in the mechanical characteristics of glass-strand reinforced composite noticed. The tensile behavior along with characteristics are somewhat transformed above the scope of 10-75% RH negative impact somewhere in the range of 75% and 98% RH. The above-mentioned things are present to an unpredictable climate that consolidate temperature, moisture, mechanical stress at the time of automobile's life cycles.

According to Leif A. C. et al. [127], knowing the processes driving water absorption and the chemical interactions involved in the deterioration of the matrix and the fiber/matrix interface is essential for assessing the long-term durability of polymer matrix composite materials in humid air or liquid water. The matrix swells due to the additional water mass, which weakens the link between the fiber and matrix. Water can collect in voids, and if such voids are at the fiber/matrix contact, the pooled water may lead to hydrolysis. Furthermore, voids are geometrical abnormalities that result in

a concentration of stress and a decrease in strength. The analysis of moisture uptake in polymers and void-free composites is thought to be valid using Fickian diffusion. However, we discover Fickian diffusion aberrations for composites with voids. Capillaries in the shape of voids along the fibers provide flow channels and encourage "wicking," a quick technique for absorbing water. A considerable reliance of voids is revealed by experimental research on water absorption in polymer matrix composites. Any amount of void volume fraction in a composite will cause it to absorb more moisture than the matrix resin can hold. Using a mix of moisture diffusion in the matrix resin and capillary flow in the voids, the moisture uptake in a composite submerged in saltwater has been predicted. Although saturation timings are incorrect, forecasts and experiments qualitatively accord. To correctly forecast the dynamics of water uptake in a composite, more precise flow modeling and extensive characterization of the void structure are needed.

2.10 Literature review on Swelling study

Radzi A. M. et al. [128] employ thermogravimetric analysis (TGA) to investigate how increasing the amount of sugar palm fiber (SPF) in a hybrid composite affects its thermal properties, water absorption, and swelling thickness. The hybridized forms of RF/SPF were created by melt combining and hot compression at 170 °C at various weight ratios. The water immersion time test was used to study water absorption and swelling qualities. The hybrid composites' thermal characteristics were also studied. The findings of the water absorption and swelling thickness tests showed that the RF/SPF hybrid composites absorbed less water and swelled less thickly as SPF content increased. The RST-3 hybrid composite yielded the lowest water absorption (7.35%) and thickness swelling (7.15%) statistics.

Unsaturated polyester resin (UPR), which Farid Mulana et al. [129] employ as a composite matrix, nonetheless has physical defects such density, water absorption, and thickness swelling. It is possible to make an effort to enhance these physical qualities by using filler. Fly ash and coconut fiber are two examples of all-natural fillers. Regarding the capacity to produce composite materials with the filler material—in this example, coconut fiber and fly ash—both offer benefits. The goal of this study is to determine how filler hybridization affects the physical characteristics of the composite material. In this investigation, mold pressing at a pressure of 250 bar was employed. To get rid of undesirable materials including lignin and hemicellulose, coconut fiber was steeped in 5% NaOH. The independent variable was the ratio of coconut fiber filler to fly ash, with ratios of (10:4), (7:4),

(4:4), (4:7), and (4:10)%wt. As the amount of fly ash rises, a higher density value is achieved. A composite with a greater coconut fiber to fly ash ratio absorbed more water. When more coconut fiber than fly ash was applied, the thickness altered, according to the findings of the thickness swelling.

2.11 Literature review on Bio- degradation study

Z. N. Azwa et. al. [130] done a review on polymeric composites degradability depends on the natural strands. In this research property of a few organic strand composite presented to moist, heat, fire, UV degradation via a literature survey. Hence, from the gathered information and different experimental outcomes, it was presumed that an ideal mix proportion of chemical added substances should be utilized to accomplish equity among quality, hardness, and endurance necessities for organic strand composites.

Jute/poly(lactic acid) (PLA) composites were originally made through extrusion as well as injection molding, according to Ding D. et al [131]. The American Society of Testing Materials (ASTM) criteria were followed, and the composites were then subjected to a fungal environment for 28 days that included five fungi. We examined the samples' weight loss, morphology, and mechanical characteristics on various infected days. We used differential scanning calorimetry (DSC), scanning electron microscopy (SEM), and gel permeation chromatography (GPC) to evaluate the infection process. We may deduce that the PLA on the composites' surface steadily deteriorated in a fungal environment. The interface gap between the fiber and matrix widened when surface fiber were exposed to the air, which led to a loss in mechanical characteristics.

White and brown rot fungus colonization of wood-plastic composites was studied by Jeffrey J. Morrell et al. [132] by measuring weight loss and morphological changes. Three composites were evaluated. The 70130 wood-HDPE composite was the most susceptible to fungal attack, whereas the two 50150 composites were not affected by it at all. SEM examination of fungus-free samples of all three materials revealed the presence of voids within the wood and HDPE. Similar analysis of decomposing samples of the composite with a higher wood content revealed widespread fungal colonization of the particles, notably in the vicinity of the point of first fungal exposure. Fungus hyphae were also abundant in the composite's deeper holes. The two composites with the highest HDPE content had voids, but there was no evidence of a fungal invasion.

Three different forms of biodegradation (breakdown) mechanisms of polymeric chains in plastic were described by Vijaya S. et al. [133]. 1. A biophysical phenomenon in which polymers can be mechanically harmed by cell development. 2. A biological reaction that occurs when chemicals from microorganisms interact with polymeric chains. 3. Direct enzymatic activation causes splitting or oxidative breakdown of plastic product components when enzymes from the microorganism target those parts. They explained a compostable biodegradable plastic is the plastic which produced from LDPE by adding some kind of fillers in different weight percentage and burring this plastic in compostable soil which having maximum concentration of microorganism. Microbes in compost soil secrete enzyme on thin film of LDPE enhance the rate of degradation than any other type of degradation. According to their findings, (LDPE) plastic biodegradation samples were composted in moist garden soil for 7, 14, 21, and 28 weeks to encourage microorganism biodegradation. It was also studied that some natural polymer such as starch could lose mechanical properties in plastic chain in the period of 90 to 180 days.

2.12 Matrix

2.12.1 Unsaturated Polyester Resin

Popular thermoset polymer is unsaturated polyester resin (UPR). In both developed and developing nations, it is one of the most widely employed as a matrix in composites for applications in the maritime, housing equipment, building materials, and transportation equipment. It possesses distinctive qualities such a high strength and modulus, as well as resistance to heat, corrosion, electricity, and transparency. To increase their impact strength and other mechanical qualities, UPRs have been combined with elastomers (such as nitrile butadiene rubber, maleated nitrile rubber, carboxyl-terminated butadiene acrylonitrile rubber, etc.). Typically, phenol formaldehyde resins are blended with other resins to improve fire characteristics [134]. Many benefits are provided by polyester resin, including its low cost, reasonable temperature resistance (up to 80°C), adequate resistance to water and many chemicals, good wetting of glass fibers, low shrinkage (4%–8%) during curing, and linear thermal expansion (100–200•106 K). The impact strength and other mechanical properties of UPRs have been enhanced by combining them with elastomers like maleated nitrile rubber, nitrile butadiene rubber, carboxyl-terminated butadiene acrylonitrile rubber, and others. Usually, phenol formaldehyde resins are blended in to improve fire characteristics. Unsaturated

polyesters are frequently used for the hulls, pipelines, and compartments of ships and are typically reinforced with fiber-glass or powdered minerals. UPR is still a highly significant plastic grade. UPR is used extensively in the production of composite materials, wood paints, flat laminated panels, furrowed panels, ribbed panels, gel coat for boats, automobiles and bathroom fittings, coloring pastes, fillers, stucco, putties, self-extinguishing composite materials, quartz, marble, as well as synthetic cement, as well as in a variety of other applications [135].

2.12.2 Molecular Structure of Unsaturated Polyester Resin

The condensation products are unsaturated polyester resins, which typically have glycols, saturated acids, and unsaturated acids as their structural building blocks. This form of polyester's unsaturation serves as a location for later cross-linking [136,137]. This initial class of polyesters consists of linear polyesters with aliphatic unsaturation, which serves as a crosslinking site later on. Unsaturated-saturated acid ratio, glycol structure, and the amount of monomer required for cross-linking all affect the thermal distortion temperature of unsaturated polyester resin. The majority of polyester resins are viscous, light-colored liquids made of a reactive diluent, often styrene, but which can also contain vinyl toluene and different acrylates. The unsaturated polyester resins' key characteristics are as follows: In their use, liquid: a poor linear shrinkage. Excellent charges and fiber wet ability. Hardener is added during cold cross-linking.

Appearance Yellow viscous liquid

Melting Point -31ºC

Boiling Point 145-146ºC

Density (g/cm^3) 0.906

Stability stable, but when exposed to light, they might polymerize. Often carried with a dissolved inhibitor. powerful acids, aluminum chloride, powerful oxidizing agents, copper, copper alloys, metallic salts, and polymerization catalysts are among the substances to be avoided and

Refractive Index 1.546-1.548

Viscosity at 25ºC 200-300 cps

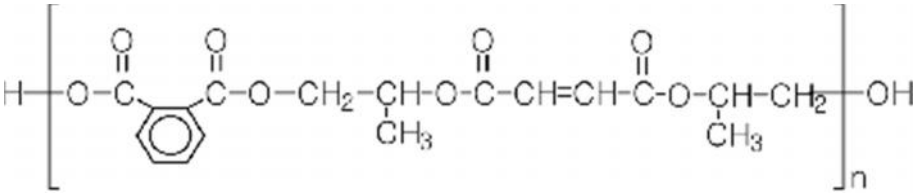
Acid value 25 $\pm$ 5 mg KOH/g

Vapor Density 3.6 (vs air)

Vapor Pressure 12.4 mm Hg (37.7 °C)

Water Solubility 0.3 g/L (20 ºC)

Flash Point 31ºC



(a)

(b)

Figure 2.13 (a) Chemical structure of unsaturated polyester resin, (b) container of unsaturated polyester resin

2.13 Composite

2.13.1 Definition

The main components of a composite material are reinforcement (fibres, particles, flakes, and/or fillers) and a matrix (polymers, metals, or ceramics). The reinforcement is held in place by the matrix to create the desired form, and the reinforcement makes the matrix stronger overall. When properly assembled, the resultant substance is stronger than each of the individual pieces is. Jartiz says that composites are systems of materials that can be used for more than one thing and have properties that cannot be found in a single material. They are structures that stay together [138]. Berghezan says that

composites are "compound materials that are different from alloys in that the individual parts keep their own properties but are put together in a way that takes advantage of only their strengths and not their weaknesses." This is done to make a better material [139].

Matrix phase

The matrix, which houses a composite fiber system, is essentially a homogenous, monolithic material. It is continuous in nature. The matrix is often less rigid and more ductile.

Dispersed (reinforceing) phase

The matrix contains an embedded continuous version of the second phase (or phases). The scattered phase is the name for the secondary phase. The scattered phase is a matrix phase that surrounds a discontinuous phase known as the matrix phase. If a phase is added to boost strength, it is frequently referred to as reinforcement during the scattered phase. The matrix is often made of a ductile material that is tough, whereas reinforcing components are typically strong and low density. Figure 2.11 shows how composite has evolved.

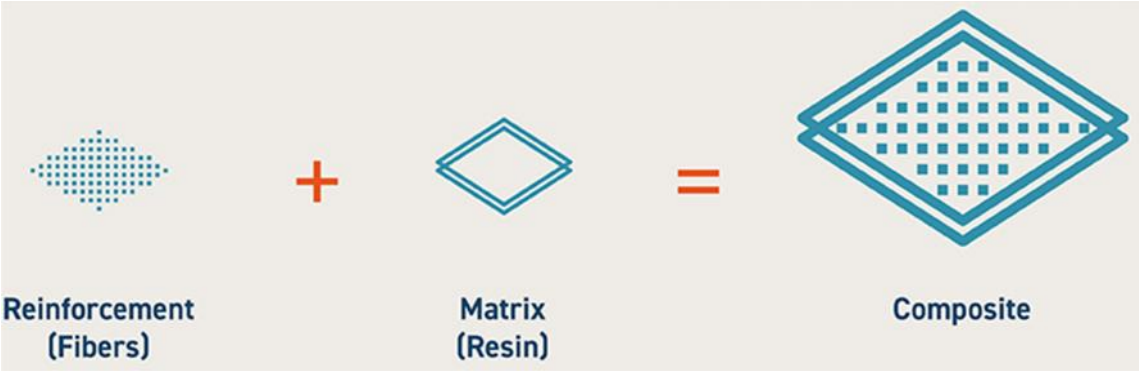


Figure 2.14 The above diagram depicts composites preparation.

Composite Materials

• Composite of fiber -reinforced polymers.

• Concrete composite

• High -strain composites.

• Sandwich -structured composites.

• Thermoplastic composite materials.

• Made up of natural parts [140].

• Advanced diamond -like carbon (DLC); it speeds up the process of making surfaces less absorbent of water, resistant to wear, and strong [141].

• Made up of small pieces

Compositional Characteristics

For example, composites are known for their lightweight and great strength. They are also known for their resistance to corrosion. Non-conductive, Non-magnetic, Very high-impact strength, Stability in Dimensions, Low Thermal Conductivity and Good Environmental Stewardship'

Construction Techniques of Composite

There are many different ways to make composite materials. The most basic way to build with thermoset composites is to lay them out by hand.

Main fabrication techniques are-

• Open Molding technique

• Injection Molding technique

• Resin Infusion Processes technique

Classification of Composite

Based on the material of the matrix, composite materials can be put into two main groups.

These are:

1. Thermoplastics and

2. Thermoset

1. **Thermoplastics:**

The materials that soften when they get hot are called thermoplastics. Engineering plastics are another name for these thermoplastics. Polyesters, polyether imides, and a few fluid crystal polymers are examples of thermoplastics. These molecules are referred to as discrete molecules because covalent bonds keep their atoms bound together. Because of this, their melting and boiling points will be low. Usually, their melting points can be anywhere from 210 to 3710 degrees Celsius.

2. **Thermosetting:**

Thermoses are made of things that get harder when they get hot. Some varieties of polyesters, vinyl-esters, epoxies, and polyamides are thermoses. Epoxies are the most often utilized resins in advanced composites, and thermosetting polymers are employed to create all different types of fiber-reinforced composites. The three-dimensional architecture of the majority of thermoses provide them excellent resistance to size, temperature, and solvents [142]. These resins often have a little lower viscosity than other resins. The cross-linked structure forms in three dimensions when they interact chemically with the polymer and connect to the whole matrix. As a result of all of the aforementioned considerations, epoxy resin was chosen to serve as the matrix material for the experiment.

The reinforcement is the part of composites that makes them strong and stiff. It will be distributed uniformly throughout the matrix material. Every type of reinforcing material has a unique set of characteristics [143]. Different kinds of reinforcements are used. Here are a few examples:

1. Particle reinforcement
2. Structural reinforcement

In this experiment, fibers are used as reinforcement because there are a lot of them. Any fiber-reinforced composite is made up of three types of fiber reinforcement:

1. Whether the fibers are continuous or not.
2. A matrix that will be spread out over the whole composite.
3. The area where things meet.

In this experimental work, the fibers that do not connect to each other are taken into account. There are both natural and fabricated fibers. When compared to natural fibers, the strength and stiffness of artificial fibers may be higher. However, this paper looks at natural fibers (chicken feathers) because

there are so many of them in nature and because they break down naturally. Even though natural fibers do not grow back and cannot be recycled, they are still used because their properties, especially stiffness, are so good [144]. Reinforcing materials divide composite materials into two groups [145].

(a) Particulate Composites

(b) Composites Made of Fibers

(a) Particulate Composites

The word implies that the reinforcement is minor. Its fundamental shape remains the same whether it is a cube, sphere, plate, or tetragon. Particulate-reinforced composites are formed of nearly equal axis flakes, rods, spheres, and other forms. Particles do not considerably improve the composite's break resistance, but they do stiffen it. Particle fillers are used to change the electrical and thermal conductivity, friction, abrasion and wear resistance, high-temperature performance, machinability, surface hardness, and shrinkage of matrix materials.

(b) Fibrous composite

A fiber is longer than its cross-sectional size. Size dictates how much reinforcement may contribute to the composite. Fibers reduce matrix cracking. Long reinforcements reduce the propagation of cracks that originate along them and might otherwise destroy fragile matrices. Non-polymeric fabricated fibers are stronger along their length than in bulk. Large defects in bulk material are less prevalent in the fiber's narrow cross-section. Molecular orientation gives polymeric materials strength and stiffness.

Constituent Materials

Reinforcing fiber, matrix, coupling agents, coatings, and fillers are the five essential components of a fiber-reinforced composite material. The essential portions that carry weigh are the fibers, and the matrix that surrounds them keeps them in place and pointing in the appropriate direction. The load is moved through the fibers by shear stress, which is accomplished via the matrix. When coupling

agents as well as coatings are applied to fibers, they make it simpler for the fibers to attach to the matrix and connect at the fiber-matrix interface. This is because the coupling agents and coatings have a hydrophobic quality. When fillers are added to some polymeric matrices, the major purpose is to reduce costs while also making the product more size stable.

2.13.2 structure of composites

Structure of a composite material determines its properties to a significant extent.

Structure factors affecting properties of composites are as follows:

- At the **scattered phase/matrix** contact, there is a **strong bond**;
- **Shape of the scattered phase inclusions** (flakes, fibers, particles, laminates);
- **Orientation of the scattered phase inclusions** (chosen or random).

Interfacial bonding

Strong adhesion or bonding within the matrix phase and the scattered phase makes it easier to effectively transfer the load from the material onto the dispersed phase across the interface. This is because the matrix phase as well as the dispersed phase are working together. For the composite to have high levels of mechanical characteristics, adhesion is required. There are three different ways for the two stages to interact:

1. Direct bonding with no intermediary layer. In this case, adhesion (or "wetting") is provided by either van der Waals force or covalent bonding.

2. An intermediate layer made up of the components of the scattered phases and the matrix as a solid solution.

3. A third bonding phase serves as the intermediate layer (interphase).

2.14 Literature survey on chicken feather fiber, cow hair fiber and leather fiber composites

Chicken feather fiber composite

Chicken Feather Fiber (CFF), one of the bio-natural fiber composites, is regarded as a decent alternative to the synthetic varieties. Chicken husbandry produces CFF as a secondary or unintended product and its analysis, treatment, and post-processing are challenging due to the absence of standardized extraction procedures. The CFF family of fibers is an intriguing group that has the potential to be used in a variety of settings because of its relative abundance and advantageous characteristics. This study shows that using CFF creates biodegradable and environmentally friendly combinations that offer a way to get rid of most of the solid waste produced by poultry farms [146].

Reusing, recycling, and reducing the rising amount of solid biowaste are all necessary. The goal of research was to create biomaterial-based reinforcements for composites. The main focus of this review is to examine and evaluate the physical, chemical, mechanical and thermal properties of CFF, as described in several research papers. The methods for creating CFF composites are also presented in this paper, along with CFF's use as a reinforcing material in composites. This evaluation shows that CFF offers ample room to investigate potential research areas for CFF as a biomaterial in composites [147].

In this study, composites made of polyester and phenyl-ester that were reinforced with chicken feather fiber were compared and contrasted for their respective mechanical properties. It was discovered that the compressive Strength of CFF-based Composite is superior to the compressive Strength of the control Composite. As a result of its better behavior and structural applications, CFF-based Composite may be employed in any engineering application.

The research looked at the mechanical properties of polymeric composites reinforced with fibers made from chicken quills and feathers. Composites reinforced with CFF were shown to have much better impact characteristics than the control composites, although having inferior tensile and flexural properties. In comparison to the control vinyl ester composites (3.31 kg/mm^2), the Charpy impact value for the material with 10% CFF reinforcement was 4.42 kg/mm^2. The 10% CFF reinforced polyester composite had an impact resistance of 4.56 kg/mm^2, which was three times

higher than the impact resistance of the control composite, which was 1.85 kg/mm^2. Thus, it was determined that CFF reinforcement increases the composite's impact strength.

The viability of using wasted chicken feathers—more particularly, the barbs and rachis—as a reinforcing material in composites of cement-based was investigated. In comparison to commercial wood fiber-cement composites of the same thickness and density, boards containing 5% to 10% fiber and ground feather by weight demonstrated comparable strength and dimensional stability. When the number of feathers was increased by more than 10%, the stiffness, flexural strength, and dimensional stability of the feather-cement boards deteriorated. Increasing percentages of feather demonstrated a noticeable drop in water absorption, thickness swelling, modulus of elasticity (MOE), and modulus of rupture (MOR) after soaking in water for 24 hours. It was determined that used chicken feathers, up to a 10% feather content, may be employed as reinforcement in cement-bonded composites.

There was supposedly an improvement in the physical and mechanical properties of wood-cement composites when chicken feathers were used as reinforcement [148].

It is estimated that feathers are composed of 50% quill and 50% fiber [149]; the fiber is constructed of the hydrophobic protein keratin, which has the strength of nylon but a smaller diameter than wood fiber. The covalent bonds also serve to maintain the intricate three-dimensional protein structure [150,151].

Recent research has demonstrated the potential of chicken feather fibers (CFF) as a reinforcing material for polymer composites [152]. It was said that the twin-screw extruder as well as an injection molding machine were used to process the thermomechanical characteristics of CFF/PLA green composites. The scientists found that adding CFF to the PLA matrix significantly increased the tensile and storage modulus [153]. The inclusion of CFF leads to a reduction in the flexural properties and tensile of both polyester matrix and vinyl ester, it was noted that the impact strength significantly improved with the addition of CFF. The authors suggest using CFF waste to manufacture composites having high impact strength based on the findings [154]. Bansal et al. additionally looked at the CFF augmented with epoxy composites' water absorption performance. The composites' density is reduced with the addition of the CFF, but their void content, water absorption, and thickness swelling are all somewhat improved [155]. Reddy, et al. demonstrated in recent study that chicken feather keratin may be utilized as an efficient sizing agent on polyester as well as polyester/cotton blends [156].

Cow hair fiber composite

A vast history extending back thousands of years may be found in the tanning industry. Cowhide is one of the most common types of leather, and cow hair is the most common byproduct of the tanning process. Around 6% of a cow's body weight is made up of hair, therefore 85 kg of hair may be extracted from a ton of salt-wet cowhide [157].

Cow hair fibers, a significant waste product in tanneries, are either burned or released into waterways by chemical deterioration. Both disposal techniques have environmental challenges. In the same vein, roasting is the primary procedure used to remove hair from abattoirs. Another pollution issue is brought on by the roasting and burning of the hair fibers [158].

To make composite materials, several materials can be mixed, with one material acting as the matrix and another as the reinforcement. Fibers or particles might be used as the reinforcement. The majority of synthetic fiber reinforcements are costly and harmful, which prompts the investigation of workable alternatives, with natural fibers emerging as the most popular. Biodegradable, all-natural fibers are preferred for their lower environmental impact and greater accessibility. Natural fiber reinforced polymeric composites have seen a surge in study as a potential replacement for synthetic fibers, which are more expensive but are now considered waste due to disposal issues. Natural fibers have unquestionably attracted attention in the creation of composite materials due to their lightweight, nonabrasive, flammable, nontoxic, affordable, and biodegradable characteristics. However, natural fiber reinforced composites are less desirable due to their poor interfacial adhesion, low melting points, as well as limited resistance to moisture absorption. Cleaning and chemical alterations to the fiber's surface can reduce moisture absorption and increase surface roughness [159].

These fibers may be used as a reinforcement in thermoplastics and thermoset polymers, which solves the disposal issue and reduces costs. Animal fibers, notably cow hairs, are unique among natural fibers because they include structural protein molecules like keratin, which generate a complex network of intermediate fibers in the cytoplasm of epithelial cells. This is essential for maintaining the integrity of cells and tissues. This makes it possible for them to withstand a broad variety of chemical and thermal treatments as well as a substantial range of physical and mechanical pressures without incurring permanent damage [160,161].

Animal hair has proven to be a dependable reinforcement material for both thermoset and thermoplastic polymers, owing to its various benefits. A number of trials that focused on animal fibers, particularly those that are based on keratin, have yielded positive results, although they are not all-encompassing. This has led to a reevaluation of the potential of animal fibers as a reinforcement material [162].

Human hair fiber was employed to reinforce polypropylene, and the mechanical characteristics of the produced composites were significantly improved [163,164]. The flexural properties of high density polyethylene composites were enhanced when reinforced with cow hair fibers [165].

Additionally, Oladele-et al. demonstrate an progression in the tensile characteristics of composites made of low density polyethylene and cow hair fibers. Low fiber weight fractions have been shown to improve mechanical characteristics and abrasion characteristics due to their light-weight and low density, but Young's modulus and flexural modulus are found to decrease with an increase in the quantity of fiber in the polymer [166].

Foam concrete made using iron tailings as the fine aggregate and regular Portland cement as the cementitious material yielded an innovative approach to recycling tannery waste in the form of cow hair used as a fiber reinforcing material. Next, the density as well as mechanical properties of foam concrete were analyzed as a function of cow hair fiber content. The program Image-Pro Plus is used to assess how the cow hair fiber modifies the foam concrete's permeability, pore size distribution, and pore roundness. Foam concrete that protects the environment and fosters sustainable development must utilize cow hair as a reinforcing fiber [167].

Natural stockpiling is the primary technique of treating bovine hair, however storing a lot of unwanted calf hair will have an adverse effect on the environment. Therefore, it is vital to recycle the used cow hair from tanning. Protein concentrations were created from cow hair waste, and it was then examined how different fermentation techniques affected the protein properties of the concentrate [168].

Due to the high carbon concentration of cow hair, it was utilized to make porous biochar. However, those techniques used little cow hair and were laborious [169].

Cow hair also has a high elastic modulus that is 1.53–1.98 GPa, making it a candidate for usage as reinforcement material.

Human hairs are a problem for the environment. The discarded human hair fiber was blended with polypropylene for commercial use. Human hair fiber from composite materials made of

polypropylene is used. Using two roll mills, polypropylene (PP) is blended with human hair fibers at weight percentages of 3,5,10, and 15%. Compression molding of the composite occurs at a given temperature and time. The tensile strength of polypropylene and hair fiber polymer reinforced composite is lower than that of (PP) polypropylene, but it has greater flexural and impact strength than (PP) polypropylene [170].

Leather fiber composite

Landfilling is the primary method used to handle finished leather waste generated during the manufacture of leather goods, squandering the resources it contains. A more eco-friendly option would be to recycle these wastes into new composites. 12.5 to 300 parts per hundred parts of rubber (phr) of 1 mm leather fibers were added to styrene butadiene rubber and acrylonitrile butadiene rubber-based composites. Compression molding was used to vulcanize rubber-leather composites, which were then characterized with relation to their potential use as soles and other inside components of footwear. According to the results, composites with increased tear strength and up to 10–20 phr of leather inclusion were made. Even though they were still within the allowable range for application, tension and elongation reduced. These composites are suitable for use as soles since the other physical characteristics investigated in them are not considerably impacted. The qualities of composites are compatible with the use of in-shoe components over the recommended range of integration and up to 100 (phr) [171].

Epoxy resin composite sheets reinforced with scrap leather were made in several thicknesses (2.5 mm, 5 mm, and 7.5 mm) and subjected to a response surface analysis using a central composite design to determine the optimal leather loading. The completed composite sample underwent testing for tensile strength, flexural strength, impact resistance, and chemical resistance. Higher leather loading percentages in composites produced materials with remarkable mechanical qualities. Damaged surfaces were examined using SEM to learn more about the matrix's and leather's interaction. At the highest leather loading, the composite showed tight packing and adherence. TGA and DTA tests with increasing leather loading indicated remarkably high heat stability.

Leather waste fibers added to elastomers could function as short fiber reinforcement for the matrix, provided their inherent fibrous nature is retained during processing [Ravichandran, K. and Natchimuthu, N. (2005). Natural Rubber - Leather Composites, Polı´meros: Cieˆncia e Tecnologia,

15: 102108]. However, because elastomers are processed at quite high temperatures, maintaining their fibrous structure may be challenging. Due to the existence of reactive functional groups, the presence of trivalent chromium, and the acidic nature of leather, the use of leather in rubber formulations is also likely to alter the vulcanization characteristics and vulcanizate qualities. Before adding leather to rubber, methods for neutralizing its acidic nature may be used. These processes, however, need a number of preparatory steps, such as wet treatments followed by fiber drying.

Epoxy resin composite sheets reinforced with waste leather were produced in thicknesses of 2.5 mm, 5 mm, and 7.5 mm, and their performance was evaluated using a response surface approach using a central composite design. Tensile, flexural, impact, and chemical resistance tests were performed on the finished composite sample. Composites with higher leather loading percentages had exceptional mechanical properties. Using SEM to examine the broken surfaces, the bonding between the matrix and leather was investigated. At the highest leather loading, it was found that the composite showed tight packing and adherence. TGA and DTA tests showed outstanding thermal stability as leather loading increased. The DMA investigation of composites revealed an increase in storage modulus, a reduction in loss modulus, and a drop in Tan peak with greater leather loading. The enhanced chemical robustness of composites was demonstrated by the absence of any symptoms of breakdown [172].

The shape, dynamic mechanical characteristics, toluene absorption, and mechanical parameters of nitrile butadiene rubber/waste leather fiber (NBR/WLF) composites were thoroughly investigated. As a result, the tensile strength and tear strength rise from 0 to 50 wt% and drop from 51 to 100% as WLF concentration increases. The maximum tensile strength of 12.5 MPa and tear strength of 72.47 N/mm were obtained with the WLF/NBR ratio of 50/50 wt%. The hardness and resistivity of the toluene-based materials increased with increasing WLF content. The NBR matrix and the WLF had significant adhesion, according to the SEM results. The WLF and NBR matrix's excellent compatibility was shown by the rise in storage modulus (E') when compared to raw NBR. This study demonstrated that recycled materials made from used leather and NBR may be effectively created and had a wide range of applications, including playground and court flooring. [173].

CHAPTER 3

CHAPTER 3
MATERIALS AND METHODS

3.1 Materials

3.1.1 Raw Material:

Raw materials used in this research project were:

Chicken Feather Fiber (CFF), Cow Hair Fiber (CHF) and Waste Leather Fiber. Chicken feather fibers were gathered from a nearby poultry farm. Black cow hair fiber and shaving debris from the local leather industry were gathered in the area of Hemayetpur, Savar, Dhaka, Bangladesh.

3.1.1.1 Chicken Feather Fibers

Chicken Feathers are the byproduct of preparing chickens for human consumption. Chicken feather originates from free, renewable animal byproducts. By mass, chicken feather consists of 91% keratin, 8% water, and 1% lipids. Due to the presence of hydrophobic keratin in both the fiber and the quill, CFF exhibits an uneven surface finish during composite construction [174]. In Bangladesh's capital city of Dhaka, Hazaribag Bazar, chicken feathers were gathered.

3.1.1.2 Cow Hair Fiber (CHF):

A large amount of wastes is produced while processing raw hides and skins into leather. Each process produces different types of wastes. During the processing of hides and skin huge amount of solid wastes are created. For this study only Cow hair is considered. For processing 1000 kg of raw hides and skins about 100 kg of solid waste is created. Among them the amount cow hair is 100 kg/ton. [175] That’s a huge amount of solid waste. For this study the cow hair used was from the tail portion of the cow. These hairs were collected from the local Govt. Butcher shop at Jhauchor, Hazaribagh, Dhaka, Bangladesh.

3.1.1.3 Buffing Dust:

Buffing dust is a fine powder of leftover collagen fibrils created during the buffing and milling processes of producing chrome tanned leather. As of right now, the most common methods of disposal for this very difficult to handle tannery solid waste are incineration and land field disposal. Buffing dust also contains potentially harmful heavy metals like chromium.

The scientific literature reports the results of several studies looking at its potential use in the production of composites. Buffing dust, a solid waste product of chrome-tanned leather, has been utilized as filler for numerous polymeric matrices to generate leather-like composites for prospective purposes including hand bags, wallets, key chains, purses, and footwear items such as shoe bottoms, insoles, heels, etc. The features of composites are also discussed, with reference to previous studies done using different polymer matrices and published in journals. According to scholarly research, buffing dust can be used to make fiber-reinforced composites with improved mechanical properties; these composites can then be put to use in a variety of contexts; they can save energy; they can reduce depletion; they can prevent the wasteful disposal of virgin raw materials; and so on. In addition, they address the environmental challenges of the leather industry's waste management.

Trimming dust

Trimming dust is produced during trimming operation. Trimming means to reduce unused part of leather. Trimming is occurred pre-tanning, tanning and post-tanning operation. Outer side of leather is cut by sharp knife because outer side fibers strength is very much lower than the inner part of leather. In this research, the wet blue trimming wastes were used to convert it into trimming dust

3.1.2 Chemicals:

ZnO, Al_2O_3, and $CaCO_3$, KOH (Merck, Germany), as well as Unsaturated Polyester Resin (UPR) as well as Hardener (MEKP) from Pidilite Industries Ltd. in India, were purchased from Lucky Acrylic Ltd. in Dhaka's Hatkhola Chemical Market.

3.1.2.1 Unsaturated polyester resin (UPR)

Unsaturated polyester resin (UPR) and MEKP hardener are used as the matrix for composites. UPR is easy to work with, cheap, stays the same size, and has good mechanical, chemical, and electrical properties. Polyester resins are the least expensive type of resin, so they are the most cost-effective way to mix resin, filler, and reinforcement. Hatkhola Chemical Market in Dhaka, Bangladesh (LUCKY ACRYLIC LTD.) was where we sourced our unsaturated polyester resin (UPR) and hardener. It has properties like a pink color, a density of 1.12 g/cm3 , and the ability to stay stable in the dark at temperatures below 25 0C. Polyester resins are made when dibasic organic acids and polyhydric alcohols react. They are unsaturated synthetic resins. Maleic Anhydride is a common raw material that can be used as a di-acid. Toner for laser printers, bulk molding compound, and sheet molding compound are all made with polyester resins. Known as fiberglass reinforced plastic (FRP), wall panels constructed of polyester resins and fiberglass are frequently used in restaurants, kitchens, restrooms, and other locations where walls must be simple to maintain and clean.

3.1.2.2 Hardener-Methyl Ethyl Ketone Peroxide (MEKP)

Liquid hardener MEKP. Methyl ethyl ketone peroxide, or MEKP, is a catalyst that is added to polyester and vinyl resins. MEKP reacts chemically with the resin when it is mixed, creating heat that cures or hardens the resin. 2-Butanone peroxide, also known as methyl ethyl ketone peroxide, is a highly oxidizing (caustic) organic peroxide used in the manufacture of acrylic resins as well as a room-temperature hardening and curing agent for unsaturated polyester resins and fiberglass-reinforced plastics. The range for the catalyst-to-resin ratio is 1% to 2% of the total volume of resin to be employed. Methyl ethyl ketone Peroxide (MEKP) was obtained from the same supplier and utilized as a catalyst and accelerator for unsaturated polyester resin.

3.1.2.3 Zinc Oxide

Zinc Oxide is an inorganic compound that is also called Zinc White or Calamine. It can be found in the earth as the mineral zincate. Most of it is made artificially [176]. General Properties of ZnO:

1. Chemical properties: Although pure zinc oxide is a white powder, it is found in nature as the rare mineral zincate, which contains manganese and other impurities that give it a yellow to red color Amphoteric oxides, such as zinc oxide, are a type of oxide. It is nearly insoluble in water, although most acids, such as hydrochloric acid, will dissolve it [177].

2. Physical properties: ZnO is a somewhat soft substance with a Mohs hardness of about 4.5 [178].

Strong bonds may be formed between zinc oxide and resins on its surface, which is often more active. It is also thought that incorporating inorganic particles into the polymer and spreading them out uniformly might help boost the material's mechanical characteristics and thermal stability. ZnO's non-toxicity and ability to block UV radiation [179-181] have made it a popular choice for use in a wide variety of research and practical settings.

3.1.2.4 Aluminum Oxide

Alumina, also known as aluminum oxide (Al_2O_3), is an inert, odorless, white amorphous substance that is frequently used in industrial ceramics. Due to its exceptional characteristics, alumina has been utilized in numerous life-extending and society-improving applications. It is employed extensively in the medical field and modern warfare.

General Properties of Aluminum oxide [182]

- Melting point : 2,072 °C (3,762 °F; 2,345 K)
- Boiling point : 2,977 °C (5,391 °F; 3,250 K)
- Hardness: 15 – 19 GPa (9 on the Mohs scale)
- Electrical resistivity: 1012 – 1013 Ωm
- Mechanical strength: 300 – 630 MPa
- Compressive strength: 2,000 – 4,000 MPa
- Thermal con ductivity : 20 – 30 W/mK

• Molecular mass: 101.96 g/mol

• Density: 3.95 g/cm3

• Appearance: Solid

3.1.2.5 Calcium Carbonate

Calcium carbonate is a naturally occurring inorganic component that is commonly referred to as limestone, chalk, or marble.

General Properties of Calcium carbonate [183,184]

• Molar mass: 100.0869 g/mol

• Appearance: Fine white powder; chalky taste

• Odor: odorless

• Density: 2.711 g/cm3 (calcite)

• Melting point: 1,339 °C (2,442 °F; 1,612 K)

• Boiling point: 825 °C (1,517 °F; 1,098 K)

Figure 3.1 Image of different used animal fiber.

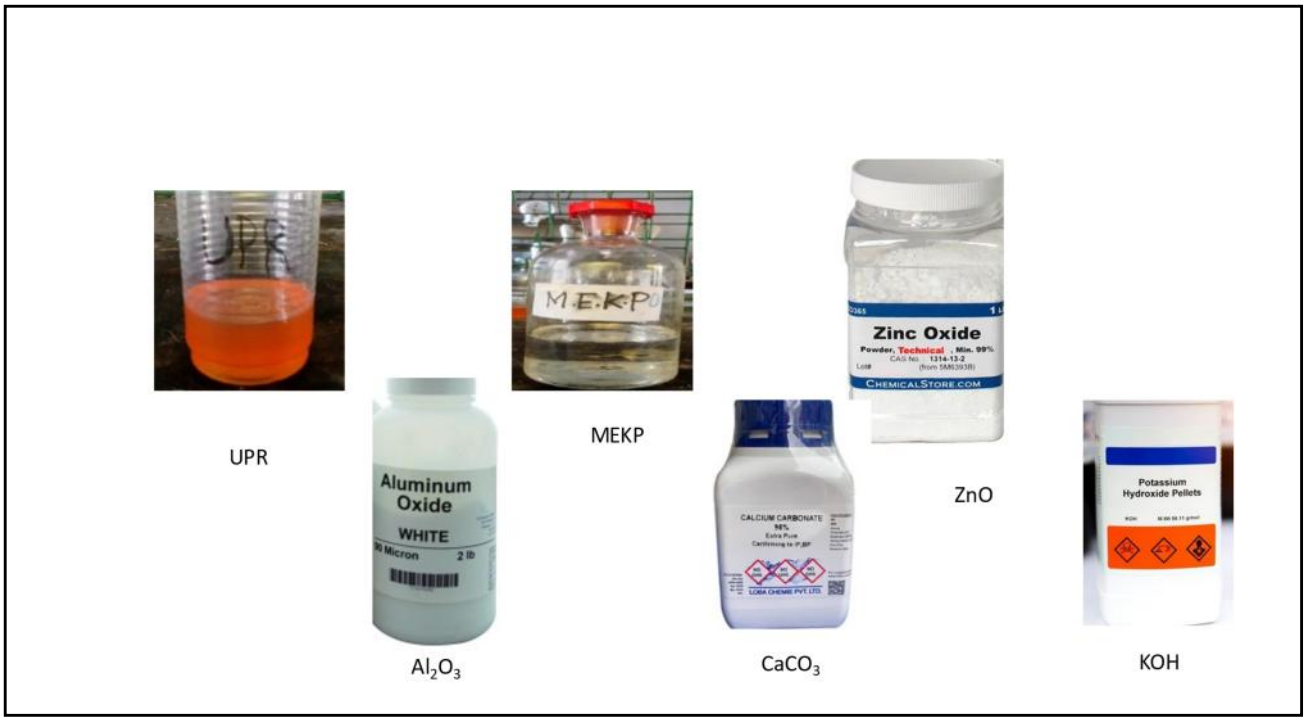


Figure 3.2: Image of different used chemicals with container.

Advantages of Using Animal-Fibres in UPR

A. Property Advantages

- Moderate fibre strength, flexibility and elasticity
- Fibre uniformity
- Moderate moisture absorption characteristics
- Lightweight
- Chemical Resistance

Advantages of Using Animal-Fibers in UPR

B. Environmental & Socio-Economic Advantages

- Biodegradable
- Wide variety of fibers available throughout the world
- Non-food agricultural economy

- Low cost
- Reduction of environmental pollution
- Expansion of job field

3.2 Methods

3.2.1 Washing and cleaning fibers:

Prior to casting a bio composite employing CFF, CHF, or LF as fiber, it is necessary to clean the feather surface to get rid of any dirt or other impurities. In order to make fibers clean, white, sterilized, and odor free, they are often washed with water and ethanol and dried [185]. Then, using a patented method [186], Baron and Schmidt produced keratin and collagen biofibers. Griffith [187] showed that a fatty coating on the feathers' surface may be removed using ethanol. The dynamics lab at G. B. Pant University used water and hair-drying shampoo to clean the chicken feathers. Depending on how many times they were cleaned, the fibers spent 24 hours drying in the open after being submerged in a pail of water. The results showed that the substance was completely dry, clean, and fewer sticky than expected. Thus, the most effective method was developed, albeit at the expense of other chemical processes. These dry fibers were separated into two sections, one of which received KOH solution treatment and the other of which was untreated.

3.2.2 Fiber Preparation:

For better adhesion and mixing the fibers used here crushed before mixing. The machine used here is crushing machine.

Cow Hair/Chicken Feather/Leather Fiber:

The collected hair/chicken feather/leather fiber were crushed in Crushing Machine at 300 rpm until they are finely crushed. Then they were weighed for the individual samples.

Figure 3.3: Image of crushing machine.

3.2.3 Chemical Treatment

Because natural fibers are hydrophilic, their potential as reinforcing agents is often limited by the poor interfacial properties between the fiber and the polymer matrix. Chemical modifications are being considered to optimize this interface. The goal of chemically modifying natural fibers was to increase the interfacial adhesion as well as wettability between the fiber and matrix in composites by removing lipids and inorganic compounds from the surface of the fibers. Chicken feathers, cow hairs and leather are mainly made of proteins. The protein present in hair and chicken feather are called keratin and collagen is present in the leather. There could be blood, dust and also the hairs are covered with wax type of materials. So, it was needed to be removed for better adhesion with the matrix. Several types of chemical treatments are done for the fiber treatment. For this method

Alkaline treatment method was used. Alkaline materials can remove extractable materials like lignin, waxes and oils that covered the outer cuticle of the fibers. So, the fiber surface became clearer and uniform. The cow hair fibers were treated with 0.20 M solution of KOH. The solution was taken in a 100mL of beaker. Then the fibers were dipped into the 1-Inch below the water surface of the beaker. Then it was covered and kept in the shaker water bath at 60ºC for 6 hours. After that these were cooled down and then rinsed thoroughly with water. The presence of KOH was checked using phenolphthalein indicator. The KOH was removed by washing with distilled water from the hair fibers until the indicator's color was turned from pink to colorless. Then they were sun dried. The day temperature of that place was 27ºC. Then oven dried at 60ºC temperature for 3 hours. They were then prepared for crushing.

Figure 3.4: Chemical treatment of fiber

3.2.4 Composite fabrication

The selected chicken feathers (CFF), cow hairs (CHF), and waste leather (LF) were washed with distilled water and detergent, sun-dried for 12 hours, and then oven-dried at 30°C for five days to

eliminate different sorts of pollutants from the surface. To make two equal parts, we used a cutting instrument from FRITSCH, Industries tr. 8, 55743 Idar-Oberstein, Germany, to sever the rods into segments measuring an average of 5 mm in length. After cleaning, a portion of the samples was subjected to a two-hour soak in 0.20 M KOH at 50°C, followed by five hours of drying at 60°C. The remaining half was not attended to. After placing a glass slab on a table, a sheet of transparent, flawless plastic paper (Mica) was placed on top of it. Then, in a sterile plastic beaker, we mixed together MEKP hardener, unsaturated polyester resin (UPR), treated and untreated chicken feather fibers, and chemical components (ZnO, Al_2O_3, and $CaCO_3$). Constant stirring and thorough mixing were achieved with the help of a glass rod. It was carefully poured over the plastic paper to prevent the matrix from escaping, and care was taken to ensure that no air bubbles remained in the mixture. Mica, a clear, clean plastic paper, was used to cover the sample combination. The matrix was then rolled with a glass rod over its whole surface to disperse the material uniformly. After crosslinking and solidifying for 24 hours in the fume hood, the mixture was transferred to polythene bags for storage. By combining the fiber parts of 2%, 5%, 7%, 10%, 12%, and 15% by weight with the matrix (UPR), the CFF-UPR, CHF-UPR, and LF-UPR reinforced composites were made using the hand lay-up technique. Ionizing gamma radiation was applied to a section of the produced composites in order to enhance their physio-mechanical characteristics [188,189].

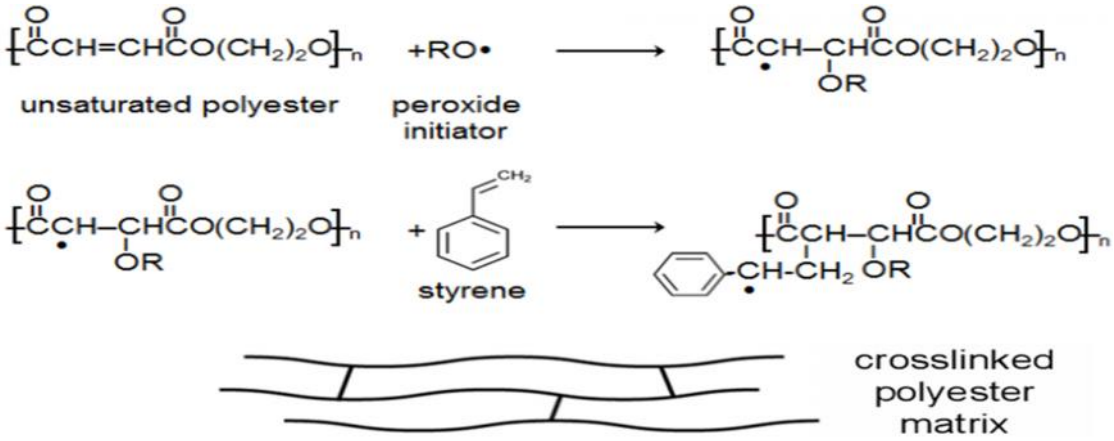


Figure 3.5 Crosslink formation within a polyester resin [190]

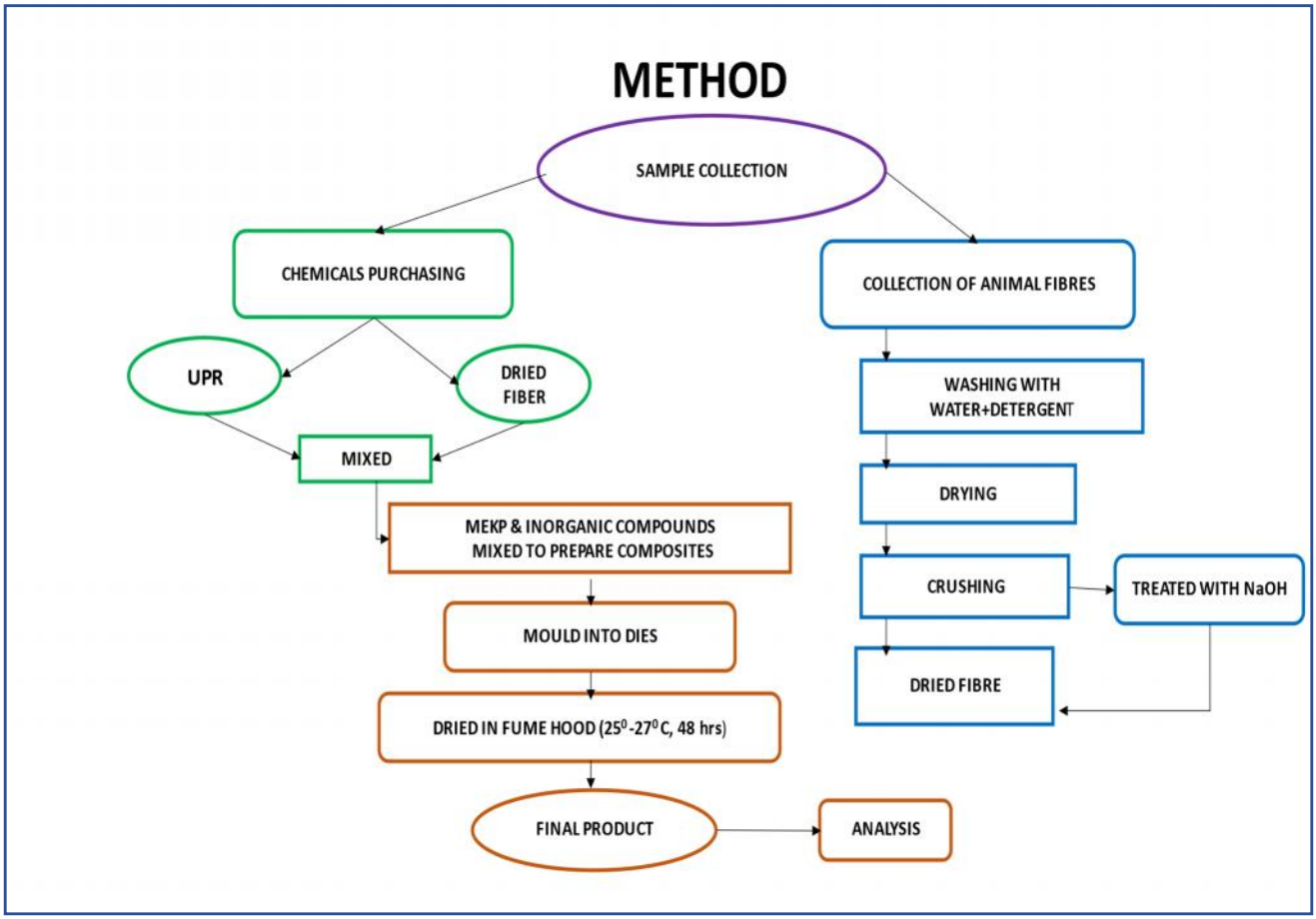


Figure 3.6: Image of flowchart of composite preparation.

Figure 3.7: Preparation process of composite with image.

Table 3.1 Compositions of the composites

Composite	Chicken Feather Fiber/Cow Hair fiber/leather fiber	UPR	ZnO/ Al_2O_3/ $CaCO_3$	Composite	Treated Chicken Feather Fiber/Treated Cow Hair fiber/Treated leather fiber	UPR	ZnO/ Al_2O_3/ $CaCO_3$
1	2%	98%		2	2%	98%	
3	5%	95%		4	5%	95%	
5	7%	93%		6	7%	93%	
7	10%	90%		8	10%	90%	
9	12%	88%		10	12%	88%	
11	15%	85%		12	15%	85%	
1	2%	98%	1%	2	2%	98%	1%
3	5%	95%	1%	4	5%	95%	1%
5	7%	93%	1%	6	7%	93%	1%
7	10%	90%	1%	8	10%	90%	1%
9	12%	88%	1%	10	12%	88%	1%
11	15%	85%	1%	12	15%	85%	1%

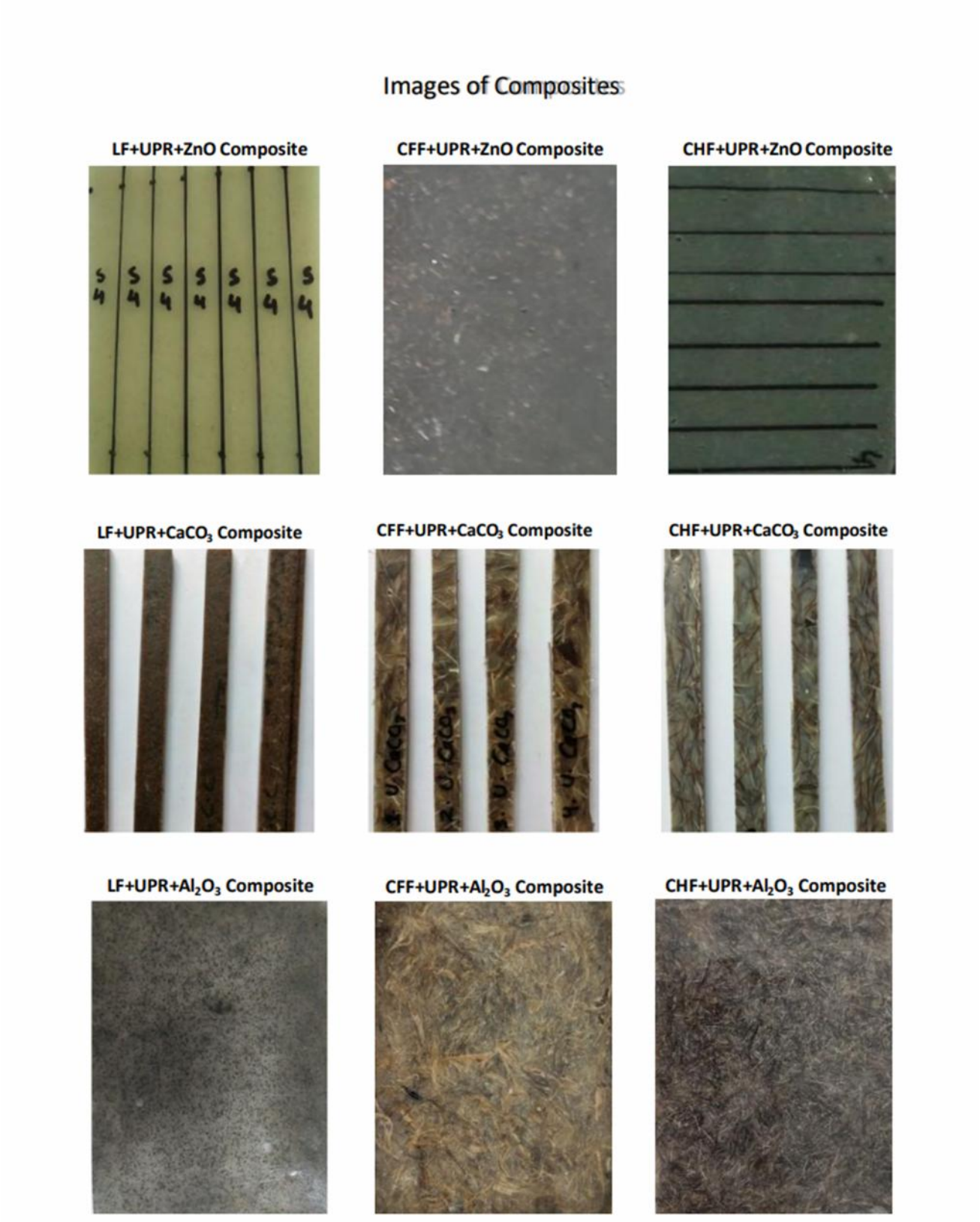
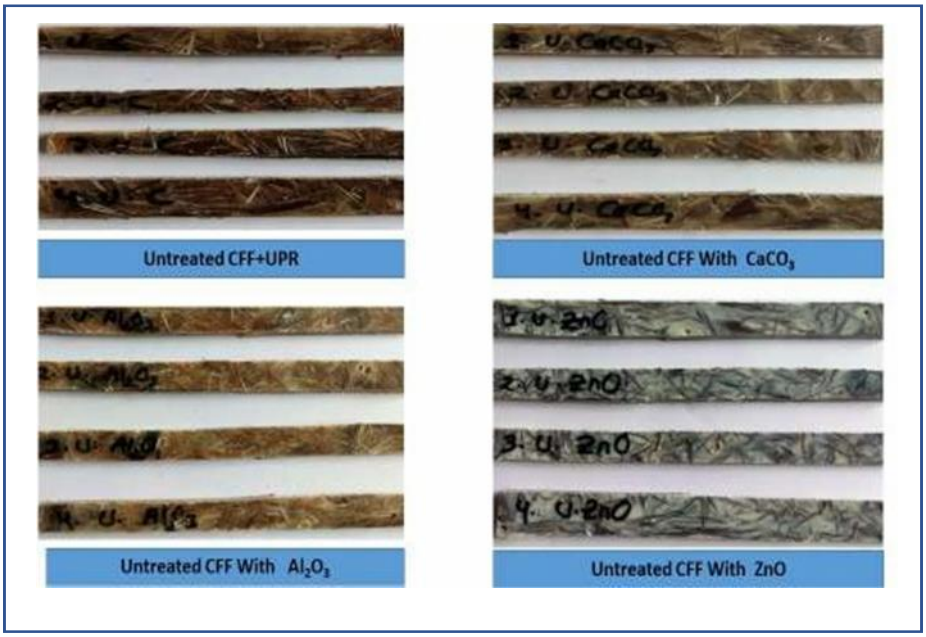
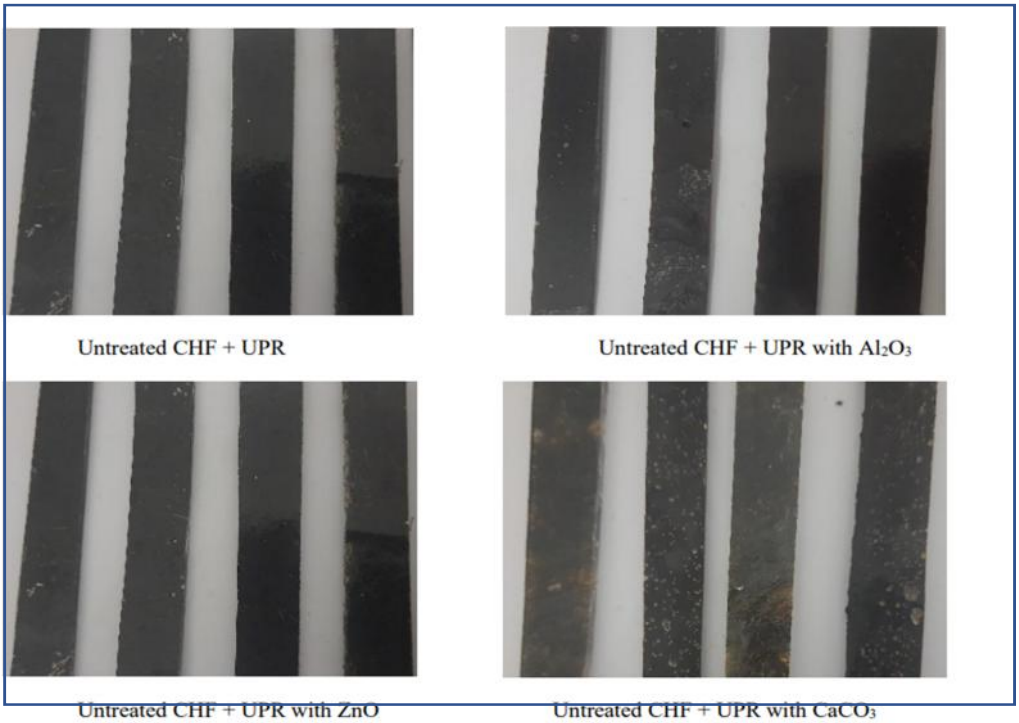


Figure 3.8: Image of CFF/ CHF/LF reinforced UPR polymer composites by incorporating $ZnO/Al_2O_3/CaCO_3$.

Figure 3.9: Image of control sample (UPR)





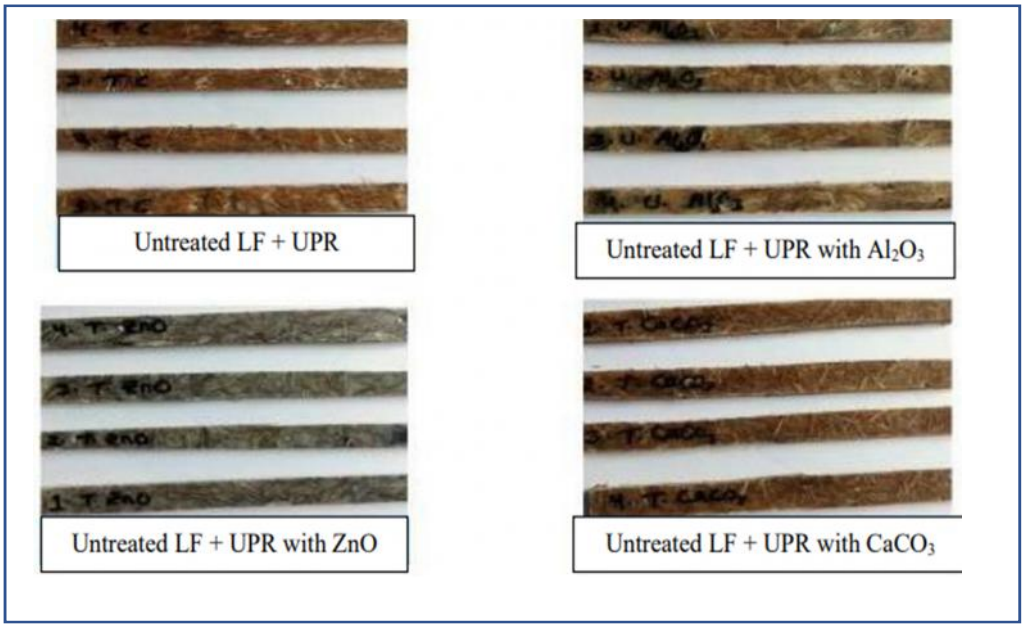


Figure 3.10: Sample preparation for mechanical property test.

Gamma radiation

Gamma radiation was added to the composite sample to enhance its mechanical characteristics. The composite was pre-cut to the required dimensions (60 mm × 20 mm × 2 mm) and then sealed in a plastic bag. 90 kCi Cobalt 60 sources used as the radiation source. 2.50, 5.0, and 7.5 kGy radiation doses were applied to the composite sample.

This experiment used a 60Co gamma source. It is a capsule-shaped housing in a hollow that rises via a remote-controlled electromechanical system. Its strength was 25 kci. Model was a gamma beam made up of 36 double-encapsulated capsules and filled with source GBS-98. It was a Type C-252 loaded with 60Co paellets. Each of the unit's 12 tubes, which contain three active capsules, has an interface made of springs. The predicted dosage rate's accuracy is 5.5% at the 95% confidence level.

First ^{60}Co decays to excited ^{60}Ni by β emission:

$^{60}Co \rightarrow {}^{60}Ni^{*} + e^{-} + \nu_e$

The ^{60}Ni then emits two successive gamma rays before falling to the ground state.

$^{60}Ni^{*} \rightarrow {}^{60}Ni + \gamma$

1.17 MeV and 1.33 MeV gamma rays are generated.

3.3 Methods of Chemical, Physical Testing and Morphological Analysis

3.3.1 Mechanical Testing of Sample

The mechanical characteristics of a bird's feather and its keratin structure are closely connected, as are the functions of the feather. The structure of keratin allows for the minimal distortion of force transmission. According to reports, the elastic moduli of feather keratin range from 0.045 GPa to 10 GPa.Chicken feathers are used in technical textiles. It was discovered that the Young's modulus of chicken feather fibers ranged from 3 to 50 GPa, while the tensile strength of oven-dried chicken feather fibers ranged from 41 to 130 MPa.

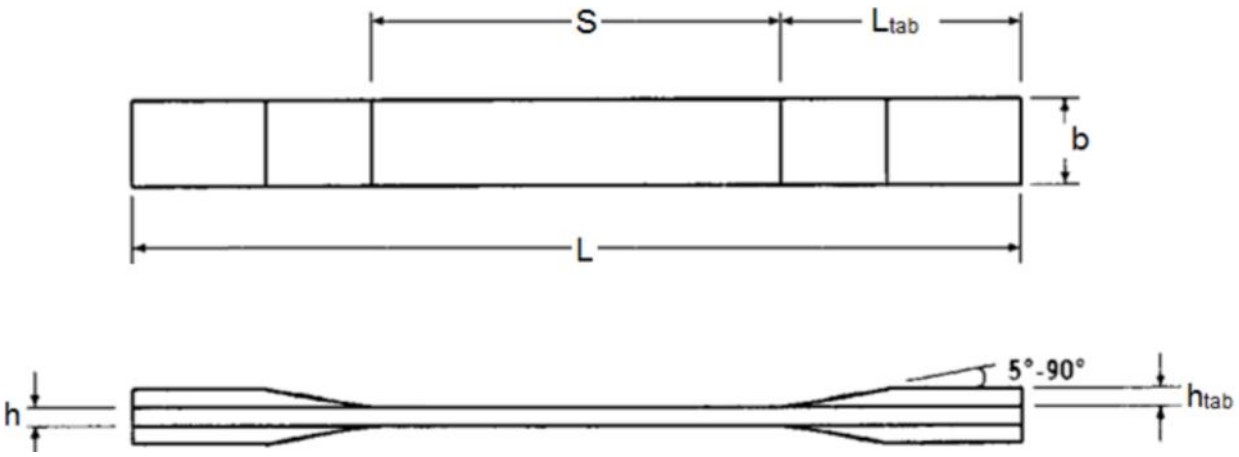


Figure 3.11: **The dimensions of the tensile test specimen for matrix**

3.3.2 Test of Tensile Properties of the Sample

To comply with ASTM D 638, the tensile test was carried out using a Universal Testing Machine (UTM) (Model No. Testometric M-500-30 KNCT). During the test, the speed was 10,000 mm/min.At initially, there is a 20mm gap between the UTM's two jaws.

Figure 3.12: Universal Testing Machine-UTM

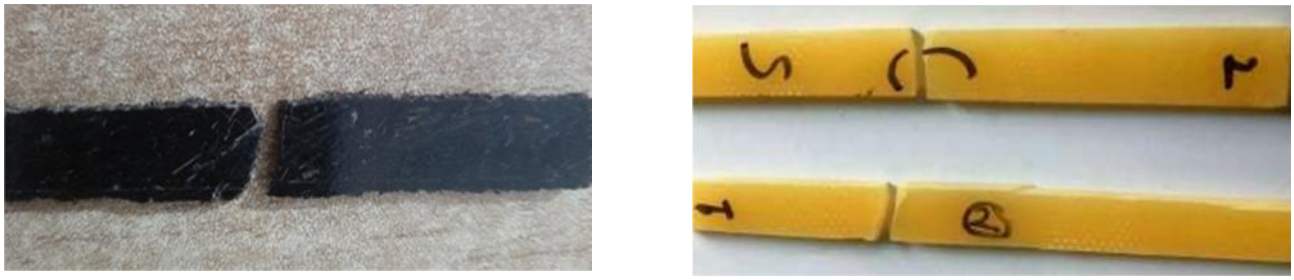


Figure 3.13: Broken specimens of composite

A tensile test was performed in accordance with ASTM D 638 using a universal tensile machine. Different UPR concentrations were used to prepare the sample. After the composites have been made, they are cut to the right size. The samples were made to have different amounts of chicken feather, cow hair and leather fibers with UPR. All of the samples were cut into flat shapes with the following dimensions: length 150 mm, width 12 mm and thickness was 4-4.5 mm. For the tensile test, the cut samples were placed vertically in the machine's grips with a 30 mm gauge length.

A gauge length of 30 mm as well as a crosshead speed of 10 mm/min were used for the testing. The average tensile strength and modulus of 10 samples were recorded. Throughout the test, the stress-strain curve was produced to calculate the elastic modulus and ultimate tensile strength.

3.3.3 Bending Strength Test

Bending strength (BS) and bending modulus (BM) of the composites were also carried out by using the same universal testing machine (M-500-30 KNCT), with a span distance of 30 mm and a crosshead speed of 10 mm/min. All the samples have experimented at the same conditions, and the data were documented from the average of at least five values.

Figure 3.14: Universal Testing Machine-UTM

3.3.4 Scanning Electron Microscopy (SEM) Analysis

Using a 5 kV-set Hitachi S-4000 field emission scanning electron microscope, the surface morphologies of composites were studied. The composite samples were attached to separate aluminum stubs using carbon tape so they could be easily seen with a SEM before being palladium and platinum sputtered. The cross section of the fibers in the composite was examined using the Scanning Electron Microscopy (SEM) method. To study the morphology of the composites' fracture surfaces, such as the interaction between the different dimensions of hybrid composites made of chicken feather fibers and unsaturated polyester resin, the composite specimens were analyzed.

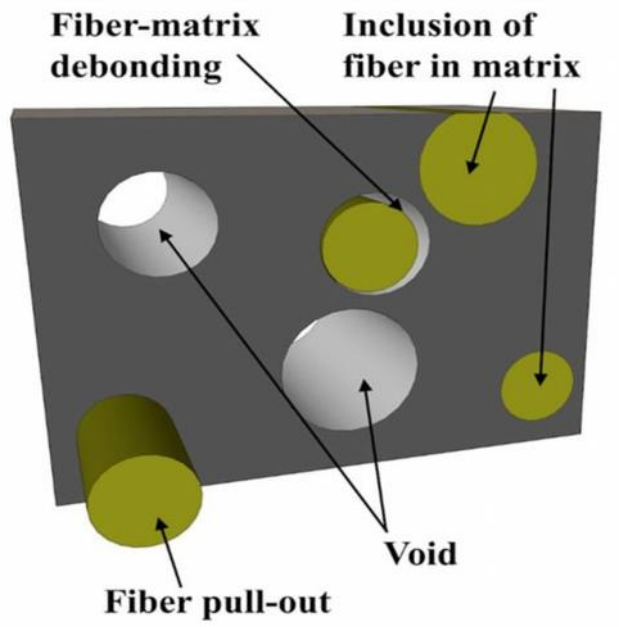


Figure 3.15 **a)** Surface analysis of cracked fiber-reinforced composites [191].

Figure 3.15 b) **Scanning Electron Microscope**

3.3.5 Fourier Transform Infrared Radiation (FTIR) Analysis

An analytical technique called FTIR Analysis, often called Fourier Transform Infrared Spectroscopy or FTIR Spectroscopy, is used to differentiate between organic, polymeric, and occasionally inorganic materials. The FTIR analysis method scans test materials and examines chemical characteristics using infrared light. With the use of a Prestige 21 SHIMADZU spectrometer, the Fourier Transform Infrared (FTIR) spectrum was acquired.

Figure 3.16: SHIMADZU spectrometer

The presence of several functional groups was confirmed by Fourier transform infrared analysis (FTIR). The functional groups linked to the infrared spectrometer were identified using FTIR. Within the wave number range of 500 to 4000 cm^{-1}, FTIR spectrum analysis was carried out. The surface of the composite is evaluated qualitatively using Fourier transform infrared spectroscopy (FTIR). In this method, infrared light is passed through the sample to calculate the percentage of incident radiation that is absorbed at a specific energy. Each spectral absorption peak corresponds to a certain functional group's frequency.

To identify the presence of functional groups, chicken feather-unsaturated polyester resin reinforced composites were brought under Fourier Transform Infrared (FTIR) spectrophotometer. The range of the machine's web number was 400-4000cm^{-1}. The FTIR spectrum was taken in a transmittance.

In a conventional spectrometer, a sample is exposed to electromagnetic radiation, and the transmitted radiation's response intensity is evaluated. After the radiation's energy is varied throughout the necessary range, the response is shown as a function of radiation energy (or frequency). A sequence of peaks in the spectrum that may be used to identify the sample will be produced as a result of the radiation's absorption at particular resonance frequencies that are unique to the individual sample.

Resonance in the sample will cause some resonant frequencies to predominate in the signal, and the frequency spectrum may be calculated by performing a Fourier transform on the response signal. The absorption bands for common functional groups, such as OH, N=H, C=O and CH_3, are often found in the 4000-500 cm^{-1} wavenumber range. The fingerprint area is often referred to as the range between 1500 and 400 cm^{-1} wavenumbers. This region's absorption bands are typically caused by

intramolecular processes and are very material specific. Nearly any polymer's chemical structure can be determined using FTIR, which is also one of the most effective methods for determining the different kinds of chemical bonds (functional groups).

The measured spectrum and the best library spectrum that the FTIR program could discover to suit the results of the experiment are shown in this graph. Fourier Transform-Infrared Spectroscopy (FTIR) is a reliable and reasonably priced analytical method for detecting polymers and assessing the quality of polymer products.

3.3.6 Thermo-Gravimetric Analysis (TGA)

Thermogravimetric analysis (TGA) is a crucial laboratory device for characterizing materials. Materials utilized in different environmental, culinary, pharmaceutical, and petrochemical applications can be characterized using the TGA approach. In thermo-gravimetric analysis, the sample is heated at a controlled pace in a specific environment (air, N2, CO_2, He, Ar, etc.). According to temperature or time, the substance's weight changes are noted. For a known beginning weight of the substance, the temperature is raised steadily, and the variations in weight are noted over time as a function of temperature. The fundamental idea of TGA is represented by this graph of weight change vs temperature, also known as a thermo-gravimetric curve or thermo-gram. A thermo-gravimetric analyzer (TGA 8000) was used for this test.

Figure 3.17: Thermo-gravimetric analyzer TGA 8000 with computer and printer

A thermal gravimetric analyzer consists of a precision balance and a sample pan that are both housed in a furnace with programmable temperature control. In order to initiate a thermal reaction, the temperature is often raised gradually over time (or, in other cases, the temperature is maintained for a constant mass loss). On the y-axis, thermogravimetric data from a thermal reaction is shown as a function of temperature or time as well as mass or a percentage of the initial mass. This plot aims to produce a TGA curve. A TGA thermal curve is displayed from left to right. The TGA thermal curve's downward slope indicates weight loss. Thermogravimetric data from a thermal reaction is represented on the y-axis as mass or a percentage of the starting mass vs. temperature or time. This plot's purpose is to make a TGA curve**.**

3.3.7 Water-Uptake Test

In distilled water, water uptake on chicken feather/cow hair/leather fiber reinforced UPR composites was examined. An oven was used, firstly to dry all the samples at 50∘ C during 24 h, and then they were cooled to room temperature. The drying process was repeated, until the weight of the specimens was constant (mass $m1$). The distilled water-filled beakers were submerged with the CFF/CHF/LF composites within. After that, composites were removed from the beakers and dried between the layers of filter paper at regular intervals. Water uptake was measured using the difference of weight of sample before and after water uptake.

$$\%\ \text{of Water Uptake} = \frac{\text{wt. of the sample after water uptake} - \text{wt. of the sample before water uptake}}{\text{wt. of the sample before water uptake}} \times 100$$

Then the sample was again soaked in water, and this process was repeated. A graph is plotted between % water uptake and during of time.

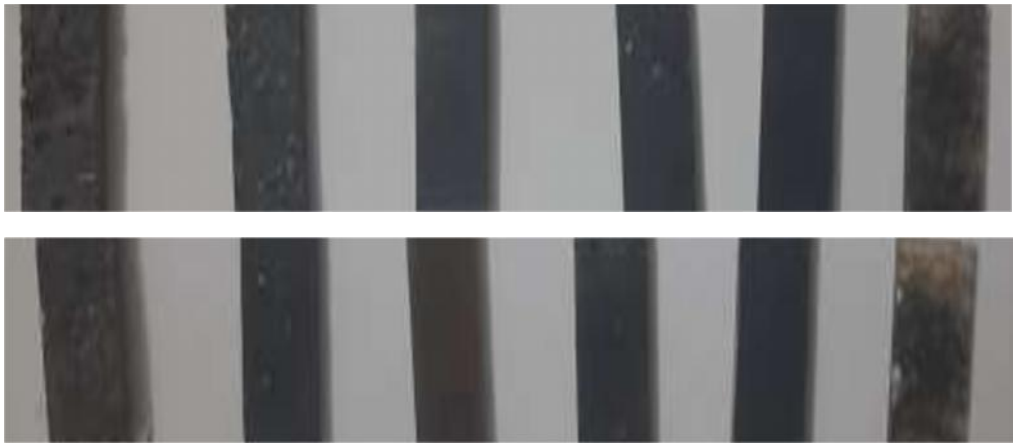
For the water penetration test, the sample components were put together. The specimens were sized by cutting the composites.

A specific amount of distilled water was then added to each of a number of small beakers after they had been thoroughly cleaned. As a result, the water level in each of the twelve beakers was the same. The beakers and samples were labeled with numbers so that they could be quickly located after the

test. After using a measuring balance to weigh the sample pieces, the results were recorded. "Before water uptake" weights are what these objects are known as. Each of the twelfth beakers had distilled water, and the sample pieces were put to it in order, until the whole sample was immersed. In an another clean beaker, the same volume of distilled water and a control sample of the same size were added. The prepared control sample was then similarly dropped into the water along with a part of it. The beakers were kept in a secure location. To determine how much water the sample pieces could absorb, they were submerged in water for five hours, twenty-four hours, seventy-two hours, one week, and two weeks.

After The sample pieces, along with the control sample piece, were taken out of the distilled water after being submerged in water for five hours, twenty-four hours, seventy-two hours, one week, and two weeks to allow for water absorption. A measuring balance machine was used to assess the samples' weights once more.

a)



b)

c)

Figure 3.18: Water Uptake Test a) Beaker with water and weight balance b) Sample pieces (5 cm X 1.5 cm) for water uptake test c) Composite samples submerged inside water

3.3.8 Swelling Test

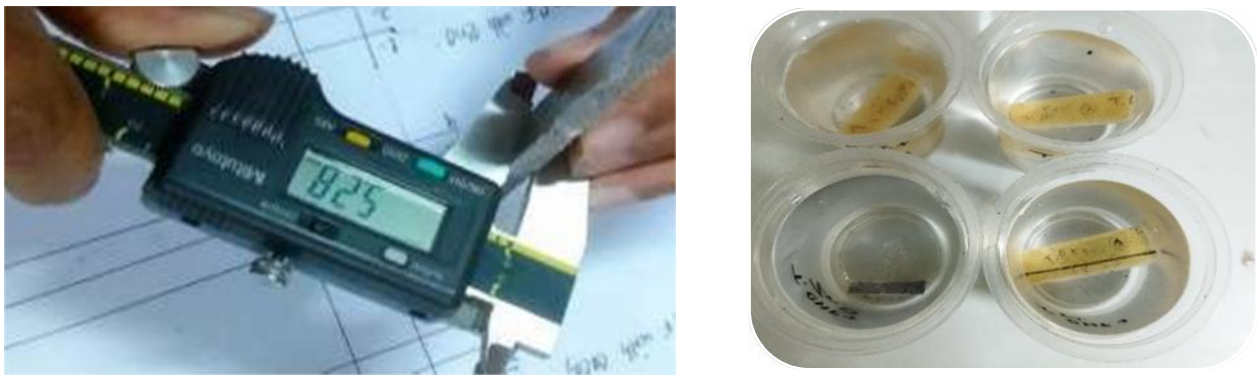
Swelling test is performed by immersing composite specimens into water at room temperature until absorption becomes constant. Most natural fibers absorbed more water compared to synthetic fibers. Water is predominantly absorbed at the fiber interface and matrix. The effect of this absorbed water is to degrade the mechanical properties such as tensile strength. Chicken feathers, cow hair, and leather fibers were used in a water swelling test for UPR-based composites. The CFF/CHF/LF composites were placed in the 500ml beakers of distilled water. The samples were then periodically removed from the beakers and cleaned clean using a cotton towel. Composites' thickness was

measured using the same digital slide scale at 5, 24, 72, 1, and 2 weeks after being applied. Then, the percentage of thickness of each composite was calculated as follows:

Percentage of thickness = $T/T_1 \times 100$

Difference in thickness=T, Initial thickness= T_1

This study showed the amount of fiber loading in the composite increase with time and later it became constant.



a) b)

Figure 3.19: a) Measuring thickness by Digital slide scale b) Samples immerged in water

3.3.9 Bio- degradation Test:

Biodegradation is the chemical dissolution or break down of materials. There were several types of degradation tests were done here. The degradation means the degradation of the polymer composites means the degrade of its normal condition. The degradation can be done by several natural phenomena like temperature, pressure, growth of micro-organisms (bacteria, fungi), water, moisture, CO_2 and so on. Depending on the applications where the composites will be used, the degradation tests were done to see if the materials would sustain on that environment, if does how long it will sustain. Degradation causes the original form to vanish by triggering bond scission reactions in the polymer's backbone. The rate of biodegradation may be maximized by keeping the right environmental parameters (such as temperature, pressure, and nutrient concentrations) in place. Biodegradable materials are typically safe for humans and ecosystems. The composite material will be biodegradable or not it can be measured by this test. For determining the degradation rate the samples were kept under the fixed environments.

Percentage weight loss of the composites after degradation was measured as

$$wt = \frac{w_0 - w_{(t)}}{w_0} X\ 100$$

Here, w(t) is the weight after time t, w0 is the reference dry wt of the specimen before biodegradation.

Composite degradation has occurred in four steps such as

- Degradation in weather
- Degradation in water
- Degradation in brine
- Degradation in soil
- Degradation in compost

There were several types of degradation tests were done here. The degradation means the degradation of the polymer composites means the degrade of its normal condition. The degradation can be done by several natural phenomena like temperature, pressure, growth of micro-organisms (bacteria, fungi), water, moisture, CO_2 and so on. Depending on the applications where the composites will be used, the degradation tests were done to see if the materials would sustain on that environment, if does how long it will sustain. The composite material will be biodegradable or not it can be measured by this test. For determining the degradation rate the samples were kept under the fixed environments. Their degradation rate was calculated by subtracting the initial weight from final weight. The rate of degradation can be calculated as follows:

$$\text{Degradation} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial Weight}} \times 100$$

All degradation is measured for 30, 60 and 90 days interval. For this Cow hair reinforced polymer composites the degradation test done were as follows:

3.3.9.1 Weather degradation:

Composites are subjected to weather testing, which entails the gradual deterioration of polymers and polymer coatings in controlled laboratory or outdoor settings. Polymer morphology may be altered by chemical cross-linking or chain scission during photo-degradation of certain thermo-plastics. The moisture level of the compost has been significantly changing as a result of weather and the respiration of organisms. The growth of living organisms that produce enzymes involved in the breakdown process was affected by the varying humidity of compost. Depending on the level of microbial growth, the absolute value of dehydrogenase activity decreased during degradation of composites with decreasing moisture content. We weighed the samples and stored them in a dry place for up to 90 days. Figure 6 shows the results of weight measurements taken at 30, 60, and 90 days for the samples presented in [192]. The composites were left out in the weather to observe how it breaks down. he composites were kept outside for 90 days. The analysis was being done to find out how much damage the weather does.

Weather degradation

Figure 3.20 Weather degradation result

3.3.9.2 Degradation in Water*:*

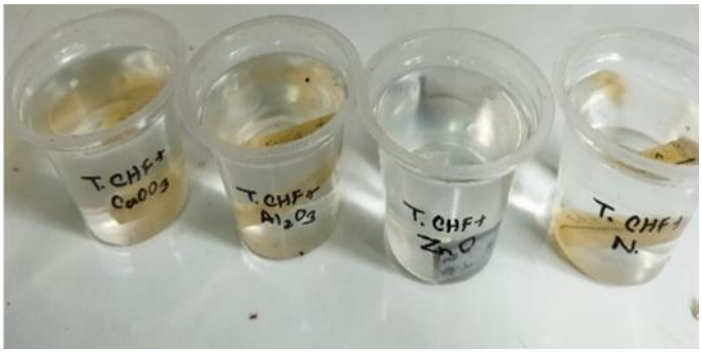
Degradation in water means the change of weight of the composites while submerged into the water for a certain period of time. UPR is a non-biodegradable material. But natural fiber reinforced UPR composites are slightly degradable. Although the composites are hydrophobic, its uptakes water slightly. Generally, UPR based composites contain about 8 to 10% of water. Although being a hydrophobic composite, it absorbs water because of the cross linking, porosity and viscosity of the composite surface**.** For measuring the degradation rate in water, the composites were cut into required pieces and size. 100 ml beaker of distilled water were used for this perpuse . The samples

were kept there. The reading was taken in regular interval 30 days, 60 days and 90 days.. The degradation rate was calculated using the same formula.

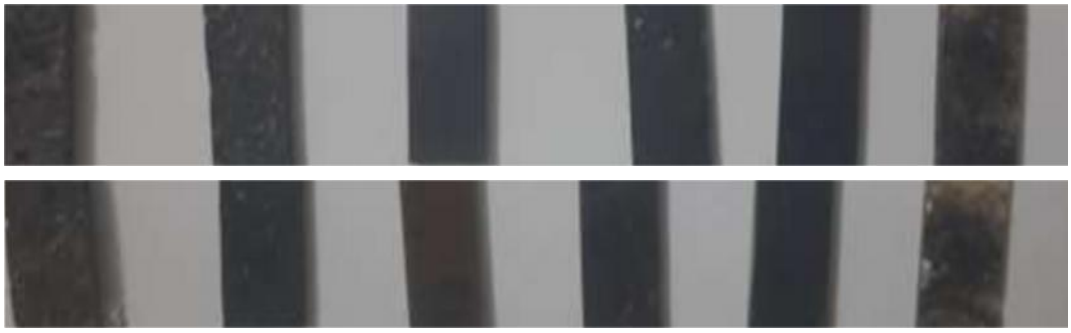
$$\text{Degradation} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial Weight}} \times 100$$

The samples were taken out from the water and dried out using a c

cotton cloth. They spent the next six hours drying in a 105 degrees Celsius oven. Their weights were recorded at that time.



a)



b)

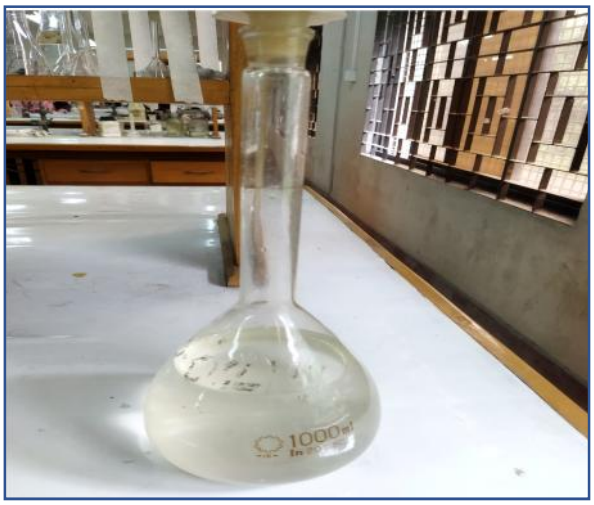
Figure 3.21 Degradation in water a) specimen emerged in water b) water degradation result.

3.3.9.3 Degradation in Brine Solution:

As we want to use this polymer composites in the interior designing of ships it would come in touch with sea water. Corrosion is a pre-existing menace in the ocean and environment. So, it's difficult to erase from any system. So the surface of the composites degrades in the sea water due to this corrosion and also by the under water pressure, temperature and composites water content level. The salinity rate is different in different parts of oceans throughout the world. [193] The salinity of seawater around the world is about 3.5 %. This can be expressed at 0.6 mol NaCl or wind 6 mg/L.

So, to create these salinity conditions a 5% solution NaCl was prepared. The samples were cut into required size and kept under the brand solution for a certain period of time. The samples were kept there for about 3 months and their weights were measured after 1 month, 2 months and 3 months. The test is being done to find out how much the material is breaking down when it is in brine. The amount of change of weight in percentage was then calculated.

a)



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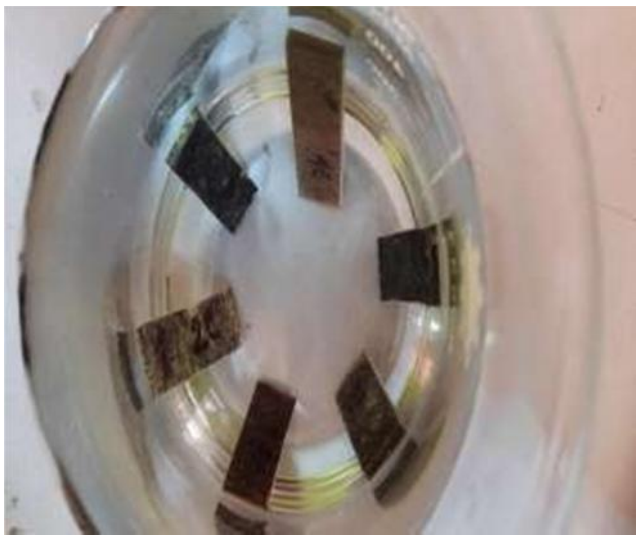

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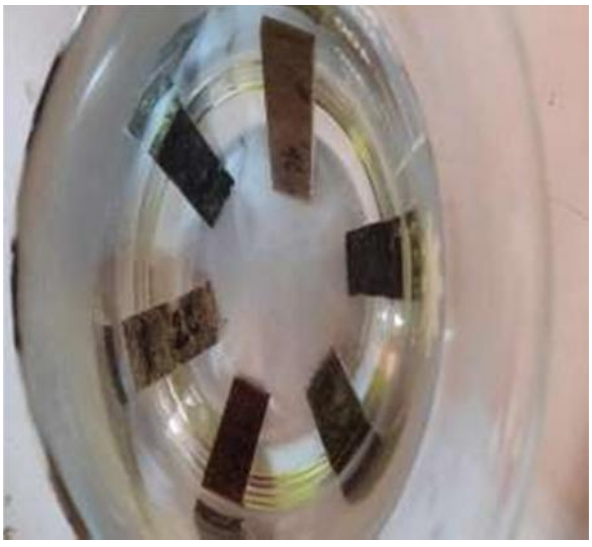

d)

e)

Figure 3.22 Brine degradation a) common salt, b) Brine solution, c, d) emerged composite samples in water, e) Brine degradation result

3.3.9.4 Degradation in Soil Test:

The samples of the CFF/CHF/LF reinforced UPR composites were buried in soil, covered with a plastic net, and exposed to atmospheric conditions for 90 days in order to study the biodegradation of the materials. The results of the soil degradation test reveal information about the composites' mechanical characteristics. It gives details on the characteristics of composites that were held onto for a predetermined amount of time [194]. The samples were prepared as needed (4cm×2cm ×.5cm) size. The degradation test of the composites was carried out on the composites based on variations in the weight loss of the samples at intervals of 30 days for a total of 90 days, as shown in Figure 3.23. The composite samples were buried six inches beneath the surface of the earth. Following a 30-day break, the samples were carefully removed, loose soil was removed with a soft brush, excess moisture was quickly wiped off with a dry cloth, and the samples were then combined with 5 mL of dichloromethane solvent in a small beaker and left to sit overnight. The beaker's solvent was taken out. The weight loss of the degraded samples was measured by the following formula:

$$\text{Degradation} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial Weight}} \times 100$$

Figure 3.23 a) Degradation in moist Soil b) Soil degradation result

3.3.9.5 Compost degradation:

The compost used here was mainly vermicompost. [195]. Vermicompost is a type of compost that results from the breakdown of organic matter utilizing different worm species, such. Earthworms such as White worms, Red wigglers, and others. The decompositions of the mixture of vegetable or food waste, bedding materials, and vermicast created the vermicompost [196]. The Vermicompost used for this component was made from the mixture of the vegetable waste and old leaves. The samples were cut into required shape (4cm×2cm×.5 cm) The composites were kept in the compost and observed how quickly it break down. The containers made of soil were filled with 1kg compost. Composites were put in the compost for 90 days and assessed its degradation 30, 60 and 90 days interval. The containers were coated with a single layer of parafilm and sealed with lids that had three 1 cm diameter air holes to allow for gaseous exchange. The incubator kept the boxes at room temperature. Every 30 days, samples from compost were taken, cleaned with cotton cloth, mixed with 5 mL of dichloromethane solvent in a tiny beaker, and then left overnight. The beaker's solvent was taken out. The samples that had deteriorated were weighed. Following that, the following formula was used to determine the rate of degradation:

$$\text{Degradation} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial Weight}} \times 100$$

Figure 3.24 a) Compost degradation b) Compost degradation result

3.3.10 Abrasion Test

Abrasion testing can be performed to assess and forecast the material's overall durability as it would function in practical applications. By rubbing a test item over a sheet of a certain grade of abrasive material, this test method calculates the volume loss brought on by the abrasive action.

The abrasion test was carried out using An Abrasion Tester (Model No. STM 469, SATRA). A revolving cylinder coated in a standard abrasive cloth and a circular test specimen are brought into continual contact. The specimen is then pushed along the length of the cylinder, following the abrasive's helical contact path. The test specimen's mass loss was measured and computed. A reference material is abraded to determine the degree of the abradant.

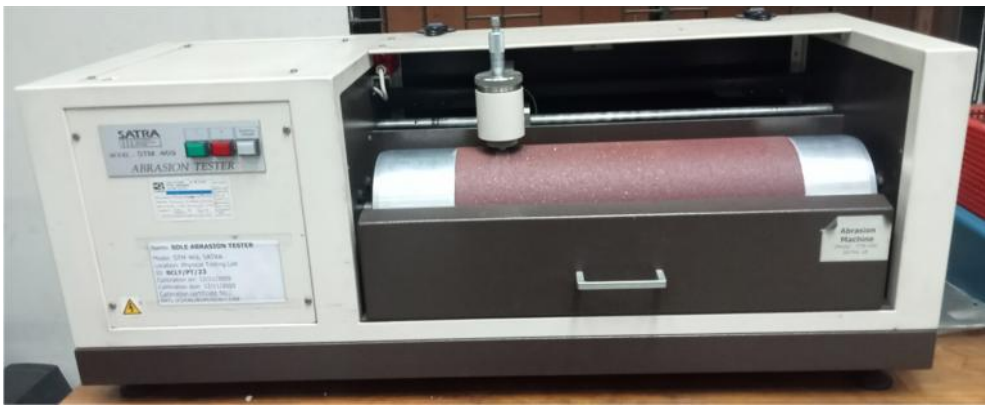

Fig.3.25 An Abrasion Tester (Model No. STM 469, SATRA).

A specimen is positioned three inches away from the nozzle, with the surface to be evaluated. After that, a shield is fastened and the specimen is clamped. For one minute, sand is blasted onto the test surface. On the test surface, this process is done at least eight times. The abrasion voids are then filled with modeling clay, which is then leveled. Before and after the voids are filled, the mass of the clay supply is measured. The volume of each abrasion cavity may be determined using this mass disparity.

The difference between before and after abrasion was used to calculate abrasion resistance.

Weight Loss = wt. of the sample before abrasion – wt. of the sample after abrasion

CHAPTER-4

CHAPTER-4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the physical and mechanical characterization of polymer matrix composites. Details on these composites' processing and testing were covered in the chapter that came before it. The results of several characterization experiments are presented here. Some of the tests that are performed include evaluating the tensile and bending properties, Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Water Uptake Test, Swelling Test, Flame Resistance Test, and Composite Degradation Test in Different Medium.

In this chapter, the experiment's results are compared and evaluated. To provide a baseline for comparisons with fiber reinforced systems in the future, the tensile properties of the pure UPR are first examined. In-depth analysis and comparisons have been carried out in order to show the strengthening effects of natural fiber on UPR, particularly after NaOH solution treatment.

This chapter will also discuss the fracture surface morphology study that relates to the composite's fracture surfaces. Morphology investigations, which are important because they assist to understand why some materials act weak or tough, disclose the internal structures of the composite. Micrographs captured by SEM (Scanning Electron Microscopy). A number of processes, such as fiber detachment, fiber deboning, and fiber pull-out, are visible in the SEM micrographs. These SEM micrographs provide an explanation for the bonding and strengthening effects of the fiber in increasing UPR's flex. There will be a water uptake test.

ZnO, Al_2O_3, and $CaCO_3$ were used as fillers in composites to provide them mechanical, physical, and antibacterial properties. The hand-layup technique was used to create the composites. Composites were successfully made after drying. Using this method prevents any unwanted consequences like air bubbles, holes, or surface cracks, and all composites seem structurally homogeneous after drying [197]. Mechanical degradation, swelling from water absorption, and solubility characteristics of the resultant film were all recorded. Significant changes were seen in solubility properties, water absorption swelling, and mechanical degradation. The mechanical properties of the composites have been examined for tensile strength, tensile modulus, elongation at break, bending strength, and bending modulus.

4.2 Tensile properties Test of Polymer Composites

4.2.1 Tensile Strength Analysis

A tensile test was carried out using an all-purpose testing device and the ASTM D 638 standard. Different quantities of chicken feather, cow hair, and leather fibers were added to the samples using UPR. All of the samples were cut into flat forms measuring 150 mm in length, 12 mm in breadth, and 4-4.5 mm in thickness.

Tensile strength is assessed by stress, which is expressed in terms of force per unit area. Tensile strength is measured in SI units called Pascal, Pa, or N/ mm^2. Mega Pascal or N/ mm^2 units are typically used to express tensile strength. Tensile strength calculation formula:

Tensile Strength = Applied load ÷ Cross sectional area of the load bearing area

$$=P \div A$$

Where, P = Applied load is in Newton(N), and

A = Cross sectional area of the load bearing area is in mm^2

Any sort of material's tensile strength (TS) is an extremely important attribute. This characteristic is crucial when it comes to composite materials. High tensile strength gives a composite material exceptional fiber strength, superior durability, and improved adhesion between the matrix and dispersion phase. Poor fiber-matrix adhesion may diminish the tensile strength of a composite. However, it can be inferred from the analysis of figure 4.1–4.7 that the manufactured control sample of unsaturated polyester resin in this study had a lower tensile strength value (18 N/ mm^2) than the other animal fiber–based polymer composite samples. All of the figures depict the variance in tensile strength and indicate that 5% fiber reinforcement produced the greatest results.

In comparison to untreated fiber-based composites (30.23 N/ mm^2 for UTCFF+UPR, 29.58 N/ $mm^2$for UTCHF+UPR, and 22.32 N/ mm^2 for UTLF+UPR), treated fiber-based composites demonstrated improved TS values (32.24 N/ mm^2 for TCFF+UPR, 30.44 N/ mm^2 for TCHF+UPR, and 23.11 N/ mm^2 for TLF+UPR). The treated chicken feather, cow hair, and leather fiber-based composites outperformed the untreated one in terms of tensile strength by 6.65%, 2.91%, and 3.53%, respectively. The structural protein, which gives the composites additional strength, remains after the impurities and other binding agents are removed during the chemical treatment of the fibers. Figures 4.1–4.2 illustrate how the presence of fibers affects the peak tensile strength for high density unsaturated polyester resin (UPR) composites. It can be shown that, up to 5% of fiber loading, the tensile strength increases, and then declines as the fiber content rises. The effective matrix cross-section decreased and stress concentration rose, which resulted in a decrease in tensile strength when fiber loading was increased. However, compared to cow hair and leather fibers, chicken feathers significantly increased the strength of polymer composites. The results showed that cow hair-based composites performed better for the samples created compared to samples reinforced with leather fibers, but composites with chicken feather and cow hair mixed in showed the highest tensile strength because the UPR's tiny spaces were filled with fibers more densely. The TS value of composites was increased when ZnO, Al_2O_3, or $CaCO_3$ was employed as filler. The composite treated (CFF+CHF)+UPR and ZnO filler presented the highest tensile strength values (34.95 N/ mm^2) compared to the control sample (18 N/ mm^2), CFF+UPR+ZnO (33.92 N/ mm^2), CHF+UPR+ZnO (32.66 N/ mm^2) and LF+UPR+ZnO (25.01 N/ mm^2) and the improvement was 94.17%, 3.04%, 7.04% and 39.74% respectively.

Due to their distinctive size-dependent electrical, magnetic, mechanical, optical, and chemical characteristics, which fundamentally vary from those of bulk materials, inorganic particles have already established themselves as an essential component for several industrial applications [198]. Because of their effectiveness and broad range with high antibacterial properties, inorganic particles including zinc oxide, aluminum oxide, and calcium carbonate are very appealing in the composite sector [199-201]. Over the past few years, ZnO filled polymer matrix composites have drawn a lot of interest. High UV-blocking ability is exhibited by ZnO nanoparticles [202]. ZnO NPs loaded polymer matrix composites have been reported to have significantly improved mechanical, water vapour barrier, and antibacterial characteristics [203].

A 1% concentration of ZnO, Al_2O_3, or $CaCO_3$ has a noticeable impact on the composites' tensile strength. In comparison to neat composites, these inorganic components improved the tensile strength of the bio-composites. The positive charges of the materials and the negative charges of the chicken feather, cow hair, or leather fiber biopolymer matrix likely electrostatically interacted to increase the tensile strength after the incorporation of the aforementioned inorganic materials, promoting the formation of strong films and more extensive biopolymer helices [204, 205].

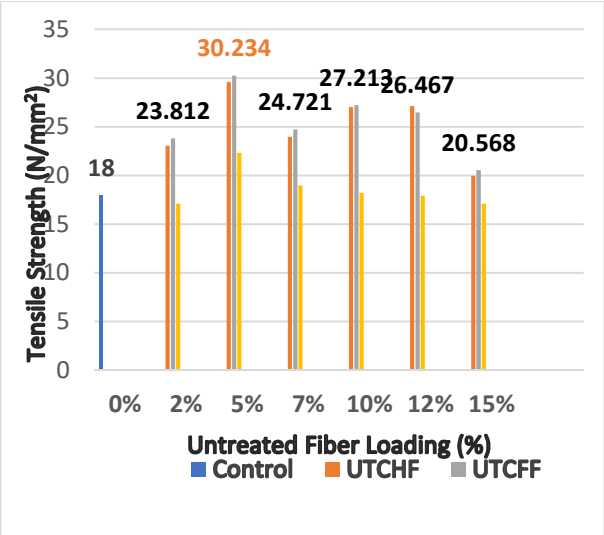

Fig 4.1: Variation of Tensile Strength peak of Control Sample,UTCHF+UPR, UTCFF+UPR and UTLF+UPR composites

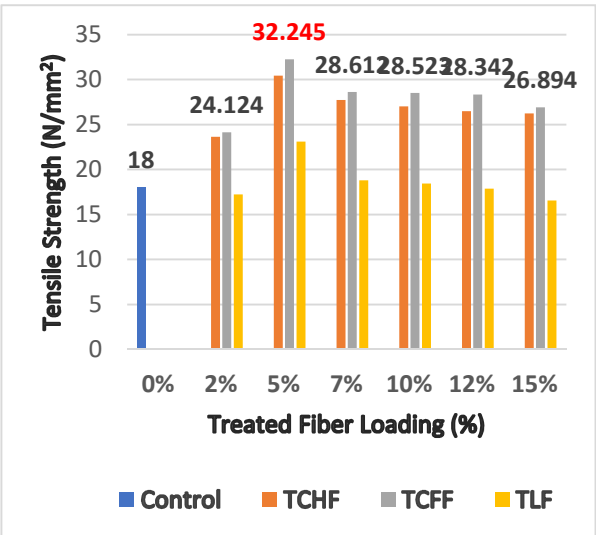

Fig 4.2: Variation of Tensile Strength peak of Control Sample, TCHF+UPR, TCFF+UPR and TLF+UPR composites

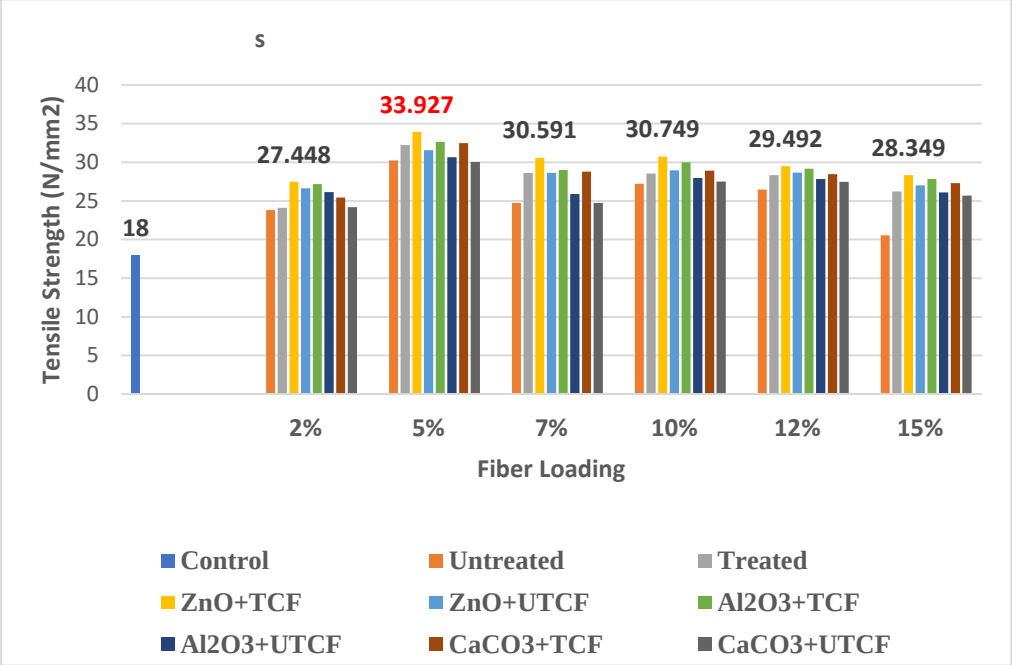

Fig 4.3: Variation of Tensile Strength peak of Control Sample, UTCFF+UPR, TCFF+UPR, TCFF+UPR+ZnO, TCFF+UPR+Al_2O_3 TCFF+UPR+$CaCO_3$, UTCFF+UPR+ZnO, UTCFF+UPR+Al_2O_3 and UTCFF+UPR$CaCO_3$ composites

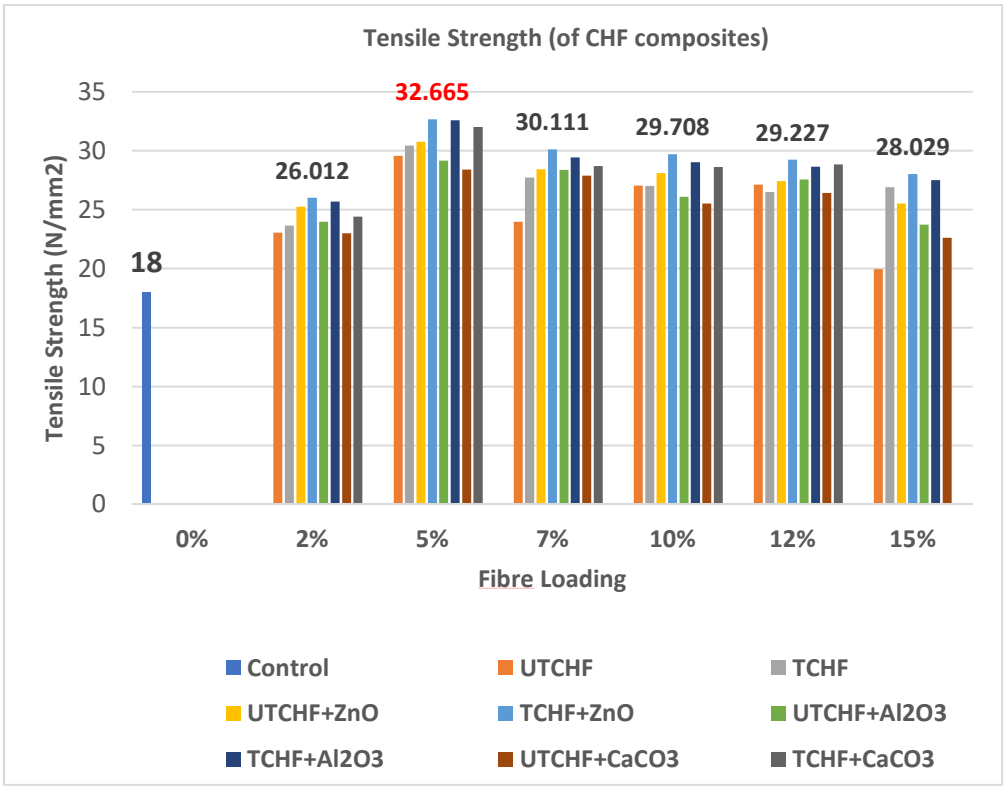

Fig 4.4: Variation of Tensile Strength peak of Control Sample, UTCHF+UPR, TCHF+UPR, TCHF+UPR+ZnO, TCHF+UPR+Al_2O_3 TCHF+UPR+$CaCO_3$, UTCHF+UPR+ZnO, UTCHF+UPR+Al_2O_3 and UTCHF+UPR+$CaCO_3$ composites.

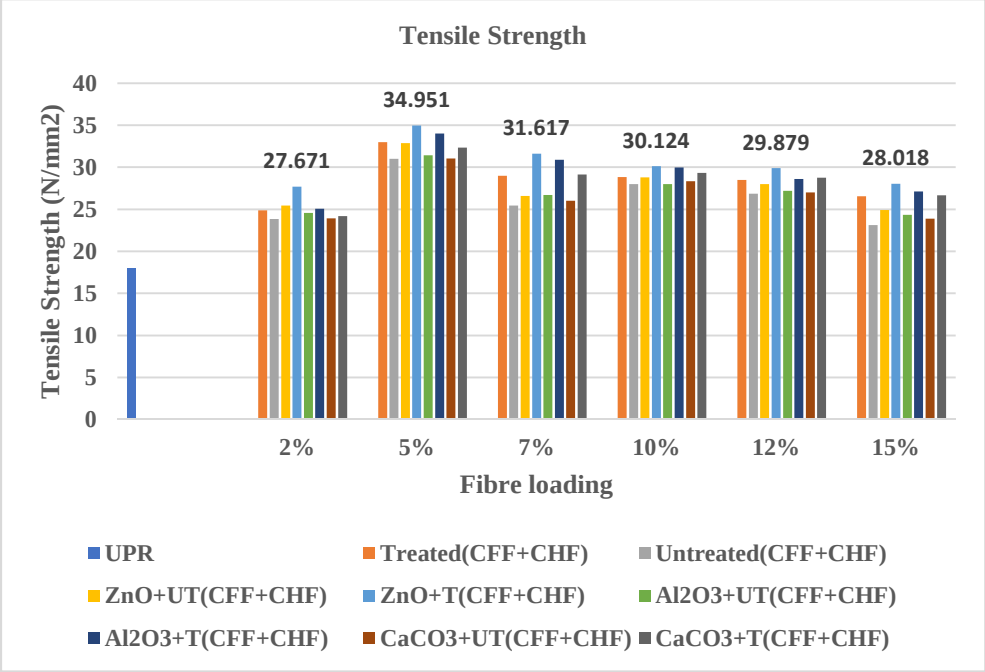

Fig 4.5: Variation of Tensile Strength peak of Control Sample, UT(CHF+CFF)+UPR, T(CHF+CFF)+UPR, T(CHF+CFF)+UPR+ZnO, T(CHF+CFF)+UPR+Al_2O_3 T(CHF+CFF)+UPR+$CaCO_3$, UT(CHF+CFF)+UPR+ZnO, UT(CHF+CFF)+UPR+Al_2O_3 and UT(CHF+CFF)+UPR+$CaCO_3$ composites

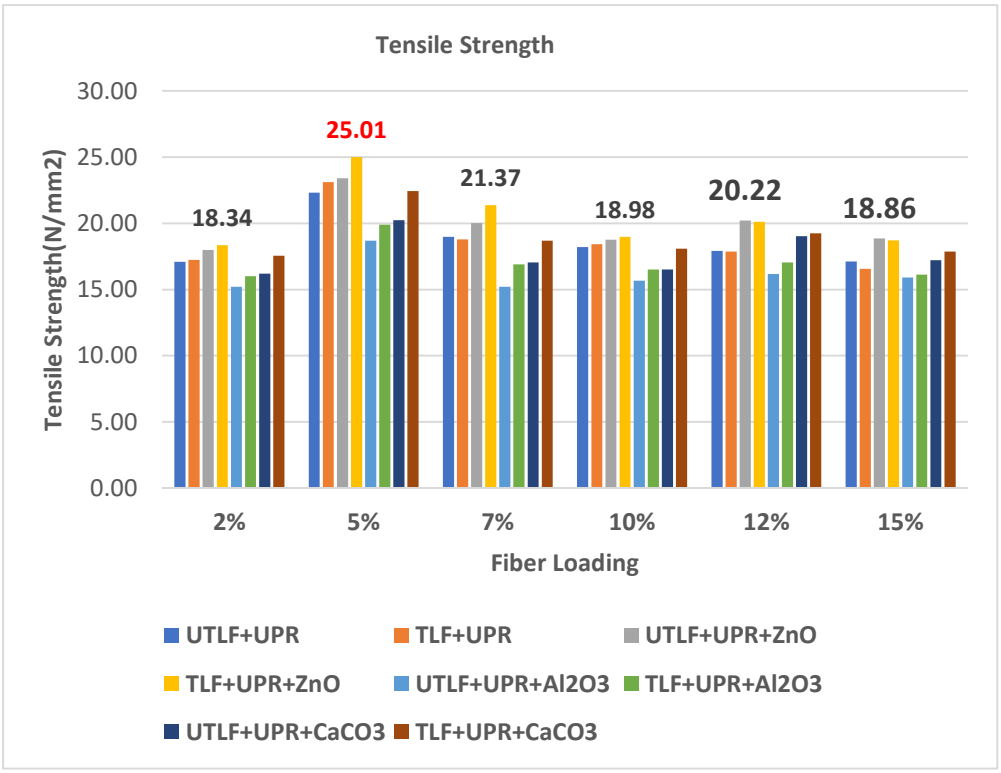

Fig 4.6: Variation of Tensile Strength peak of Control Sample, UTLF+UPR, TLF+UPR, TLF+UPR+ZnO, TLF+UPR+Al_2O_3 TLF+UPR+$CaCO_3$, UTLF+UPR+ZnO, UTLF+UPR+Al_2O_3 and UTLF+UPR+$CaCO_3$ composites

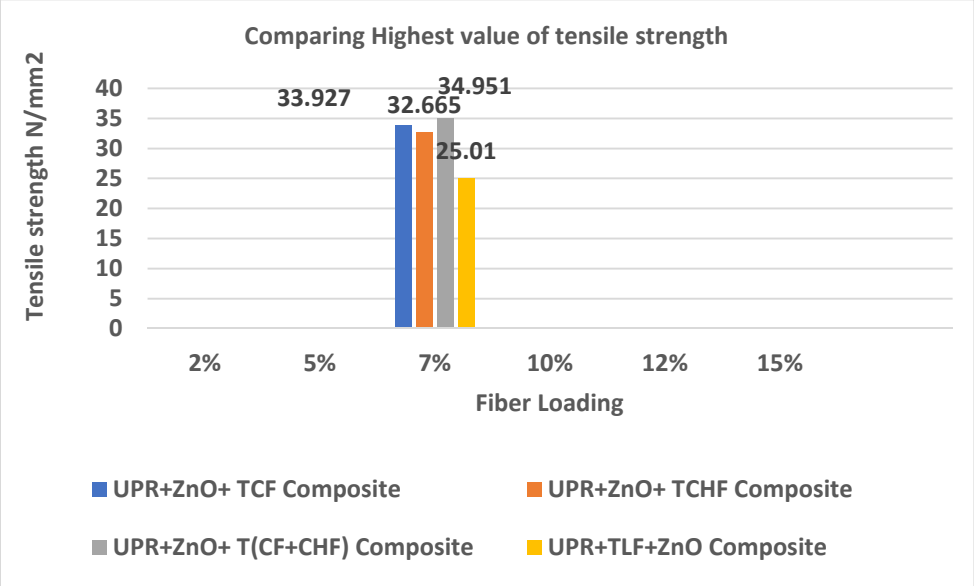

Fig 4.7: Comparing Highest value of tensile strength of the composites

4.2.2 Tensile Modulus analysis

Figure 4.8-4.14 depicts the variation in tensile modulus of the UPR, CHF-UPR, and CFF-UPR reinforced composites used as the control sample. These results showed that the control sample's peak tensile modulus was 650 N/mm^2. The 5% TCFF (Fig. 4.8) and 5% UTCFF (Fig.4.9) reinforcement produced superior results with values of 1122.01 N/ mm^{2}and 1093.14 N/ mm^2 than the treated and untreated based neat composites, increasing 72.62% and 68.18%, respectively, above the control sample. The treated chicken feather, cow hair, and leather fiber-based composites had greater tensile moduli than the untreated counterparts, respectively, by 2.64%, 10.04%, and 4.16%. When the fibers underwent chemical treatment, the contaminants and other binding substances were eliminated, leaving only the structural protein, which increased the composites' tensile strength. In compared to the other animal fiber-UPR reinforced composites, the TCFF reinforcement at 2-15% fiber loading produced the best results. Chemical treatment, namely 5% fiber loading, increased the reinforcing of CHF, CFF, and LF-based composites. Figures 4.10-4.13 show the fluctuation in TM caused by chemical treatment and the inclusion of three filler materials, ZnO, Al_2O_3, and $CaCO_3$. Tensile strength first increases to 5% of fiber loaded and then declines as the fiber concentration

increases. The decrease in tensile modulus with higher fiber loading was caused by a decrease in effective matrix cross-section and an increase in stress concentration.

The maximum value of TM obtained from the data was 1777.345 N/ mm^2 for treated 5% CFF+UPR with ZnO filler (Fig.4.11), 1399.716 N/mm^2 for treated 5% CHF+UPR with ZnO filler (Fig.4.12), 1788.741 N/ mm^2, and 1512.430 N/ mm^2 for treated 5%LF+UPR with ZnO filler (Fig.4.13). These values were 173.43%, 115.34%, 175.19%, and 132.68% greater than the control sample's value. The highest value found was 1788.741 N/ mm^2 for the treated 5%(CHF+CFF)+UPR with ZnO filler composite, with improvements of.68%, 20%, and 11.65% over TCFF, TCHF, AND TLF BASED COPOSITES INCORPORATED ZnO. Among the inorganic materials loaded in UPR, the untreated fiber added composites with Al_2O_3 filler had the lowest value. Chemical treatment enhanced the values of tensile modulus for all fibers-UPR composites. A 1% concentration of ZnO, Al_2O_3, or $CaCO_3$ has a considerable influence on the tensile modulus of the composites. Mechanical, water vapor barrier, and antibacterial characteristics of ZnO filled polymer matrix composites have been shown to increase significantly.

The inclusion of fibers in the composite reduced stress transmission between the fiber and the matrix. Conversely, lower and higher fiber percentages might offer insufficient strength to composites. As a result, the TM values of the 2% and 7%-15% fiber-based composites were lower.

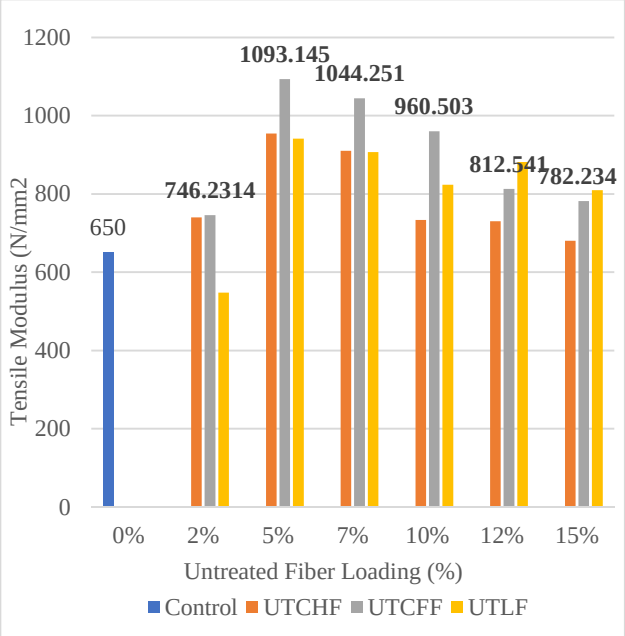

Fig 4.8: Variation of Tensile Modulus peak of Control Sample, TCHF+UPR, TCFF+UPR and TLF+UPR composites.

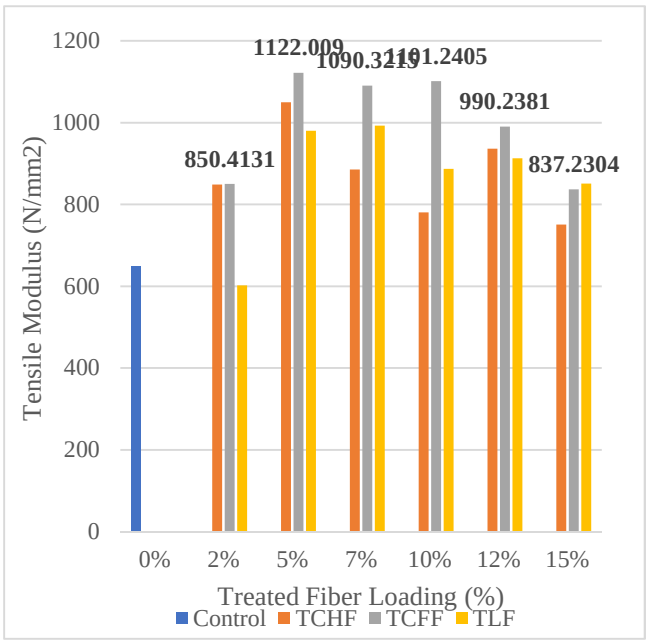

Fig 4.9: Variation of Tensile Modulus peak of Control Sample, UTCHF+UPR, UTCFF+UPR and UTLF+UPR composites.

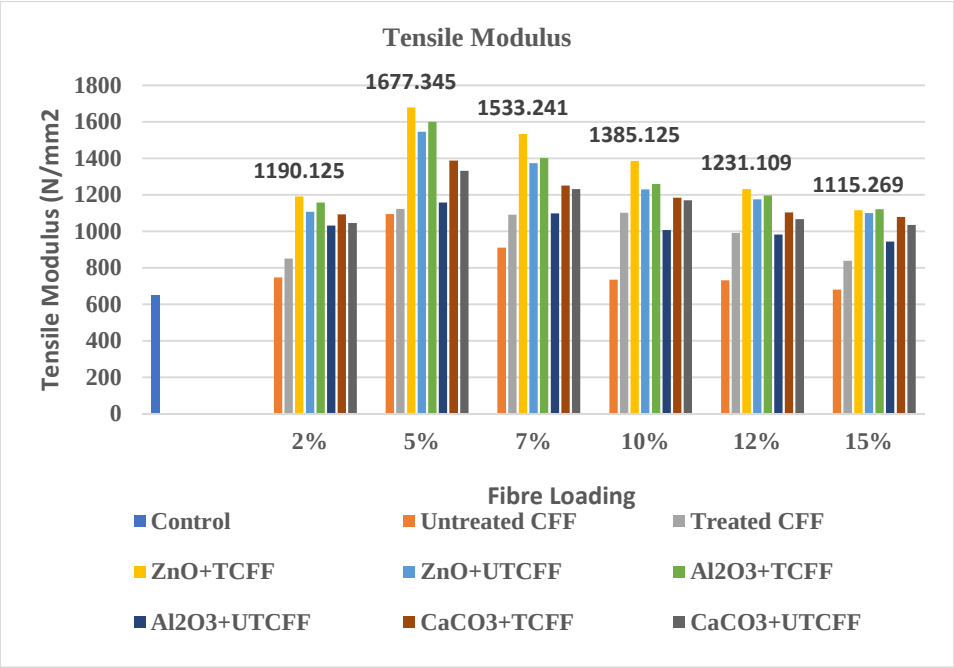

Fig 4.10: Variation of Tensile Modulus peak of Control Sample, UTCFF+UPR, TCFF+UPR, TCFF+UPR+ZnO, TCFF+UPR+Al_2O_3 TCFF+UPR+$CaCO_3$, UTCFF+UPR+ZnO, UTCFF+UPR+Al_2O_3 and UTCFF+UPR+$CaCO_3$ composites

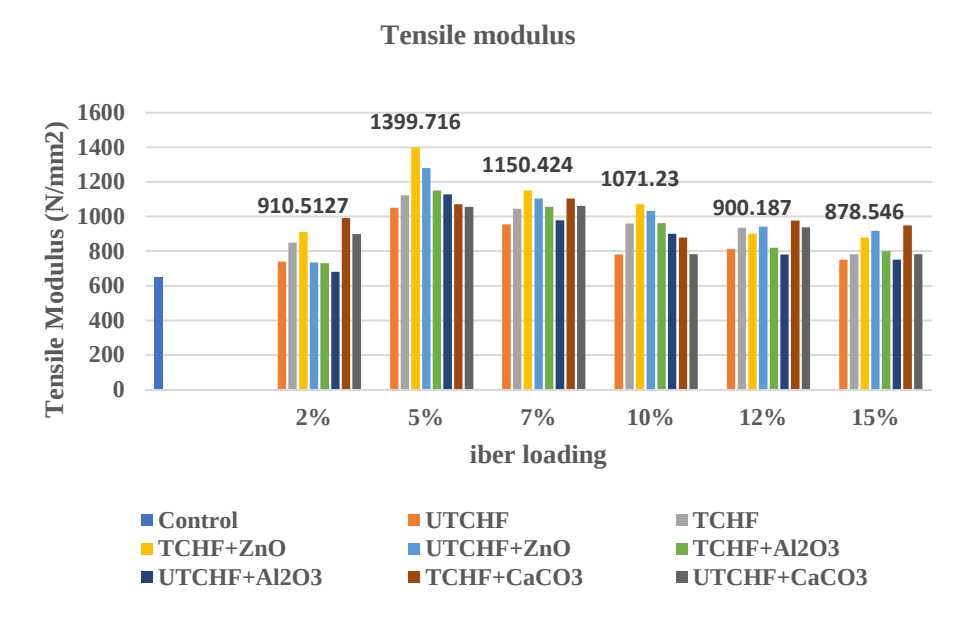

Fig 4.11: Variation of Tensile Modulus peak of Control Sample, UTCHF+UPR, TCHF+UPR, TCHF+UPR+ZnO, TCHF+UPR+Al_2O_3 TCHF+UPR+$CaCO_3$, UTCHF+UPR+ZnO, UTCHF+UPR+Al_2O_3 and UTCHF+UPR+$CaCO_3$ composites

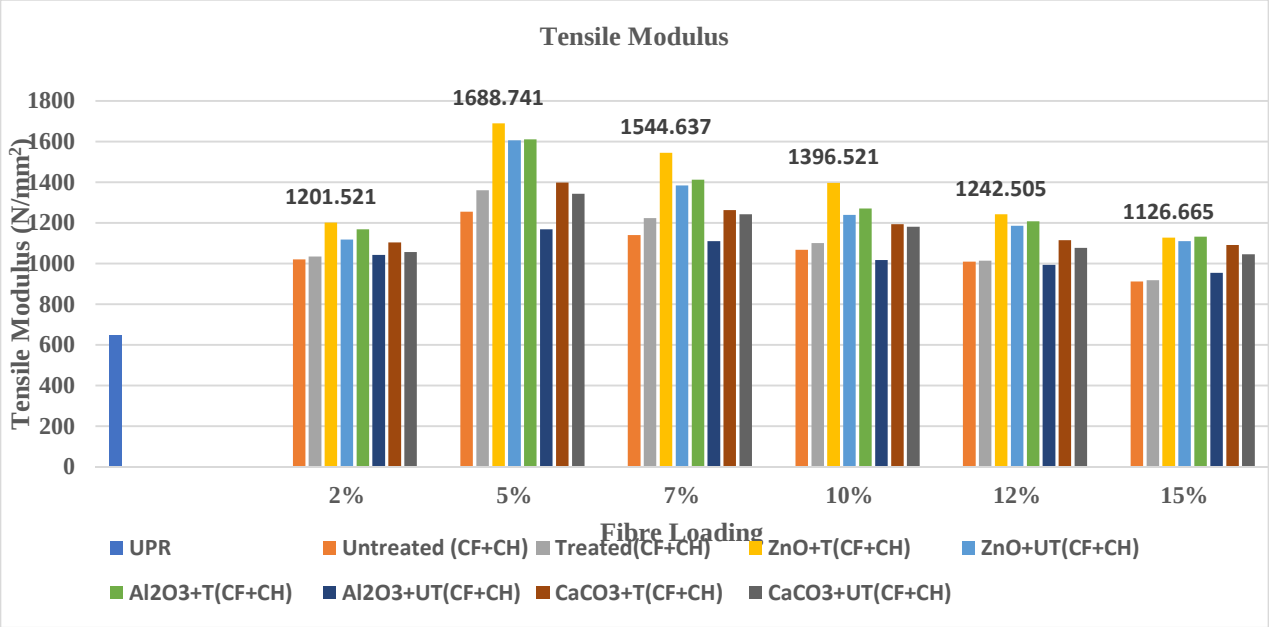

Fig 4.12: Variation of Tensile Modulus peak of Control Sample, UT(CHF+CFF)+UPR, T(CHF+CFF)+UPR, T(CHF+CFF)+UPR+ZnO, T(CHF+CFF)+UPR+Al_2O_3 T(CHF+CFF)+UPR+$CaCO_3$, UT(CHF+CFF)+UPR+ZnO, UT(CHF+CFF)+UPR+Al_2O_3 and UT(CHF+CFF)+UPR+$CaCO_3$ composites

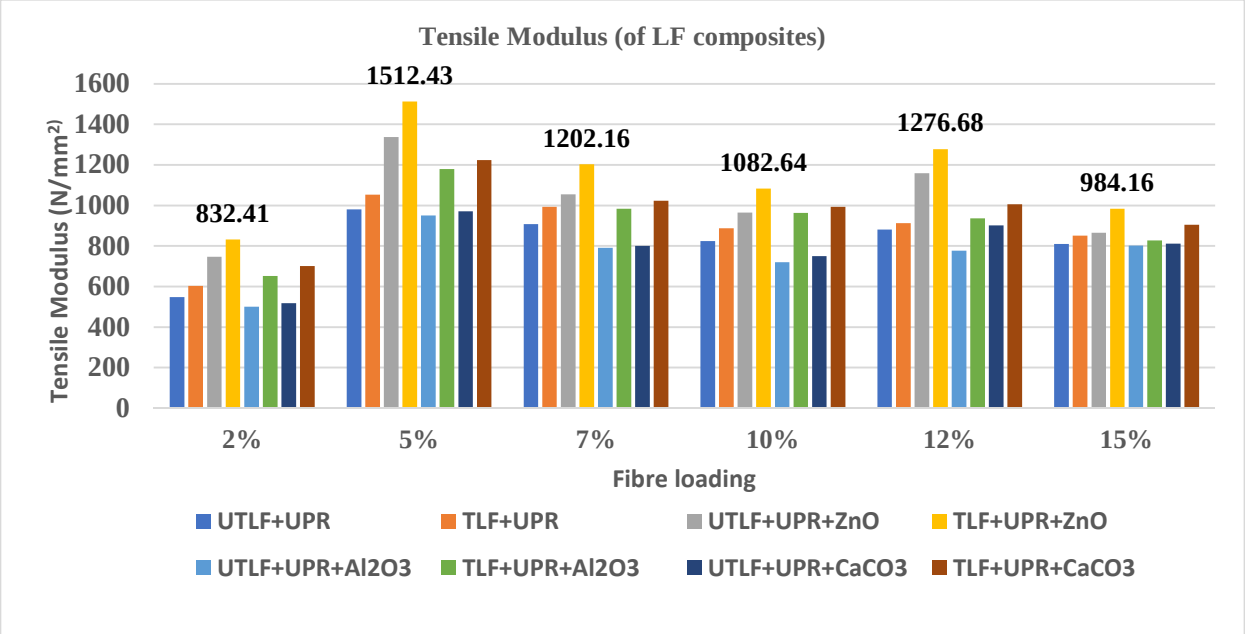

Fig 4.13: Variation of Tensile Modulus peak of Control Sample, UTLF+UPR, TLF+UPR, TLF+UPR+ZnO, TLF+UPR+Al_2O_3 TLF+UPR+$CaCO_3$, UTLF+UPR+ZnO, UTLF+UPR+Al_2O_3 and UTLF+UPR+$CaCO_3$ composites

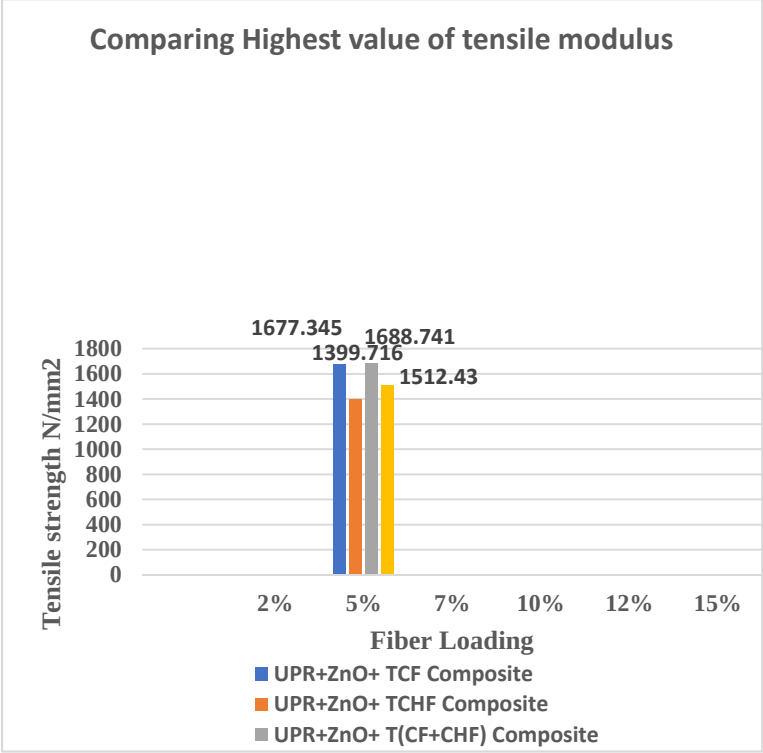

Fig 4.14: Comparing Highest value of tensile modulus of the composites

4.2.3 Elongation at Break analysis

The term "elongation" describes how a material changes in length in response to a tensile tension. When coupled with strong tensile characteristics, a higher % elongation often denotes a higher grade material. Elongation, which evaluates how much bending and shaping a material can tolerate without breaking, is significant in manufacturing. The deformation behavior of the matrix material and the fillers' capacity to absorb energy during deformation both have an impact on the length at break. Elongation at break (Eb) findings for the control sample, CHF-UPR, CFF-UPR, and LF-UPR composites are shown in Figures 4.15 to 4.21. The control sample's elongation at break value, which was 5%, was the best in the test findings. When compared to other reinforcement composites, the TLF+UPR+ZnO composite's reinforcement with a 2% fiber loading produced the best results, with a value of 2.89% that is 42.20% lower than the control sample. Comparing animal fiber-based composites to the control sample UPR, elongation at break was reduced. Chemical processing has often raised the value of elongation at break. The findings showed that in the majority of

cases of elongation at break, the chemical treatment's impact on chicken feather, cow hair, and leather fibers was less effective. Ductile polymer composites, which have high elongation to break, are made with small, evenly scattered filler particles. Due to the treatment and the addition of filling agents, the TS and TM values increased while the Eb values fell. For the (CFF+CHF) fiber-reinforced UPR-based composites, the EB must be sacrificed in order to achieve higher TS and TM values. When the leather fiber loading was 2%, the highest elongation at break (2.89%) was noted. As a result, the elongation at break rose and the tensile strength decreased. The highest values of elongation at break were 2.49%, 1.93% and 1.19% for 15% CHF, CFF, and (CFF+CHF) loaded composites. From received data (Fig. 4.18) the average value of elongation at break was better due to the ability of the fillers to absorb energy through deformation and the deformation behavior of the UPR matrix. The CFF and (CFF+CHF) loaded composites gave the average value of elongation (Fig. 4.17, 4.19), on the contrary the leather fiber based composites gave the best mean result (Fig. 4.20) because the strength increases then elongation at break decreases, and vice-versa. Animal fibers were used as a reinforcing filler in this experiment. Therefore, it was anticipated that as tensile strength and tensile modulus increased, the elongation at break values would also decrease. Similar findings have been found in other records [206-209]. It is evident from this experiment that jute composites significantly outperformed the matrix material (UPR) in terms of strength and modulus values, indicating superior fiber matrix adherence. The toughness, elasticity, and ductility of the composite are all enhanced by an increased elongation at break [210].

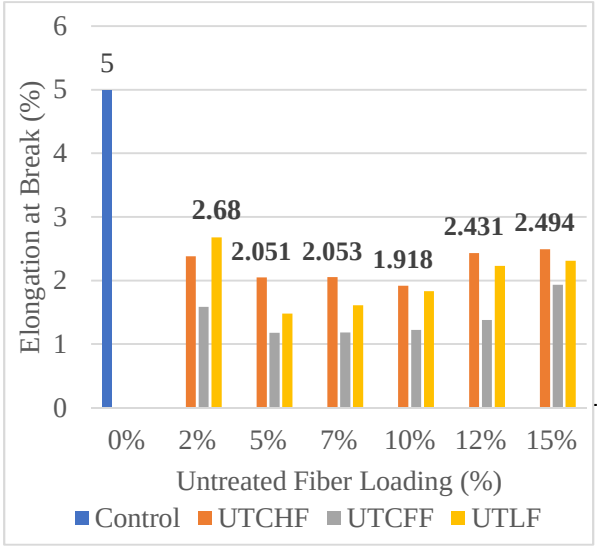

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Fig 4.15: Variation of Elongation at Break peak of Control Sample, UTCHF+UPR, UTCFF+UPR and UTLF+UPR composites

Fig 4.16: Variation of Elongation at Break peak of Control Sample, TCHF+UPR, TCFF+UPR and TLF+UPR composites

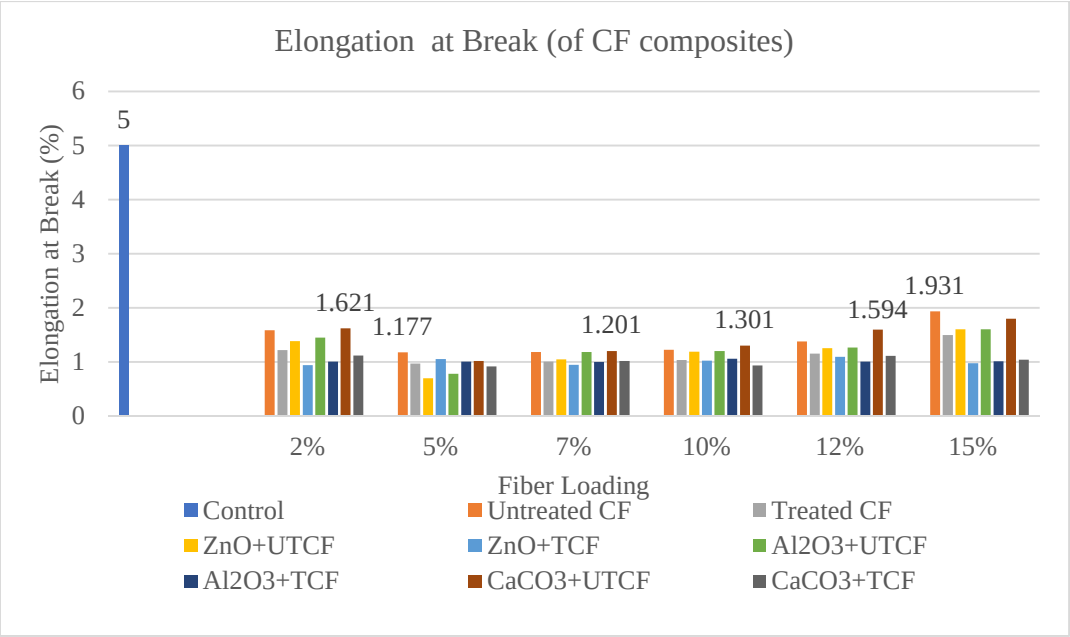


Fig 4.17: Variation of Elongation at Break peak of Control Sample, UTCFF+UPR, TCFF+UPR, TCFF+UPR+ZnO, TCFF+UPR+Al_2O_3 TCFF+UPR+$CaCO_3$, UTCFF+UPR+ZnO, UTCFF+UPR+Al_2O_3 and UTCFF+UPR+$CaCO_3$ composites

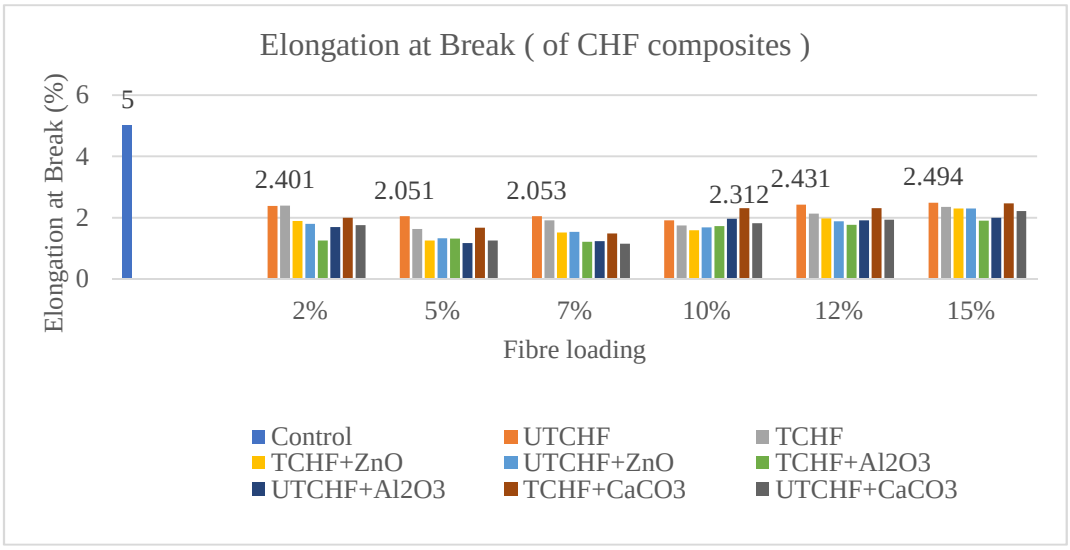


Fig 4.18: Variation of Elongation at Break peak of Control Sample, UTCHF+UPR, TCHF+UPR, TCHF+UPR+ZnO, TCHF+UPR+Al_2O_3 TCHF+UPR+$CaCO_3$, UTCHF+UPR+ZnO, UTCHF+UPR+Al_2O_3 and UTCHF+UPR+$CaCO_3$ composites.

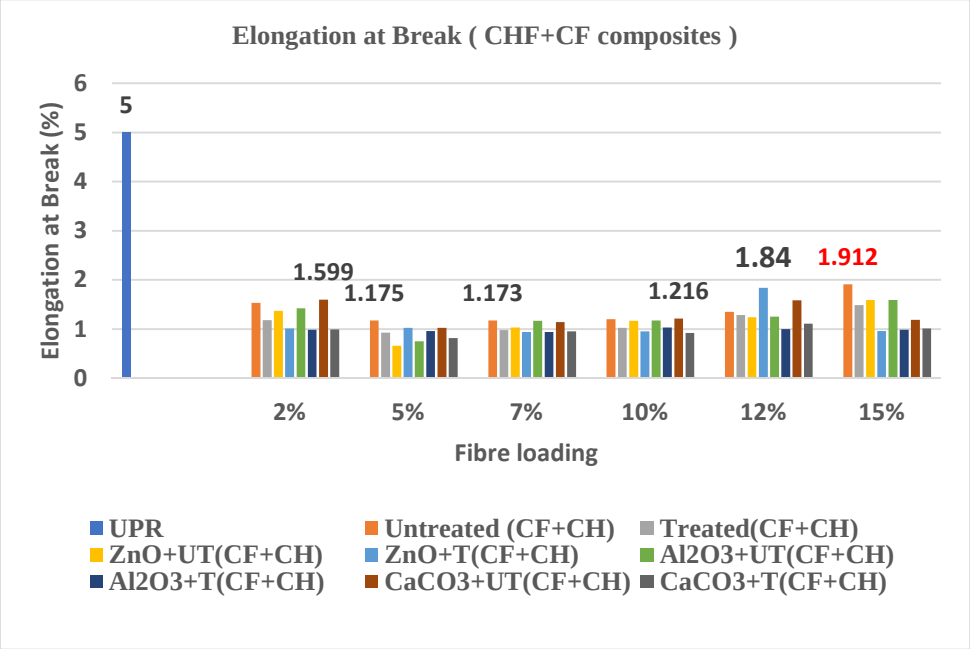


Fig 4.19: Variation of Elongation at Break peak of Control Sample, UT(CHF+CFF)+UPR, T(CHF+CFF)+UPR, T(CHF+CFF)+UPR+ZnO, T(CHF+CFF)+UPR+Al_2O_3 T(CHF+CFF)+UPR+$CaCO_3$, UT(CHF+CFF)+UPR+ZnO, UT(CHF+CFF)+UPR+Al_2O_3 and UT(CHF+CFF)+UPR+$CaCO_3$ composites

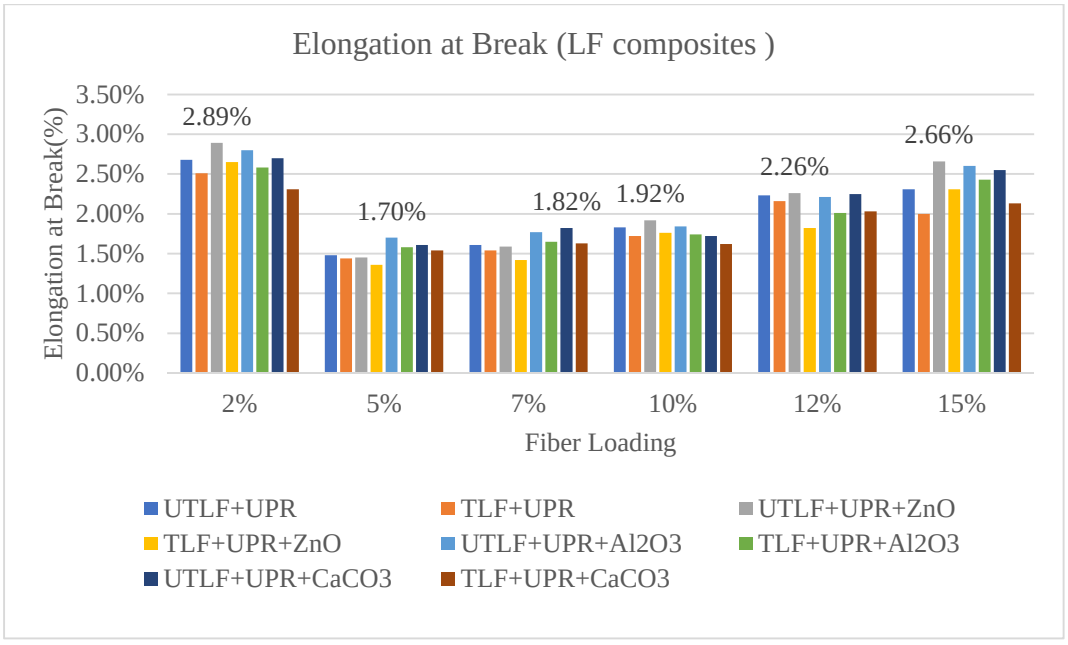


Fig 4.20: Variation of Elongation at Break peak of Control Sample, UTLF+UPR, TLF+UPR, TLF+UPR+ZnO, TLF+UPR+Al_2O_3 TLF+UPR+$CaCO_3$, UTLF+UPR+ZnO, UTLF+UPR+Al_2O_3 and UTLF+UPR+$CaCO_3$ composites

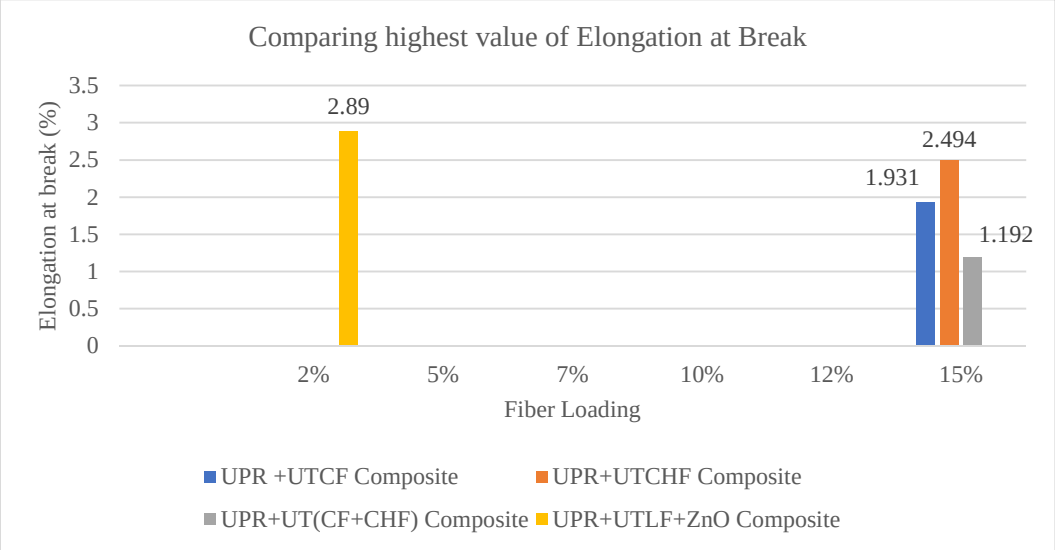


Fig 4.21: Comparing Highest value of Elongation at Break of the composites

4.3 Bending properties test of polymer composites

4.3.1 Bending Strength test

The results are shown in the N/ mm^2 unit in Fig. 4.22-4.28, which illustrates the values of bending strength (BS) of several types of composite samples. Comparing the outcomes of using animal fibers at different percentages, 5% of each reinforcement gave the greatest results. 5% of the TCFF and UTCFF loading composites provided BS values of 63.07 N/ mm^2 and 59.52 N/mm^2 respectively, which are better by 152.28% and 138.08% than the control sample (UPR), which had BS values of 25 N/mm^2 to present. The chemically fiber based composites revealed the better result than the untreated fiber based composites. The improved hydrophilic nature and surface topography of the chemically treated fibers, which resulted in a very strong interfacial adhesion between the fibers and the UPR polymer matrix, can be credited with this significant improvement in ultimate bending strengths of the developed UPR composites [37].The BS value of 5% TCFF, TCHF, TLF reinforced UPR composite incorporated ZnO was observed 67.39 N/ mm^2, 66.66 N/ mm^2 and 62.12 N/ mm^2 which is greater 169.56%, 166.64% and 148.48% than control sample. The highest value of BS was found 68.91 N/mm^2 for 5% treated fiber loading of (CFF+CHF) reinforced with ZnO filling agent composite and increased 175.62% than that of control sample. When ZnO, Al_2O_3, or $CaCO_3$ was

used as filler, the TS value of composites was improved. Due to their distinctive size-dependent electrical, magnetic, mechanical, optical, and chemical characteristics, which fundamentally vary from those of bulk materials, inorganic particles have already established themselves as an essential component for several industrial applications. Because of their effectiveness and broad range with high antibacterial properties, inorganic particles including zinc oxide, aluminum oxide, and calcium carbonate are very appealing in the composite sector. Over the past few years, ZnO filled polymer matrix composites have drawn a lot of interest. The repair of resin composite restorations involves the use of an inorganic material agent as well. Applying the filler after surface pretreatments significantly increases the bond strength of the repair restoration. This study demonstrated that chemically treating the reinforcing materials increased their bending strength. The efficacy of stress transmission from the matrix to the fiber is also determined by the interfacial connection between the matrix and the fiber. The tensile strength of the composite can only be increased with a strong bond. Any fiber-reinforced polymeric composite's overall mechanical properties are significantly influenced by the fiber matrix interface. In comparison to the control samples, the treated and untreated samples showed relatively higher values. A similar trend was noticed in the case of TS and the reasons may be similar for presenting fiber-based composites.

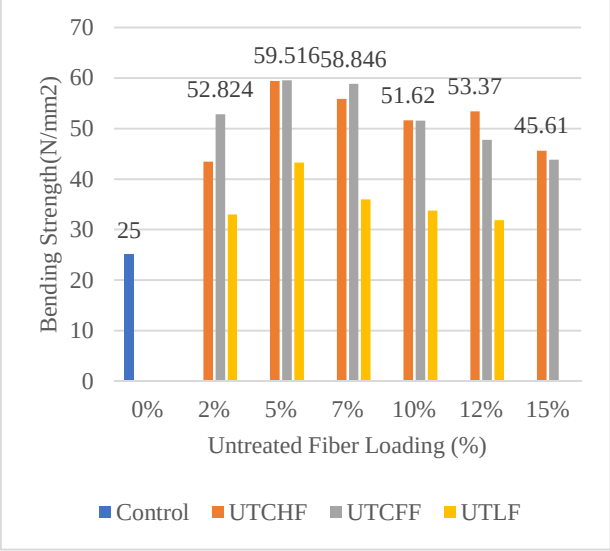


Fig 4.22: Variation of Bending Strength peak of Control Sample, UTCHF+UPR, UTCFF+UPR and UTLF+UPR composites

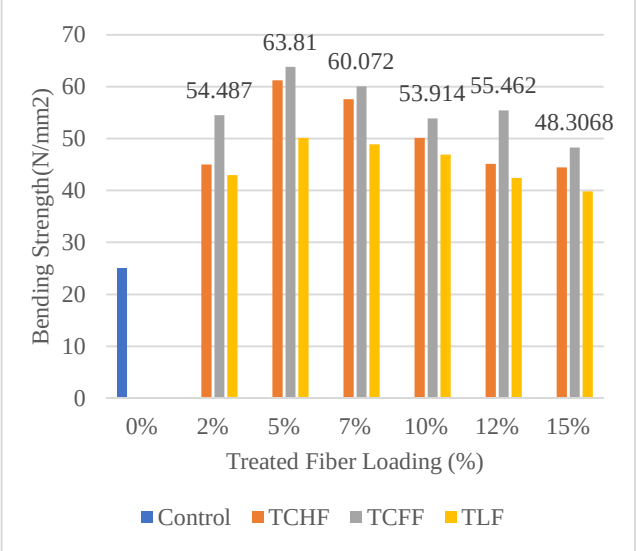


Fig 4.23: Variation of Bending Strength peak of Control Sample, TCHF+UPR, TCFF+UPR and TLF+UPR composit

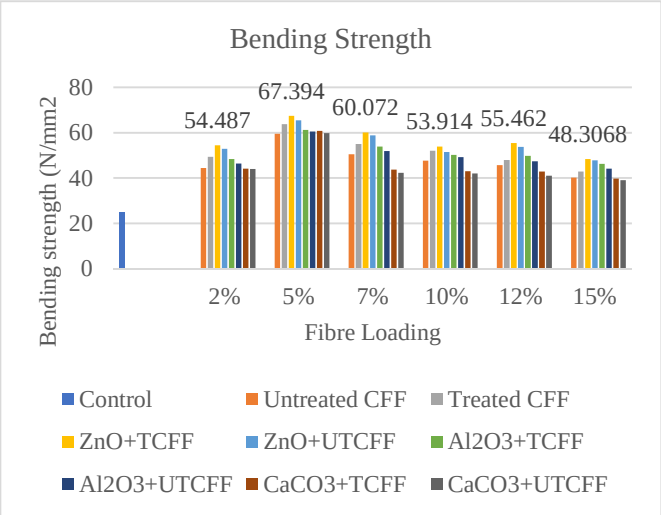


Fig 4.24: Variation of Bending Strength peak of Control Sample, UTCFF+UPR, TCFF+UPR, TCFF+UPR+ZnO, TCFF+UPR+Al_2O_3 TCFF+UPR+$CaCO_3$, UTCFF+UPR+ZnO, UTCFF+UPR+Al_2O_3 and UTCFF+UPR+$CaCO_3$ composites

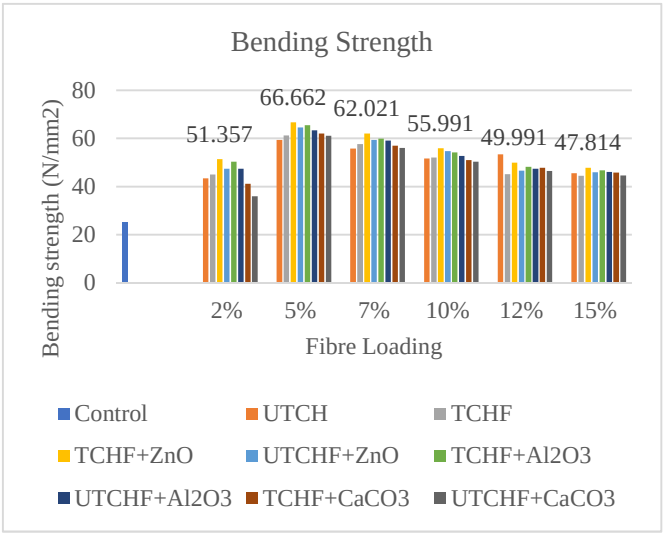


Fig 4.25: Variation of Bending Strength peak of Control Sample, UTCHF+UPR, TCHF+UPR, TCHF+UPR+ZnO, TCHF+UPR+Al_2O_3 TCHF+UPR+$CaCO_3$, UTCHF+UPR+ZnO, UTCHF+UPR+Al_2O_3 and UTCHF+UPR+$CaCO_3$ composites

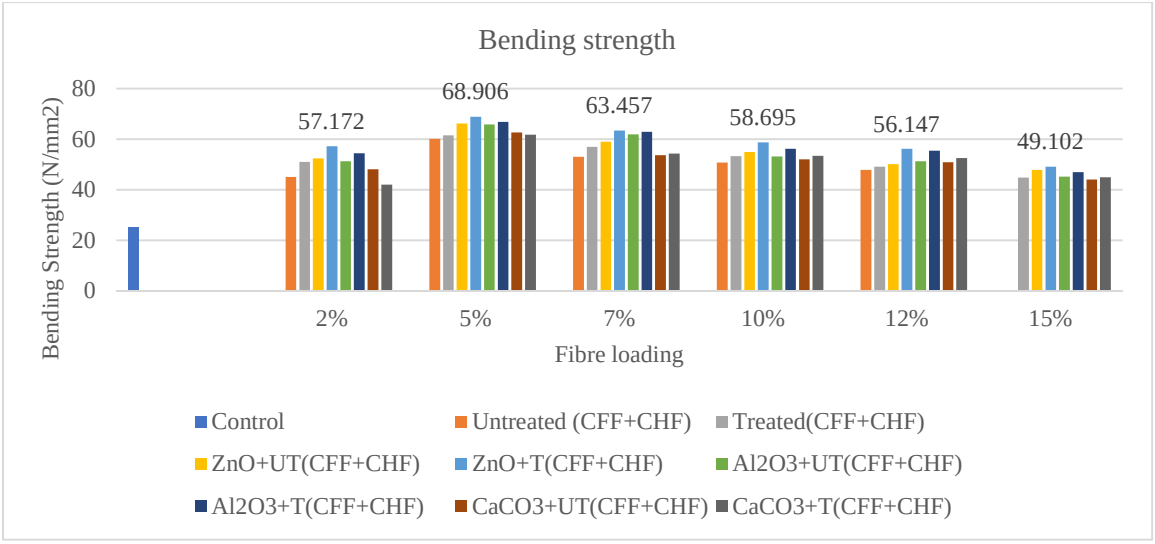


Fig 4.26: Variation of Bending Strength peak of Control Sample, UT(CHF+CFF)+UPR, T(CHF+CFF)+UPR, T(CHF+CFF)+UPR+ZnO, T(CHF+CFF)+UPR+Al_2O_3 T(CHF+CFF)+UPR+$CaCO_3$, UT(CHF+CFF)+UPR+ZnO, UT(CHF+CFF)+UPR+Al_2O_3 and UT(CHF+CFF)+UPR+$CaCO_3$ composites

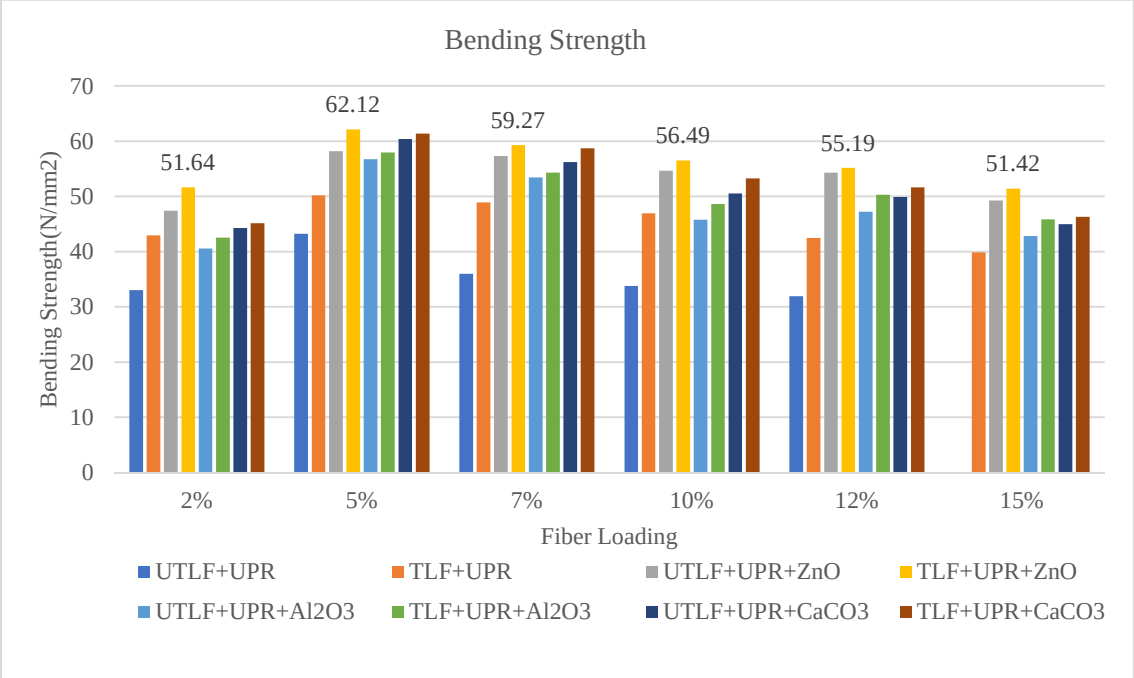


Fig 4.27: Variation of Bending Strength peak of Control Sample, UTLF+UPR, TLF+UPR, TLF+UPR+ZnO, TLF+UPR+Al_2O_3 TLF+UPR+$CaCO_3$, UTLF+UPR+ZnO, UTLF+UPR+Al_2O_3 and UTLF+UPR+$CaCO_3$ composites

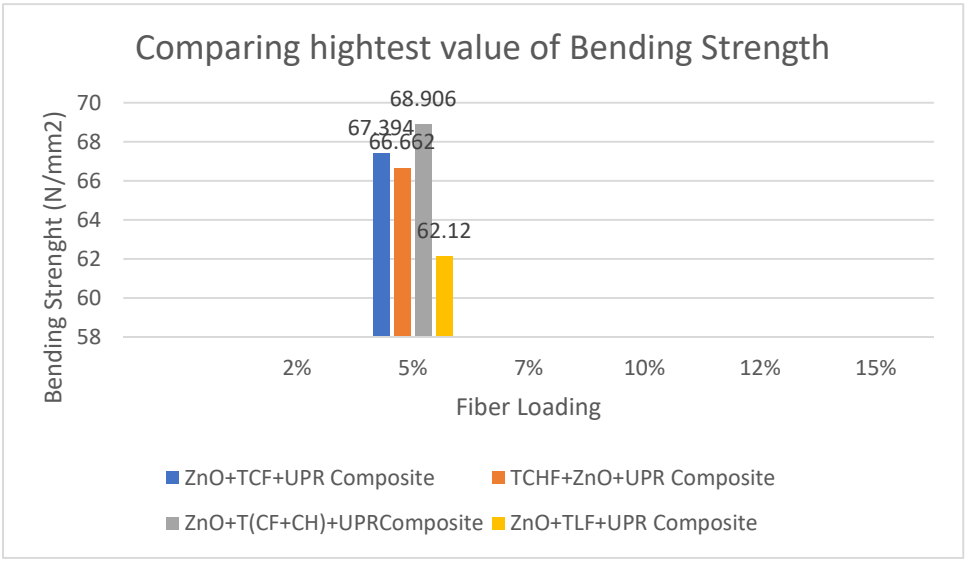
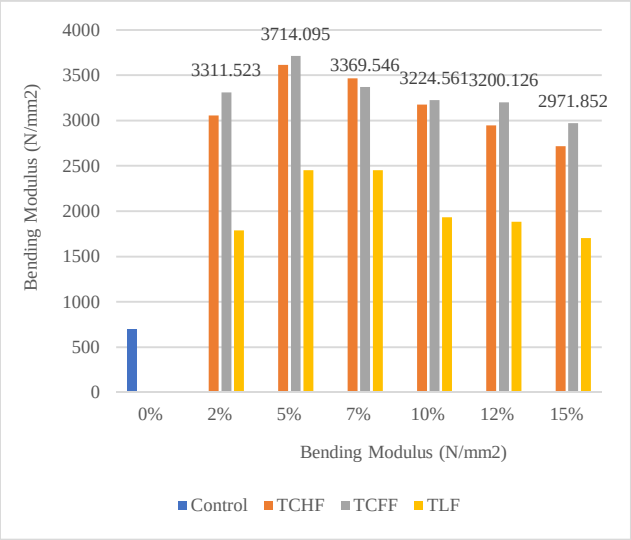


Fig 4.28: Comparing Highest value of Bending Strength of the composites

4.3.2 Bending Modulus test

Figures 4.29–4.35 show a visual representation of bending modulus (BM) for several types of composites. The bending modulus had a similar trend to that of tensile strength and modulus with varying fiber loading from 0 wt.% to 20 wt.%. The control sample UPR's bending modulus was 700 N/ mm^2. The maximum values (4400.415 N/ mm^2) of ZnO filler-5% fiber based treated (CFF+CHF) + UPR composites were nearly 528.63% higher than the values of the control sample for the BM property, and the composite with 5% chemically treated (CFF+CHF) mixed fiber loading performed 2.53% better than the composite with untreated fiber loading. The 5% treated (CFF+CHF) mixed fiber and UPR produced an excellent bonding with each other. Thus, both the constituents of composites can effectively transfer the stress that generates due to the applied load. Both bending strength and modulus decrease as the weight percentage of fibers is further increased, which is plausibly due to the inadequate bonding between the fiber and the UPR. As usual, among the two other employed fibers—cow hair and chicken feather, the leather fiber-reinforced composites showed the lowest values. According to all of the data, composites with chemically treated chicken feather fiber reinforced-unsaturated polyester resin had the second-highest tensile and bending capabilities for 5% fiber loading, whereas composites with cow hair fiber added and leather fiber added had the lowest values.



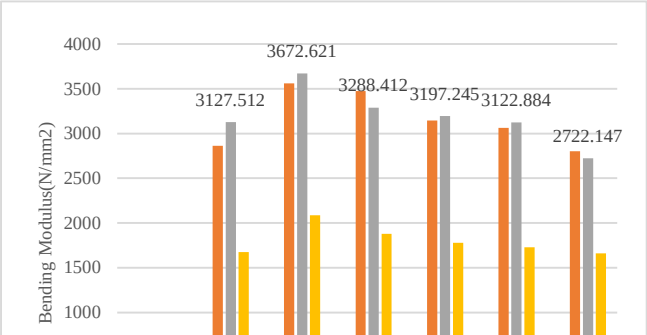


Fig.4.29: Variation of Bending Modulus peak of Control Sample, UTCHF+UPR, UTCFF+UPR and UTLF+UPR composites

Fig 4.30: Variation of Bending Modulus peak of Control Sample, TCHF+UPR, TCFF+UPR and TLF+UPR composites

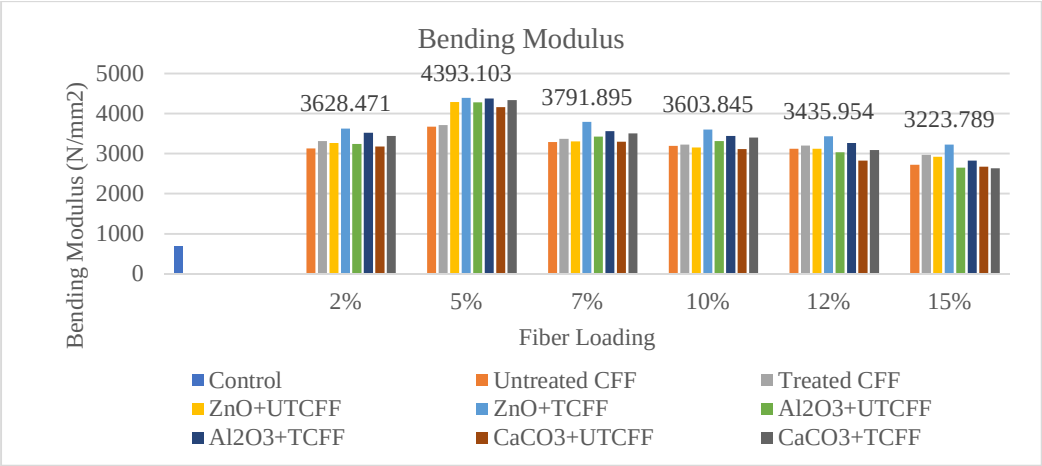


Fig 4.31: Variation of Bending Modulus peak of Control Sample, UTCFF+UPR, TCFF+UPR, TCFF+UPR+ZnO, TCFF+UPR+Al_2O_3 TCFF+UPR+$CaCO_3$, UTCFF+UPR+ZnO, UTCFF+UPR+Al_2O_3 and UTCFF+UPR+$CaCO_3$ composites

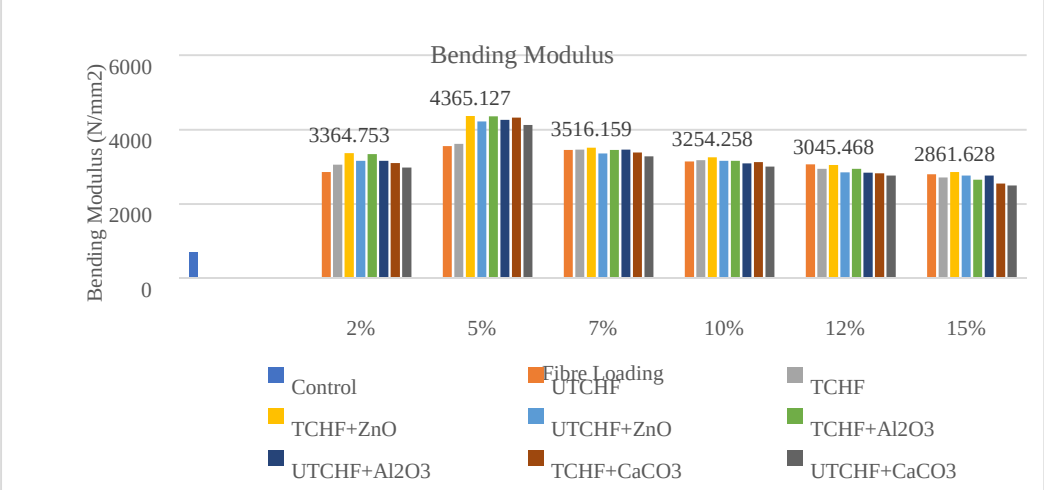


Fig.4.32: Variation of Bending Modulus peak of Control Sample, UTCHF+UPR, TCHF+UPR, TCHF+UPR+ZnO, TCHF+UPR+Al_2O_3 TCHF+UPR+$CaCO_3$, UTCHF+UPR+ZnO, UTCHF+UPR+Al_2O_3 and UTCHF+UPR+$CaCO_3$ composites

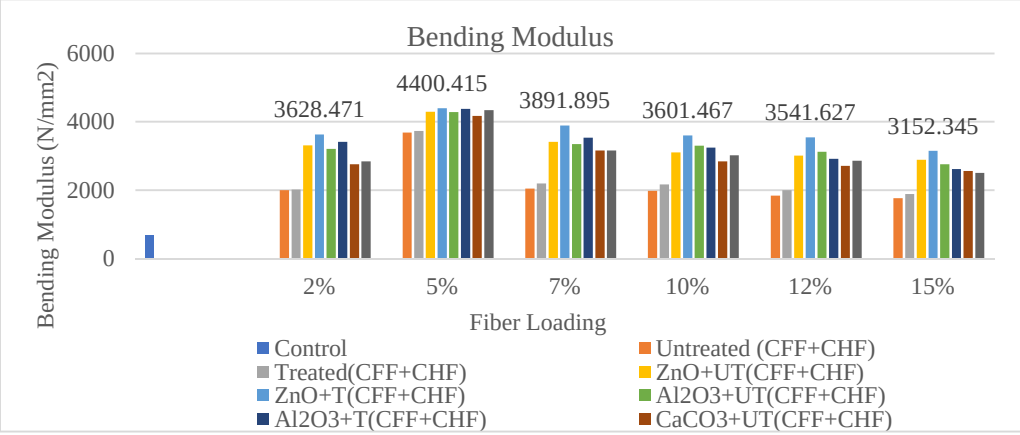


Fig 4.33: Variation of Bending Modulus peak of Control Sample, UT(CHF+CFF)+UPR, T(CHF+CFF)+UPR, T(CHF+CFF)+UPR+ZnO, T(CHF+CFF)+UPR+Al_2O_3 T(CHF+CFF)+UPR+$CaCO_3$, UT(CHF+CFF)+UPR+ZnO, UT(CHF+CFF)+UPR+Al_2O_3 and UT(CHF+CFF)+UPR+$CaCO_3$ composites

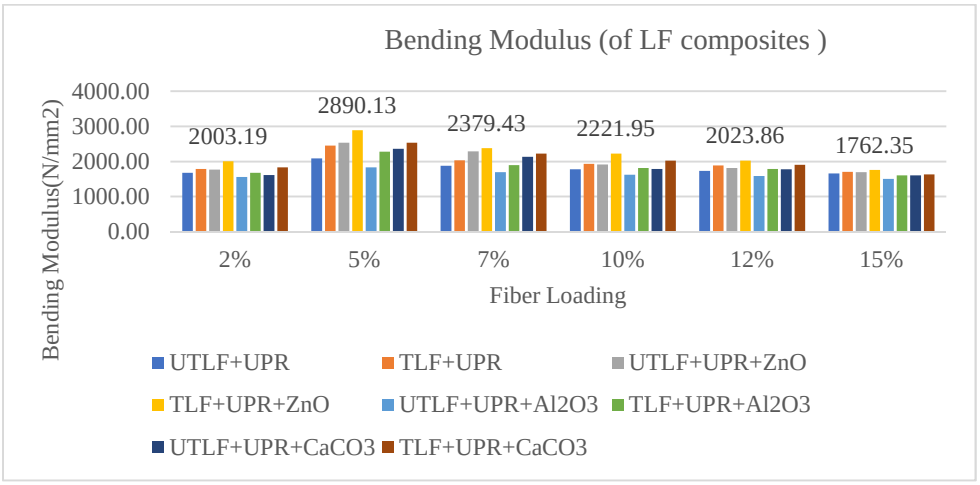


Fig 4.34: Variation of Bending Modulus peak of Control Sample, UTLF+UPR, TLF+UPR, TLF+UPR+ZnO, TLF+UPR+Al_2O_3 TLF+UPR+$CaCO_3$, UTLF+UPR+ZnO, UTLF+UPR+Al_2O_3 and UTLF+UPR+$CaCO_3$ composites

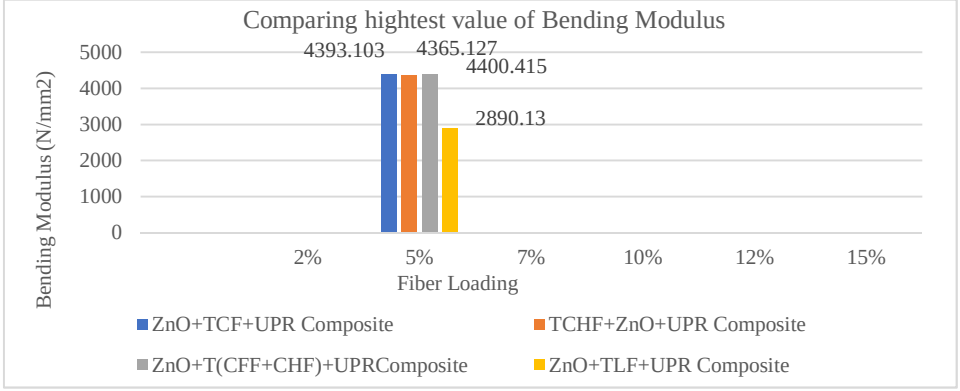


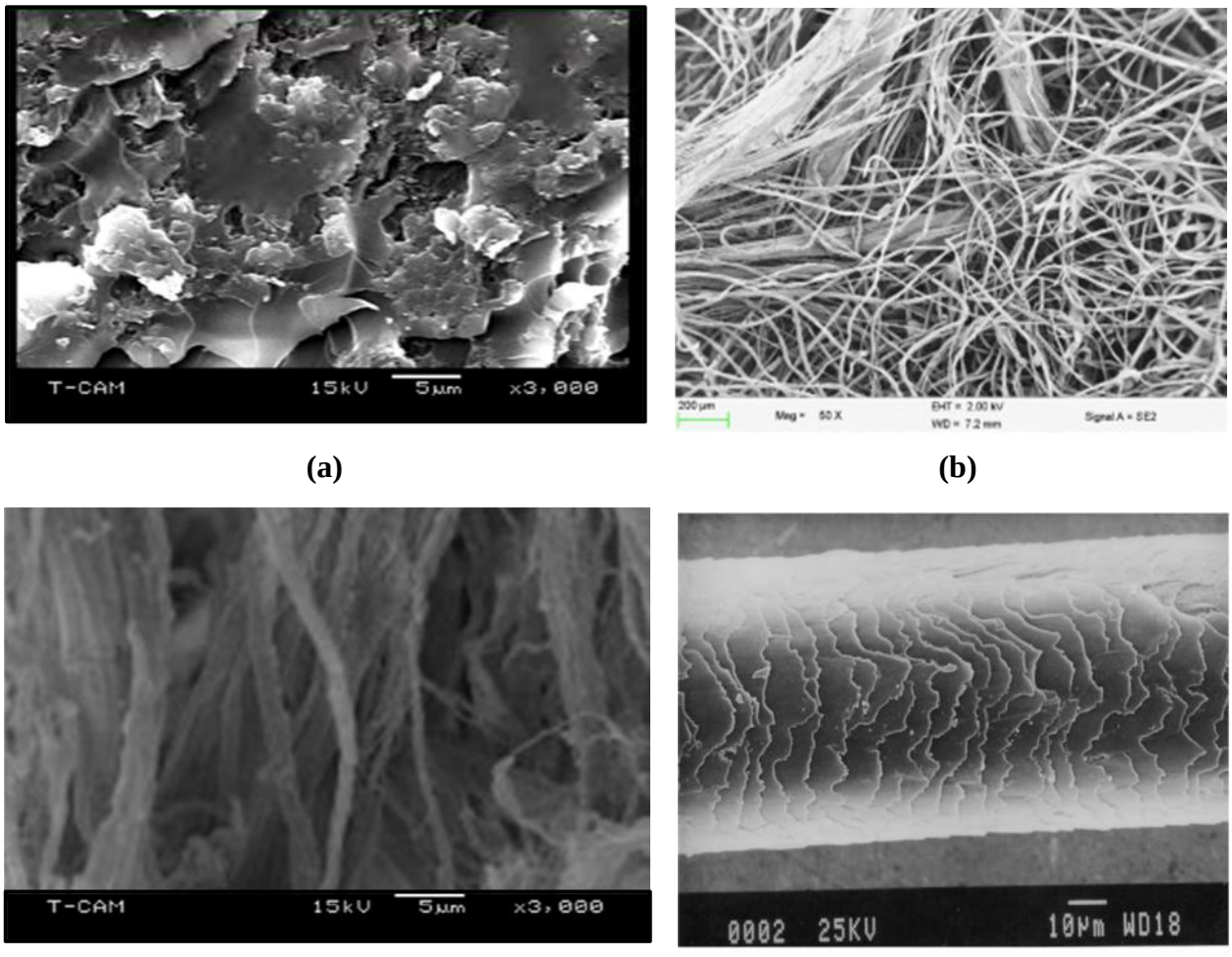
Fig 4.35: Comparing Highest value of Bending Strength of the composites

4.4 Scanning Electron Microscopic (SEM) Analysis

Figures 4.36 (a), (b), (c), and (d) show the SEM images of the neat, unsaturated polyester resin matrix, chicken feather fiber, leather fiber, and cow hair, in that order. The animal fiber's surface was not fully smooth, as seen by the SEM picture, which strengthened the mechanical bonding. After being put through a tensile test, the broken samples were chosen for surface morphology study using a SEM machine in order to examine the matrix adhesion, chicken feather, cow hair, and leather fiber in the composites. To further understand the interfacial characteristics between the matrix and the waste fibers of chicken feather, cow hair, and leather, scanning electron microscopy (SEM) analysis of the fracture surface of the composites was carried out. In the SEM image, the inorganic materials (ZnO, Al_2O_3 and $CaCO_3$ were dispersed in equilibrium.

On the fracture surface of the manufactured composite samples, the characteristics of the interface between the chicken feather fiber, cow hair fiber, and leather fiber phase and the unsaturated polyester resin (UPR) matrix were studied with a scanning electron microscope (SEM). The produced composites' morphological structure was displayed in Fig. 4.37. The photos demonstrated a close bond between the matrix and fibers. Up to a certain fiber-loading limit, the fracture surface under SEM exhibited less fiber pullout from the matrix, which enhanced mechanical properties. The poor pulling of the fibers from composites was also revealed by the SEM pictures. The strong link between cow hair and UPR was shown in SEM pictures of composite materials when the tensile test pulled a few fibers of cow hair away from the UPR. Therefore, the physico-mechanical properties can be improved by combining waste materials from the poultry, tannery, and cow hair industries with unsaturated polyester resin. There was no vacant region to be seen in the created composites. The blank spaces shown in the images [Fig. 4.37 f), k)] were used to illustrate the fiber withdrawal from the matrix. SEM images of composites showed interrupted bonding. Since the fiber and matrix are closely woven together, there is little doubt that the mechanical properties of composites are a little bit better than those of the control sample. Similar matrix and fiber adhesion was also investigated in natural fiber-reinforced composites and has been previously reported [211-213]. Animal fiber reinforced composites don't often have any cracks [214]. After tensile testing, some cracks were seen in the SEM images. The primary focus of this research was on the physical-mechanical qualities as well as the environmental problem. The characteristics were enhanced by the fiber addition up to a specific proportion. The force transmission from the matrix to the reinforcing agent was enhanced when fibers were gradually introduced to the matrix (unsaturated polyester

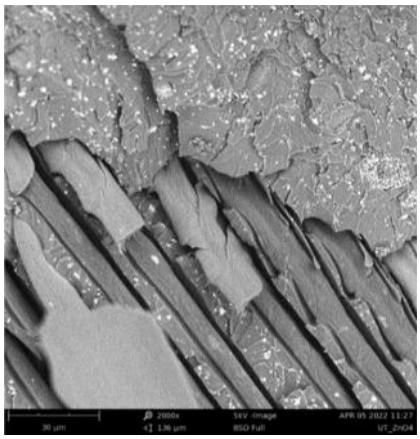
resin). The mechanical characteristics were somewhat increased by the improved force transmission between the fiber and matrix. The inclusion of filler helped to improve the fiber-matrix interaction, and the improved bonding increased the mechanical characteristics up to a point. There were some voids left by pulled-out fibers in each example, but the fibers were all remained lodged in the resin. The absence of a new bond in the FT-IR spectrum indicated that there was no chemical interaction between the fibers and UPR. SEM analysis of the interfacial properties of treated chicken feather fiber reinforced UPR composites showed that at 5 weight percent of fiber reinforcement, the fibers can effectively transfer stress between the fibers and the UPR matrix while also increasing the tensile strength. Additionally, a fiber misalignment and entanglement were visible. In terms of the general characteristics of composites, fiber alignment considerations are quite important. This fiber entanglement may result in resin-rich regions, which may aid in the development of pores and voids. Similar SEM picture types have been described in a variety of publications [215, 216].



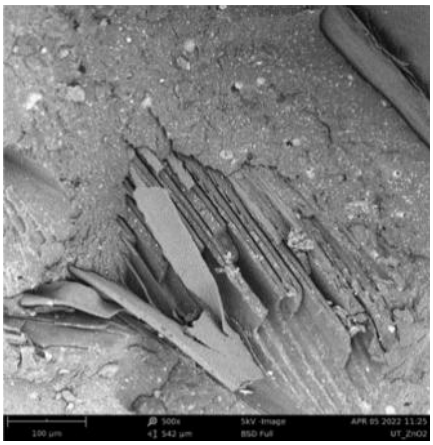
(a) **(b)**

(c) **(d)**

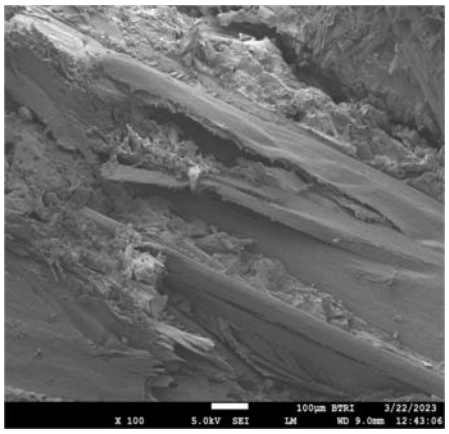
Fig.4.36: SEM image of (a) Matrix, (b) Chicken feather fiber, (c) Leather fiber and (b) Cow hair



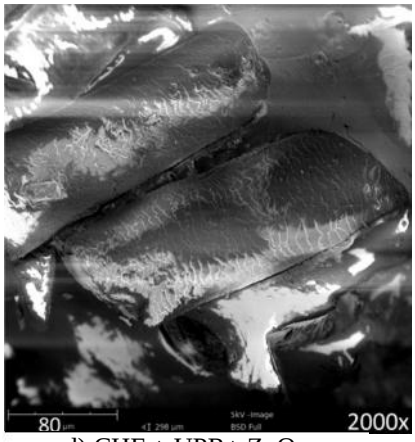
a) CFF+UPR+ZnO



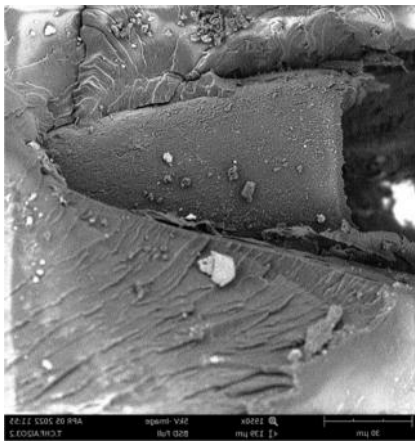
b) CFF+UPR+Al_2O_3



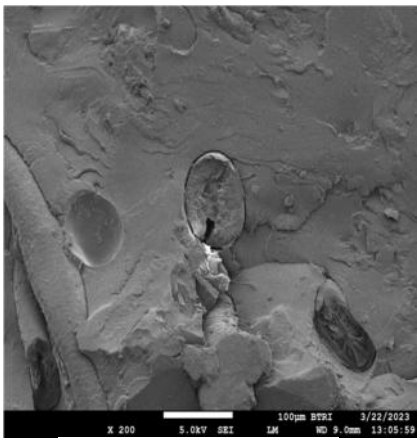
c) CFF+UPR+$CaCO_3$



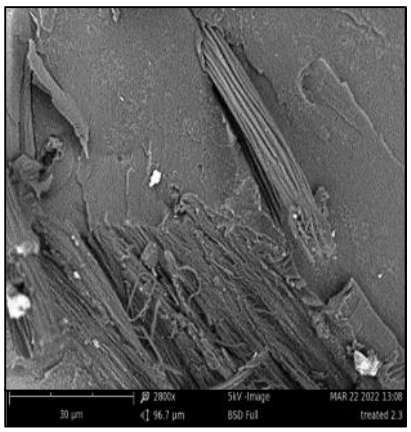
d) CHF + UPR+ ZnO



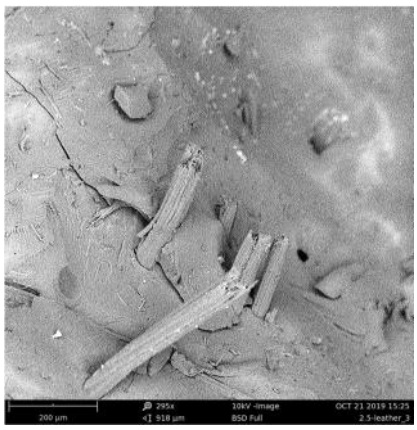
e) CHF+UPR+Al_2O3



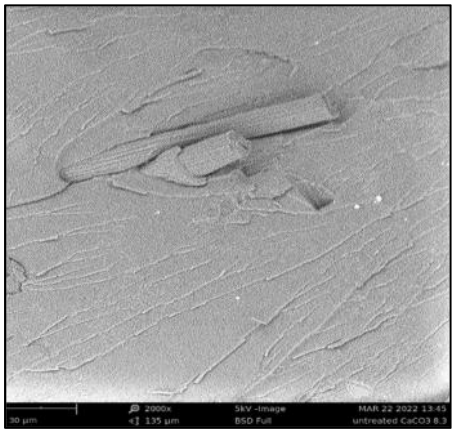
f) CHF+UPR+ $CaCO_3$



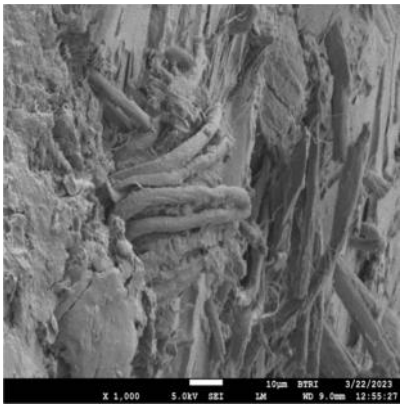
g) (CHF+CFF)+UPR+ZnO



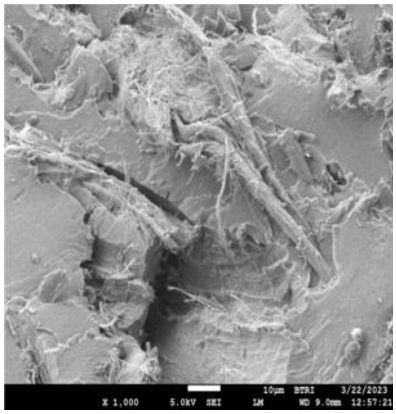
h) (CHF+CFF)+UPR+ Al_2O_3



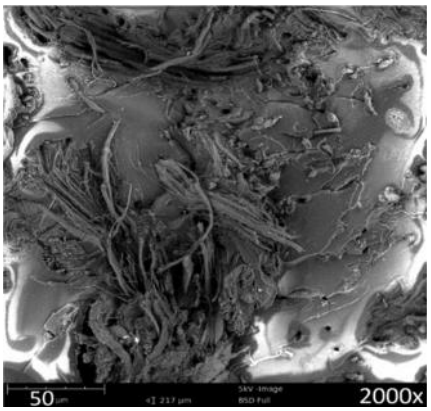
i) (CHF+CFF)+UPR+ $CaCO_3$



j) TLF+ZnO+UPR



k) TLF+Al_2O_3+UPR



l) TLF+$CaCO_3$+UPR

Fig. 4.37: SEM images of chicken feather, cow hair and leather fiber reinforced UPR composites with inorganic materials as filler.

4.5 Fourier-Transform Infrared Spectroscopy

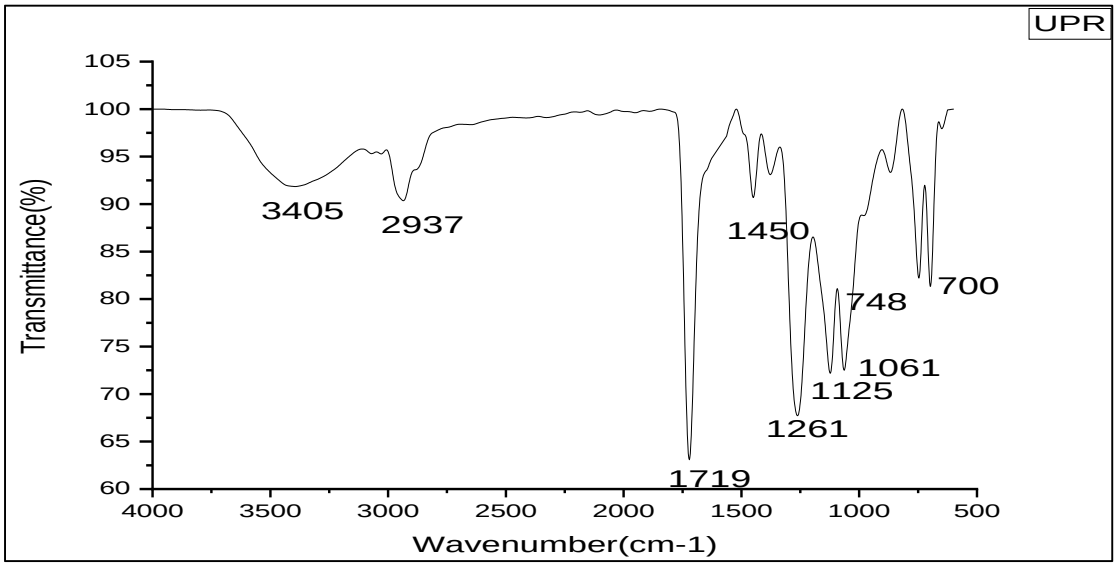


Fig 4.38: FTIR spectrum of unsaturated polyester resin.

The functional groups of the composite materials and unsaturated polyester resin (UPR) were identified using Fourier Transform Infrared Spectroscopy, and the machine-generated values are shown in Figs. 4.38-4.41. A prominent peak for the carbonyl (C=O) group was visible on the UPR graph (Fig. 4.38) at about 1719 cm^{-1} wave-number. Another significant component of the spectrum is C-O-C, which appears at around 1261 cm^{-1}. Another peak for the sp3 bending vibration of the -CH3 groups was found in the wavenumber 1450 cm^{-1} region. The existence of =C-H out of plane for bending vibration resulted in the other strong peak at 700 cm^{-1}, and -C-H stretching was given a faint peak at 2937 cm^{-1}. When polymeric -OH and -NH_2 groups were present, very significant peaks were seen at the wavenumber 3405 cm^{-1}.

The carbonyl (C=O) groups were visible in the infrared spectra of chicken feather fiber-reinforced UPR Composites at 1715 cm^{-1}, 1734 cm^{-1}, and 1734 cm^{-1} (Fig. 4.39). Because of the likely creation of a hydrogen bond between the oxygen atom of the carbonyl group and the hydrogen of the -NH group in keratin, the peaks were slightly displaced from 1719 cm^{-1}. In case of cow hair fiber-reinforced UPR Composites for carbonyl (C=O) groups same incident took place for similar H-bonding (Fig. 4.40). For fiber based composites near the wave number 3400 cm^{-1} broad peaks were

found for the presence of polymeric -OH and -NH_2 groups and little shifted from 3405 cm^{-1} due to cause of formation H-bonding between H of -NH and O of -OH groups. In the 1578 cm^{-1} – 1630 cm^{-1} for fibers/UPR composites were found medium peak which is absent in UPR spectrum. So it's responsible for bending vibration of -NH and this group comes from keratin and collagen. The same functional group appears in the same region of the IR spectra in the FT-IR functional group analysis. The created composite material is anticipated to contain C-O-C and C=C groups produced from the UPR. Peaks of C-O, C-H, and -NH that were formed from the fibers were visible on the FT-IR graph of the built composite sample. As a result, neither the feather fiber nor the filler materials developed a chemical bond with the UPR or the feather fiber. The mechanical interaction between the fibers and UPR is what gave the materials their increased mechanical properties. Similar peaks were seen in published articles [217, 218].

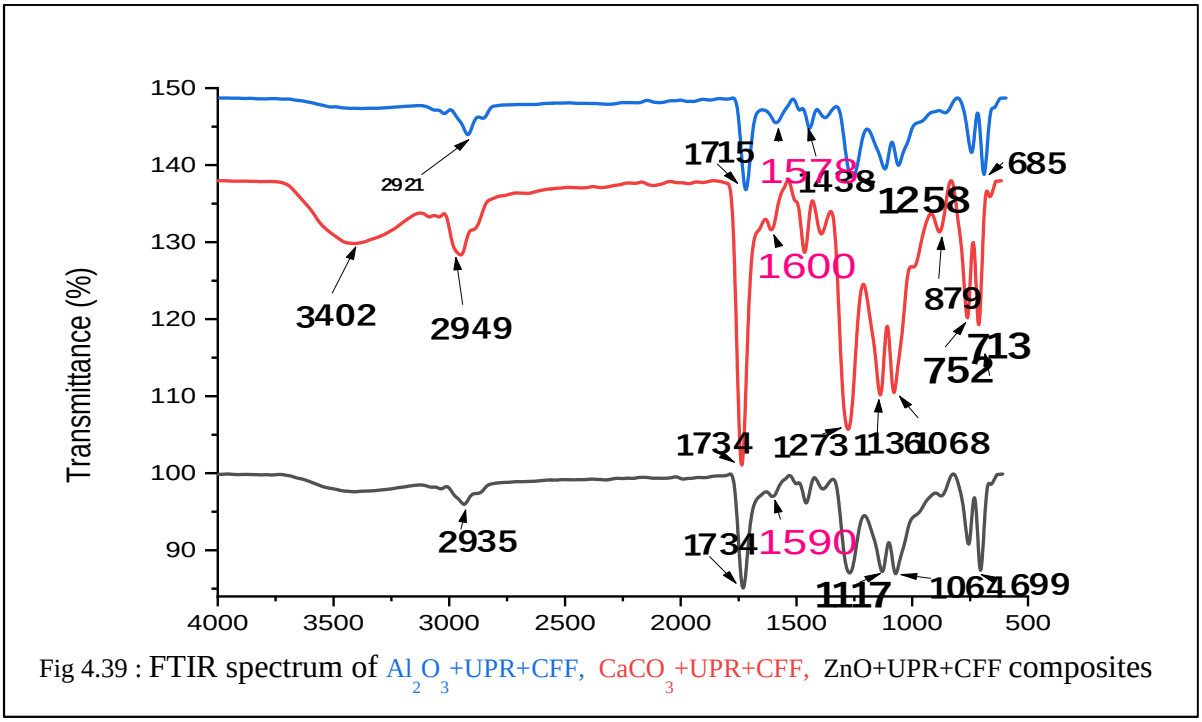


Fig 4.39 : FTIR spectrum of Al_2O_3+UPR+CFF, $CaCO_3$+UPR+CFF, ZnO+UPR+CFF composites

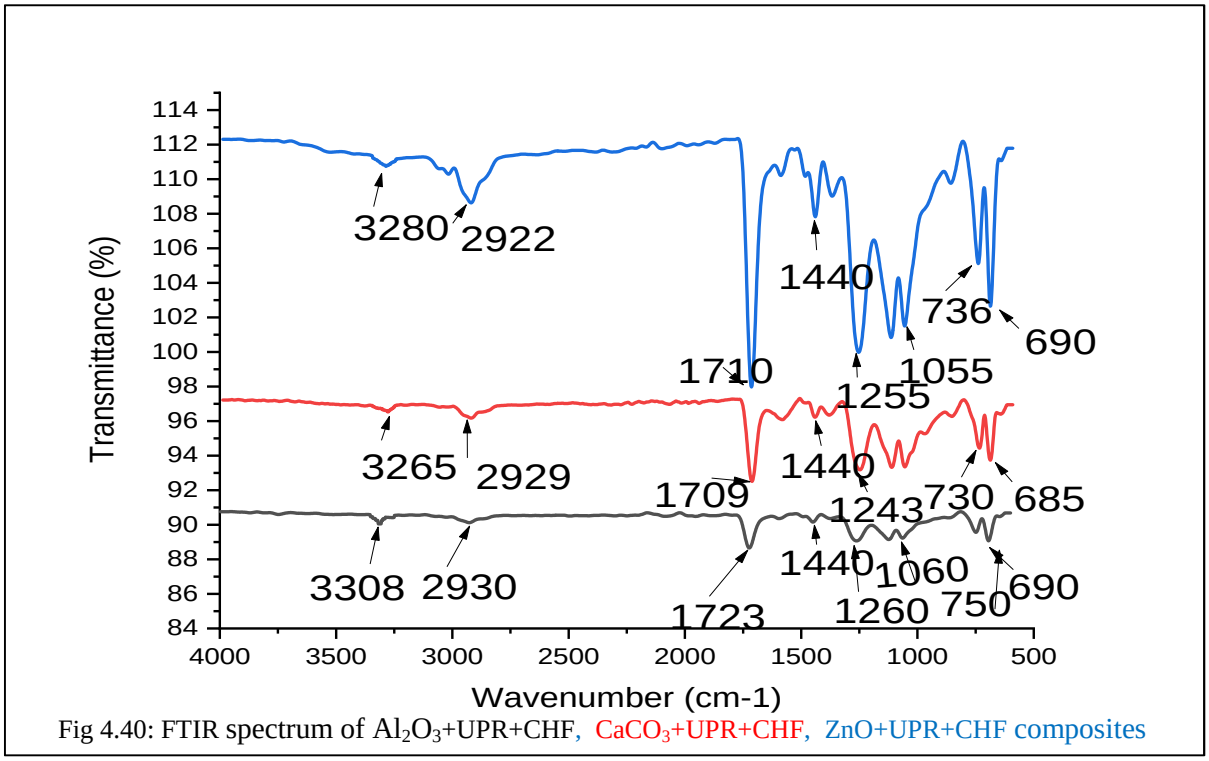


Fig 4.40: FTIR spectrum of Al_2O_3+UPR+CHF, $CaCO_3$+UPR+CHF, ZnO+UPR+CHF composites

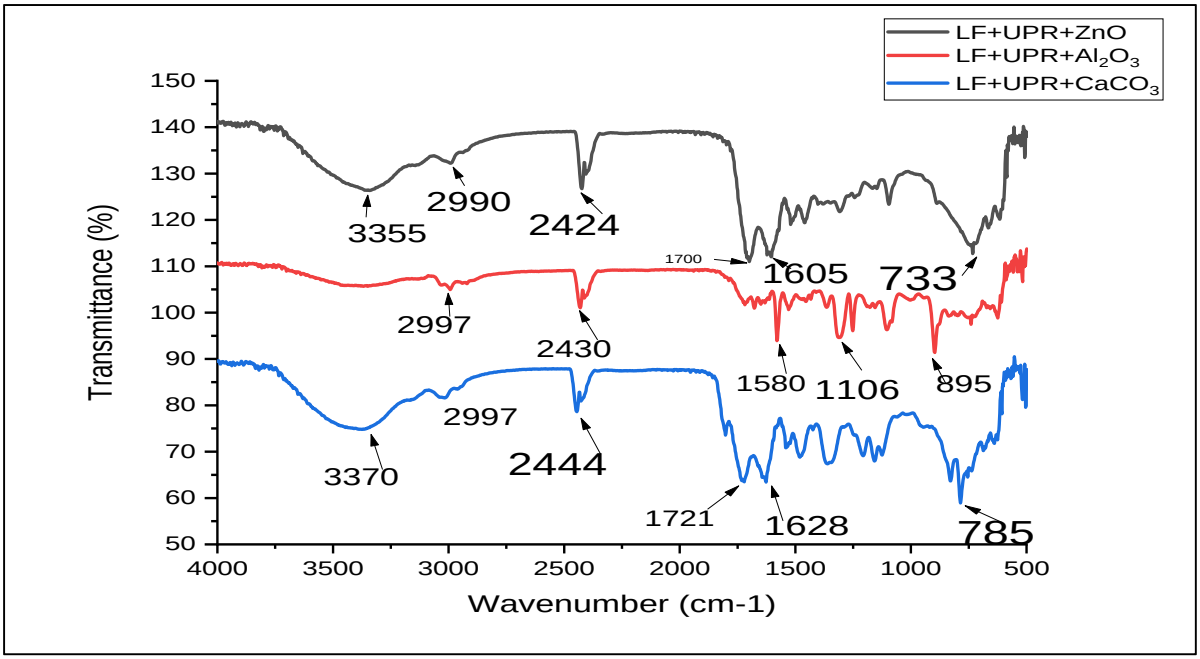
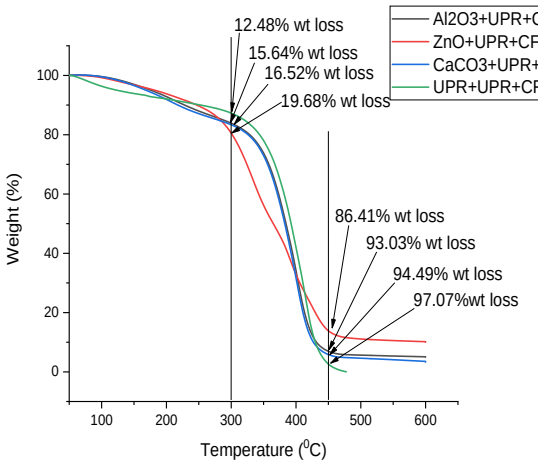


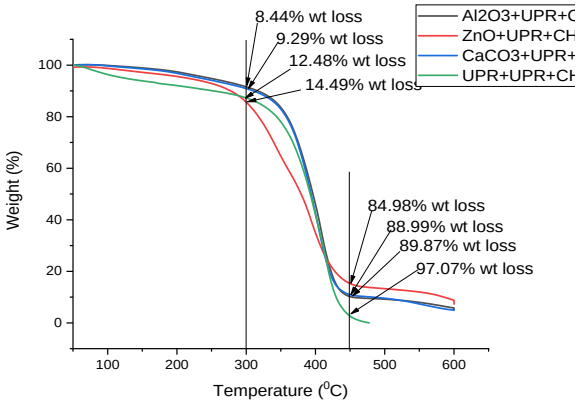
Fig 4.41 : FTIR spectrum of Al_2O_3+UPR+LF, $CaCO_3$+UPR+LF, ZnO+UPR+LF composites

4.6 Thermal Gravimetric Analysis

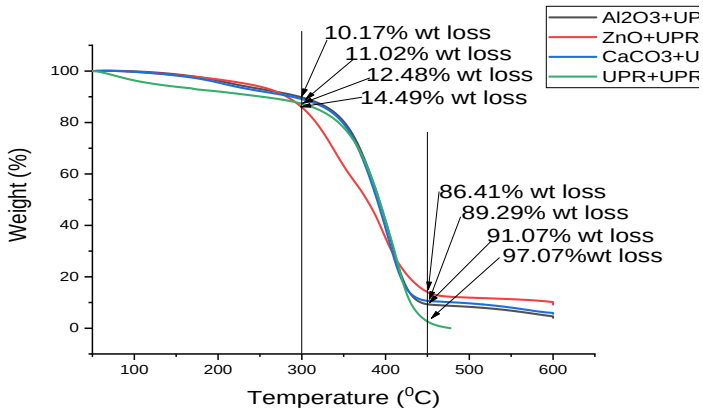
The thermal behavior of the produced composite was studied using thermogravimetric analysis. The initial temperature was 50 degrees Celsius, and the ending temperature was 550 degrees Celsius. The 5% untreated chicken feather/cow hair/leather fiber loading composites outperformed the control composites in terms of thermal resistance up to 315 °C. At temperatures near 100 ^{0}C, the composites exhibited their initial weight loss (%). The greatest weight loss occurs between 300 and 450 ^{0}C. The mass loss of the control sample was smaller than that of the fiber/ZnO, Al_2O_3 or $CaCO_3$ composites at temperatures below 350 ^{0}C. This difference might be ascribed to the greater heat conductivity of the ZnO, Al_2O_3 or $CaCO_3$ particles, which results in a larger weight loss ratio of ZnO, Al_2O_3 or $CaCO_3$ containing composites in comparison to the control sample. Higher thermal conductivity and heat capacity result in increased heat transfer to the polymer matrix and more bond breakdown [219-221]. The composites maintain 99% of their strength at 135 °C when compared to the untreated composite at the same temperature. Up until 315 °C, the rate of degradation was quite sluggish, but it then started to accelerate and continued until 450 °C. For the control sample, rapid degradation started at 207 °C, whereas it started for the composites at 385 °C, with 84% of each still present. The TGA graph of the control sample and composites is shown in Figure Fig.4.42. The control sample saw the greatest weight loss among the samples of fiber-based composites at 450 0C, losing 97.07% of its weight. Protein fiber, unsaturated polyester resin, and thermosetting polymers all degrade into other substances like CO_2, NO_2, NH_3, CO, and H_2O.



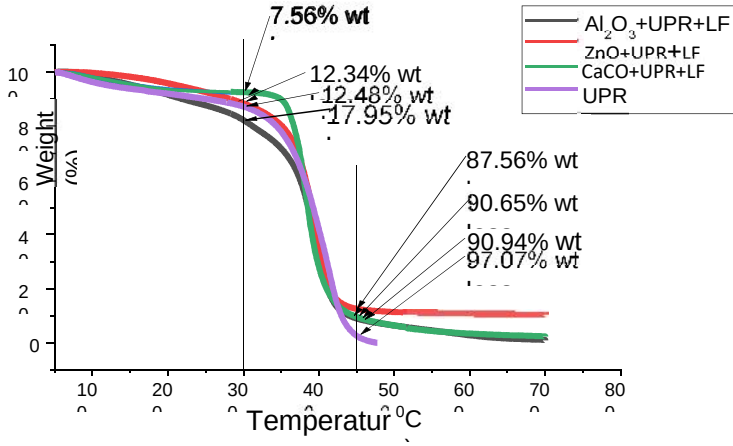
a) Image of Chicken Feather Fiber reinforced UPR composite



b) Image of Cow Hair+Chicken Feather Fiber reinforced UPR composite



c) Image of Cow Hair Fiber reinforced UPR composite



d) Image of Leather Fiber reinforced UPR composite

Fig 4.42: Thermogravimetric analysis of the composites.

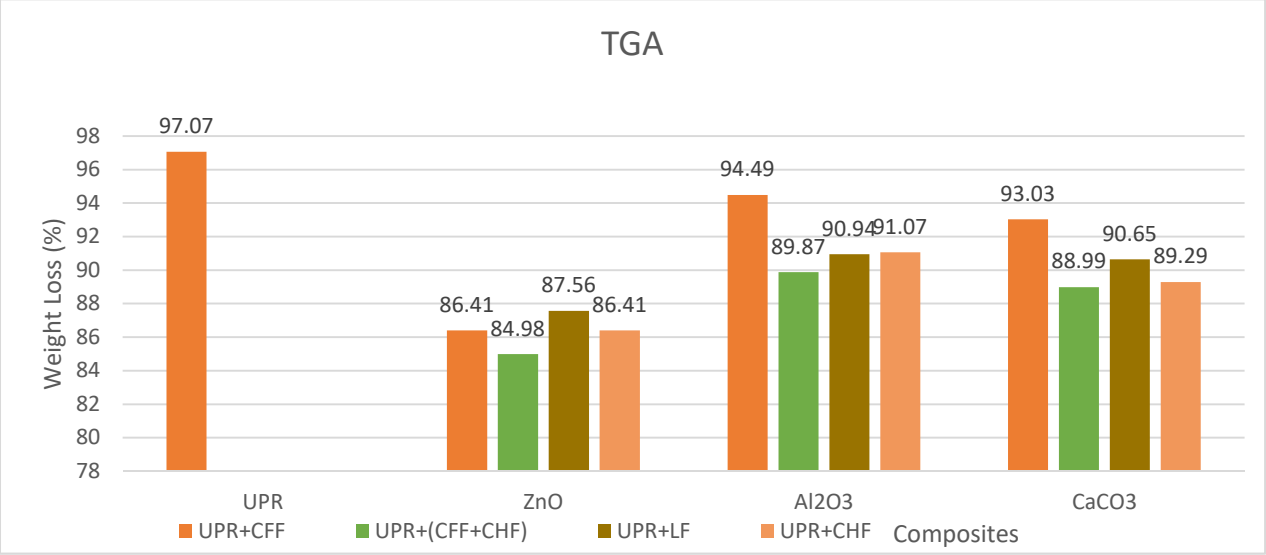


Fig 4.43: Comparing weight loss of different composites at 450 ^{0}C

4.7 Water uptake analysis

Figure Fig. 4,44 – 4.48 depicts water uptake data for all created samples. The water absorption property of chicken feather fiber, cow hair fiber, and leather fiber-reinforced unsaturated polyester resin composites and the control samples is tested by measuring the percentage of gained water after a particular time period in distilled water. The treated Leather fiber based composites with Al_2O_3 demonstrated the highest water uptake (8.87%), the second highest water uptake value for treated chicken feather fiber based composites with Al_2O_3 (7.56%), the chicken feather and cow hair mixed fiber based composites with Al_2O_3 demonstrated the third highest water uptake value (7.46%), the second lowest water uptake value for cow hair fiber based composites with Al_2O_3 (7.33%), and the control sample exerted the lowest water uptake (1.16%) percentage. The shafts of the feathers are discovered to be a fraction of the diameter of a human hair, with even tinier individual barbules - coiled hairlike extensions on the feather that extend to absorb water like a sponge. The structure of the feather is designed to store and retain water in a variety of ways. As a result, the water absorption capacity of feathers is larger than that of cow hair. The most likely explanation is that cow hair fiber is so heavily coated with natural oil and fat that it can scarcely absorb any water. Leather fibers absorb more water than the other two fibers tested in this study. It could be due to the presence of numerous pores on the surface and within the fiber structure, which can trap water molecules. Aluminium oxide, on the other hand, has a higher water absorption capacity than calcium carbonate and zinc oxide. The percentage of water inside the composites rose over time, with the highest levels obtained after two weeks. Some interesting statistics on the breakdown of composites inside the

aqueous medium may be discovered. The water absorption percentage was extremely low because unsaturated polyester resins are hydrophobic. The protein fiber-based composites likewise showed low water-gaining capacities since the UPR layer was formed outside the fibers. On the fiber and matrix boundaries, there were still some gaps that allowed water to get trapped, improving water uptake. The following equation was used to determine the water uptake. [222, 223].

$$\text{Water uptake \%} = \frac{(\text{Final weight} - \text{Initial weight})}{\text{Initial weight}} \text{ X } 100$$

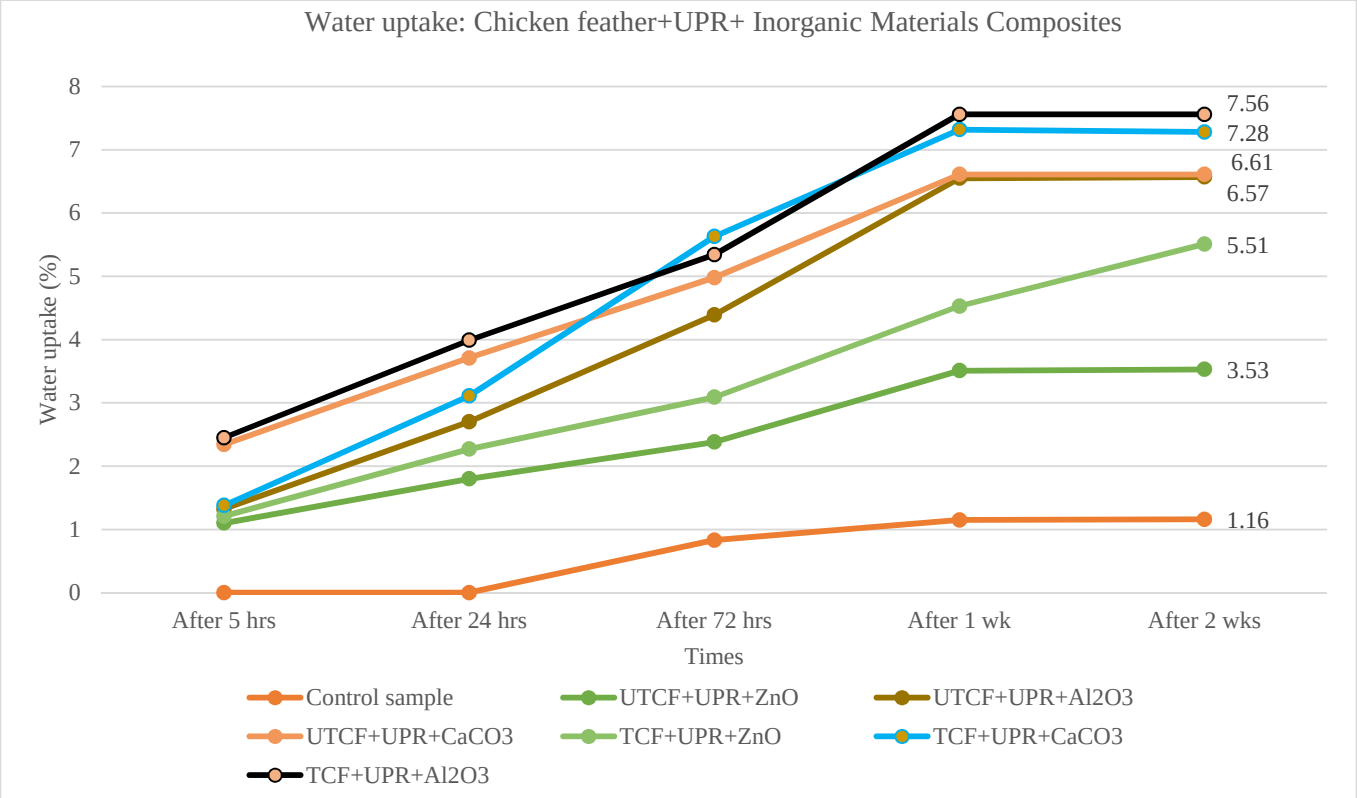


Fig 4.44: Water uptake analysis of chicken feather fiber reinforced UPR composites.

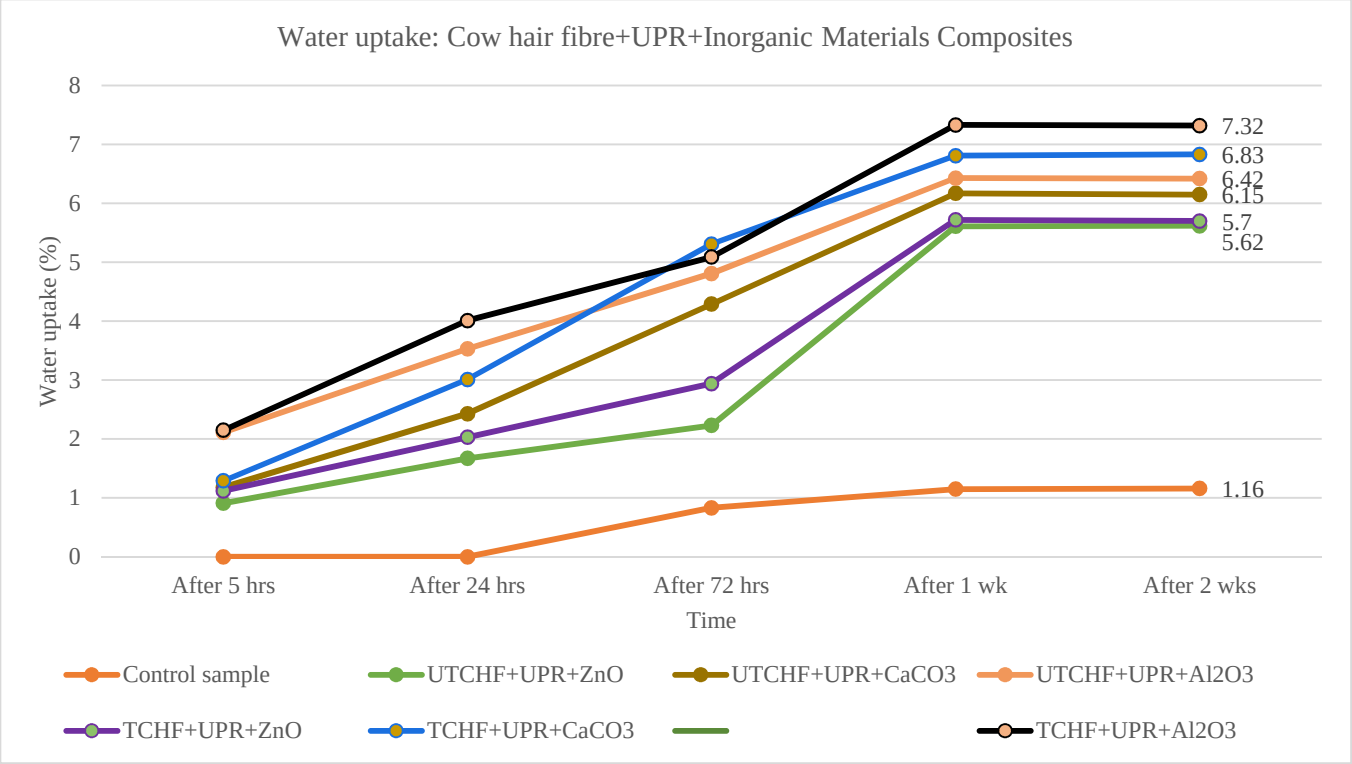


Fig 4.45: Water uptake analysis of cow hair fiber reinforced UPR composites.

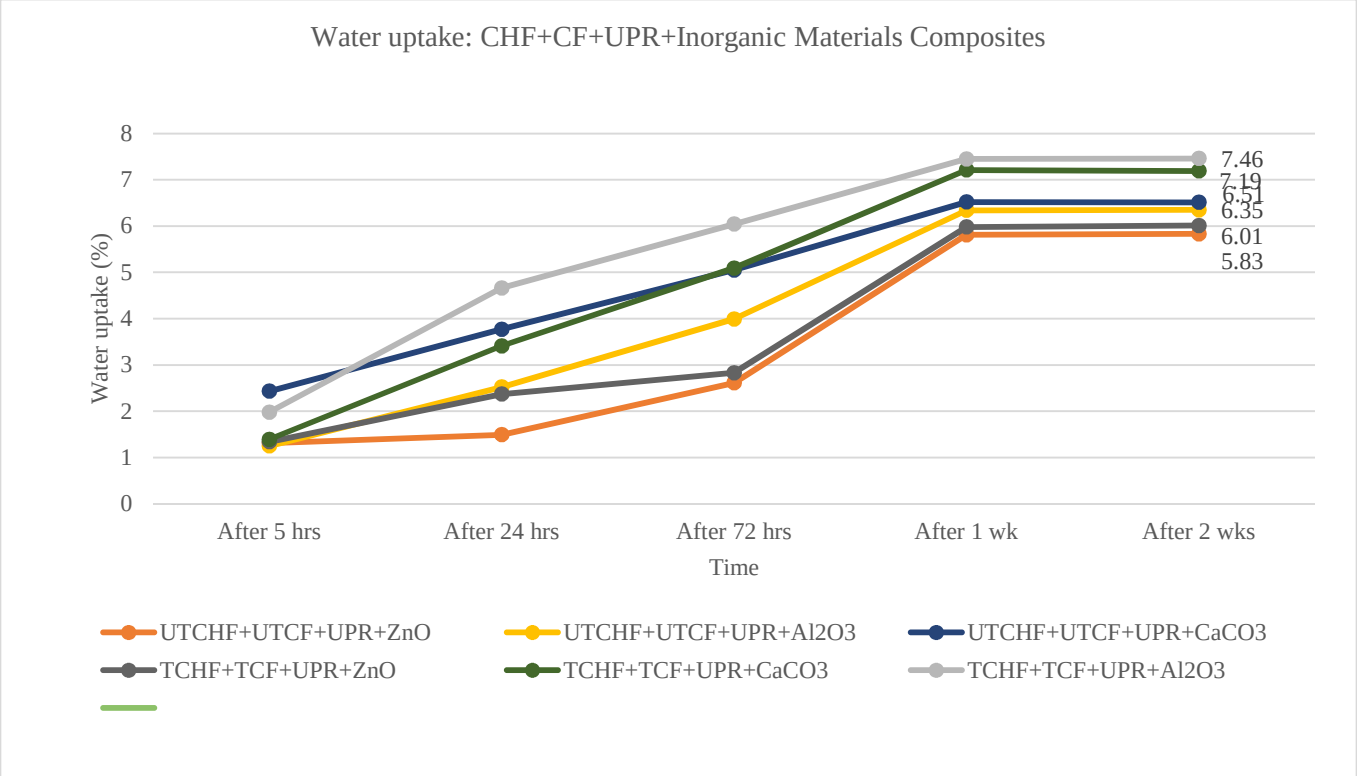


Fig 4.46: Water uptake analysis of (chicken feather + cow hair) fiber reinforced UPR composites.

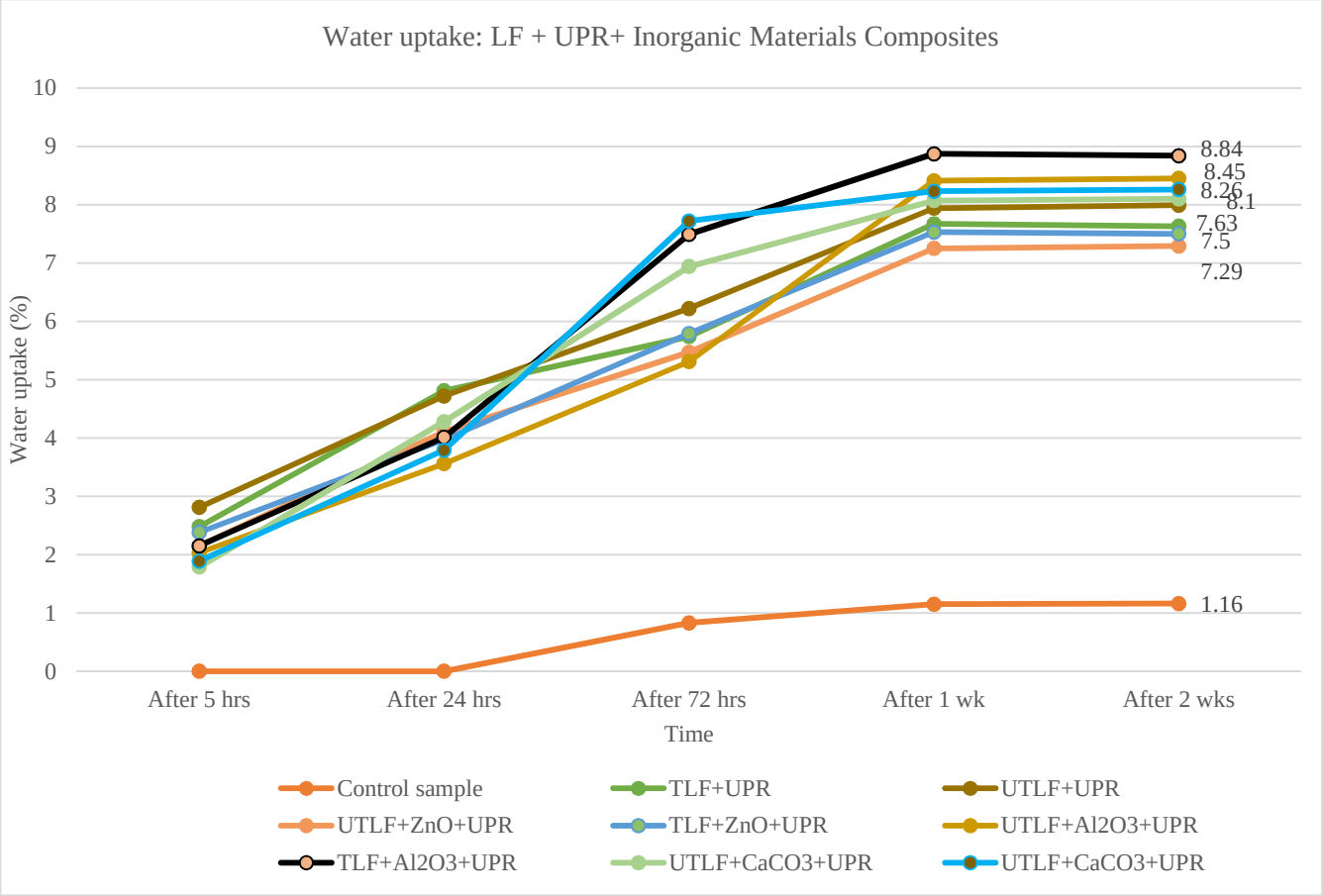


Fig 4.47: Water uptake analysis of leather fiber reinforced UPR composites.

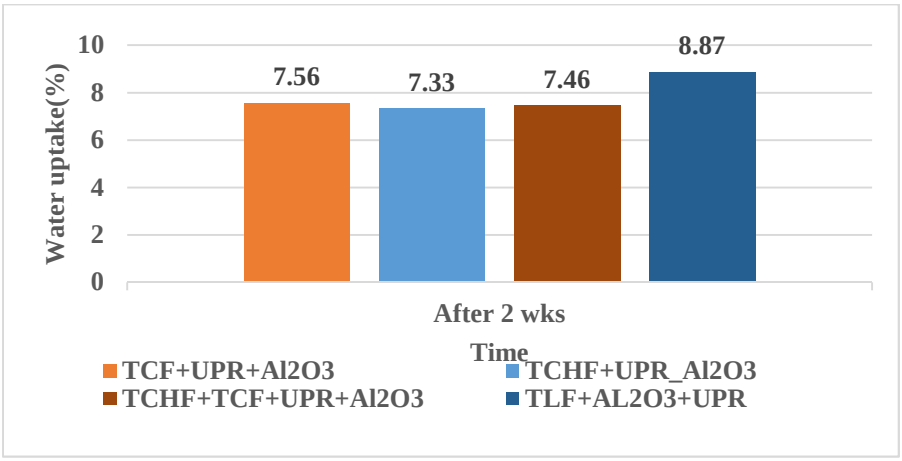


Fig 4.48: Comparing highest values of water uptake of the composites.

4.8 Thickness Swelling Test

Thickness changes in polymer composites due to swelling in distilled water conducted using digital slide scale were measured in this section. Figure 4.49- 4.53 shows the thickness Vs time curves for chicken feather, cow hair and leather fibers reinforced unsaturated polyester resin polymer composites. The thickness of swelling increases with increase in fibers loading with time and later it become constant. Maximum thickness was increased 15.81% for maximum 15% treated leather fiber based composite with Al_2O_3 followed by 13.04% for 15% treated (CFF+CHF)+UPR+ Al_2O_3 composite, 12.81% for 15% treated CHF+UPR+ Al_2O_3 and 12.62% for 15% treated CFF+UPR+ Al_2O_3 compared to remaining treated and untreated fiber based composites with inorganic materials. After three days (or 72 hours) of immersion, the influence of swelling thickness became apparent and persisted for seven days; between one and two weeks, there is no evident change in thickness. Because of this, all composites exhibit an increase with increasing the animal fiber content after 2 weeks in distilled water, and the thickness swelling is rapid in the early stages and decreases as the immersion length grows. After seven days of immersion, the influence of swelling thickness became apparent, and after two weeks, it stabilized. This result is analogous to water uptake behavior, in which the inclusion of waste leather with greater hydrophilic properties than cow hair and chicken feather boosted water absorption in composites. As a result, when submerged in water, cow hair and chicken feather fiber provide higher water resistance and a reduction in swelling thickness. Furthermore, thickness swelling and dimensional stability composite are impacted by poor interaction between fiber/matrix and fiber distribution [224, 225]. Less swelling and a larger percentage of dimensional stability may be present in composites with a good interface and distribution of CFF, CHF, and LF. The following formula was used for calculation:

$$\% \text{ of increased thickness} = \frac{\text{Final thickness} - \text{Initial thickness}}{\text{Initial thickness}} \times 100$$

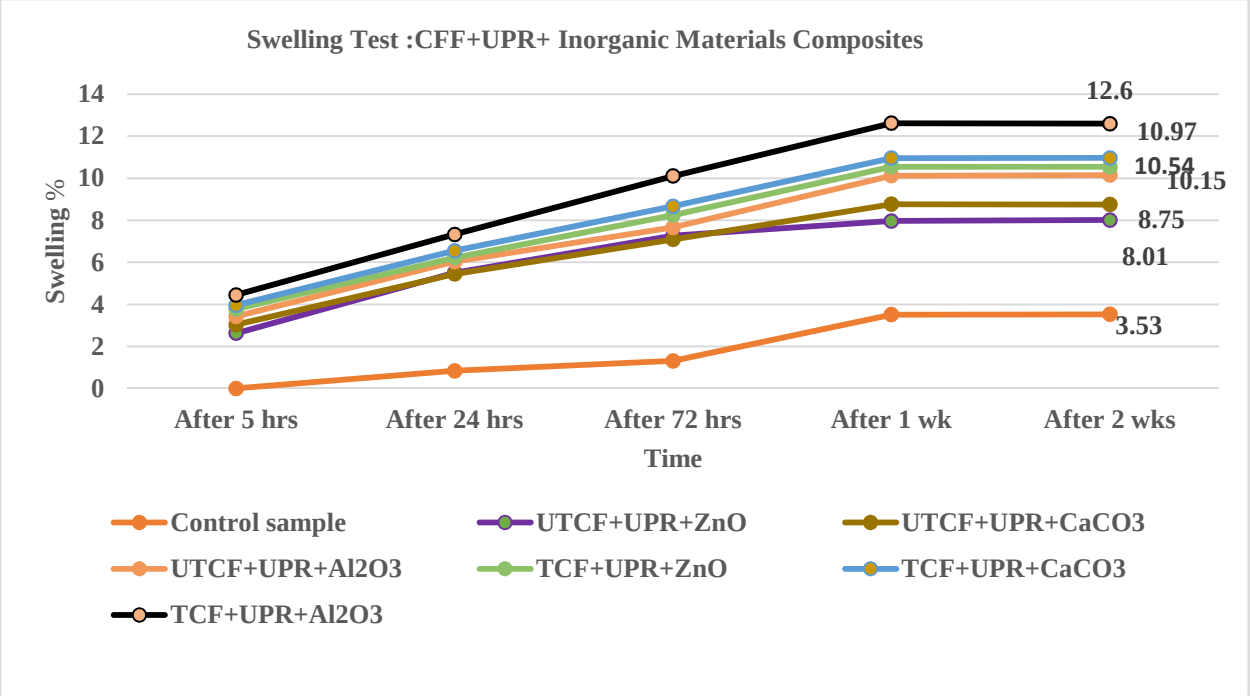


Fig 4.49: Thickness Swelling Test of chicken feather fiber reinforced UPR composites.

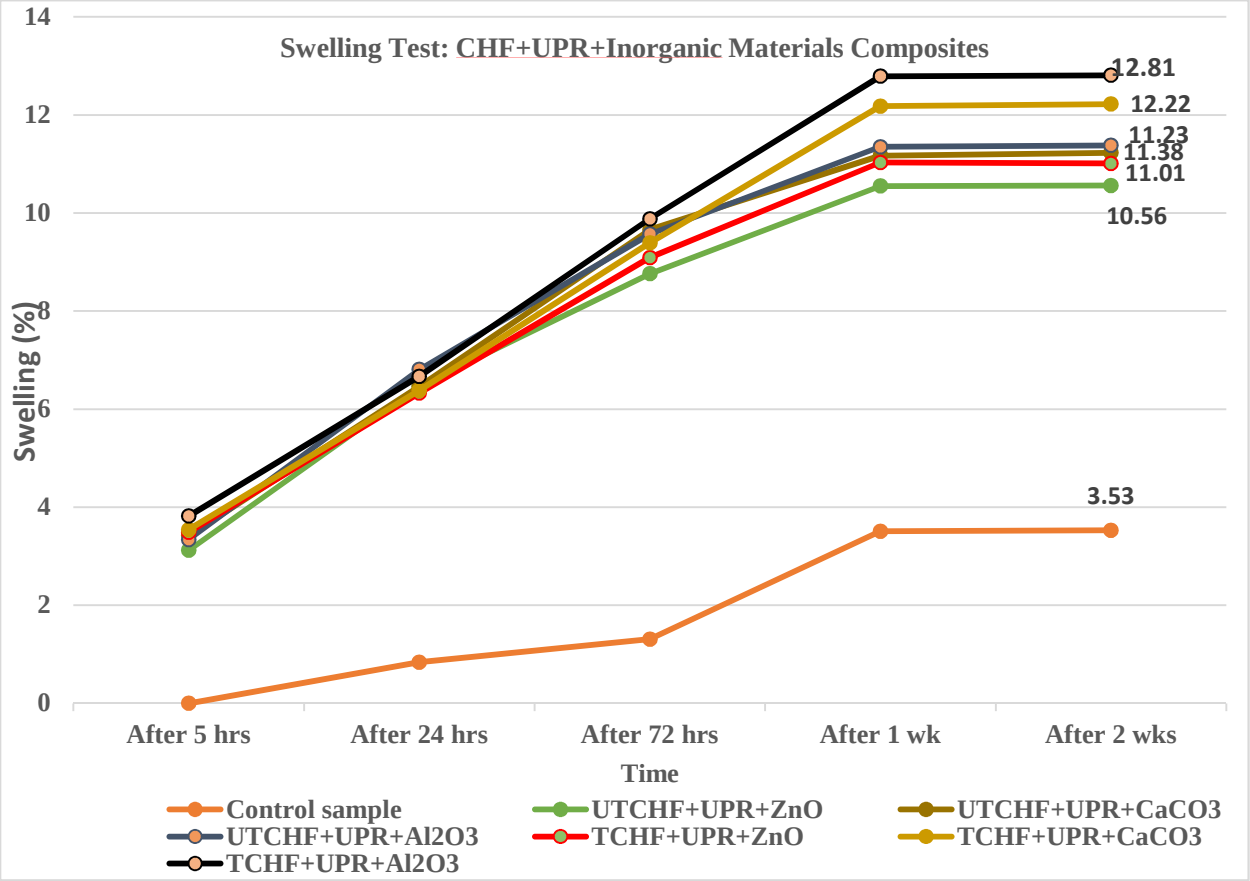


Fig 4.50: Thickness Swelling Test of cow hair fiber reinforced UPR composites.

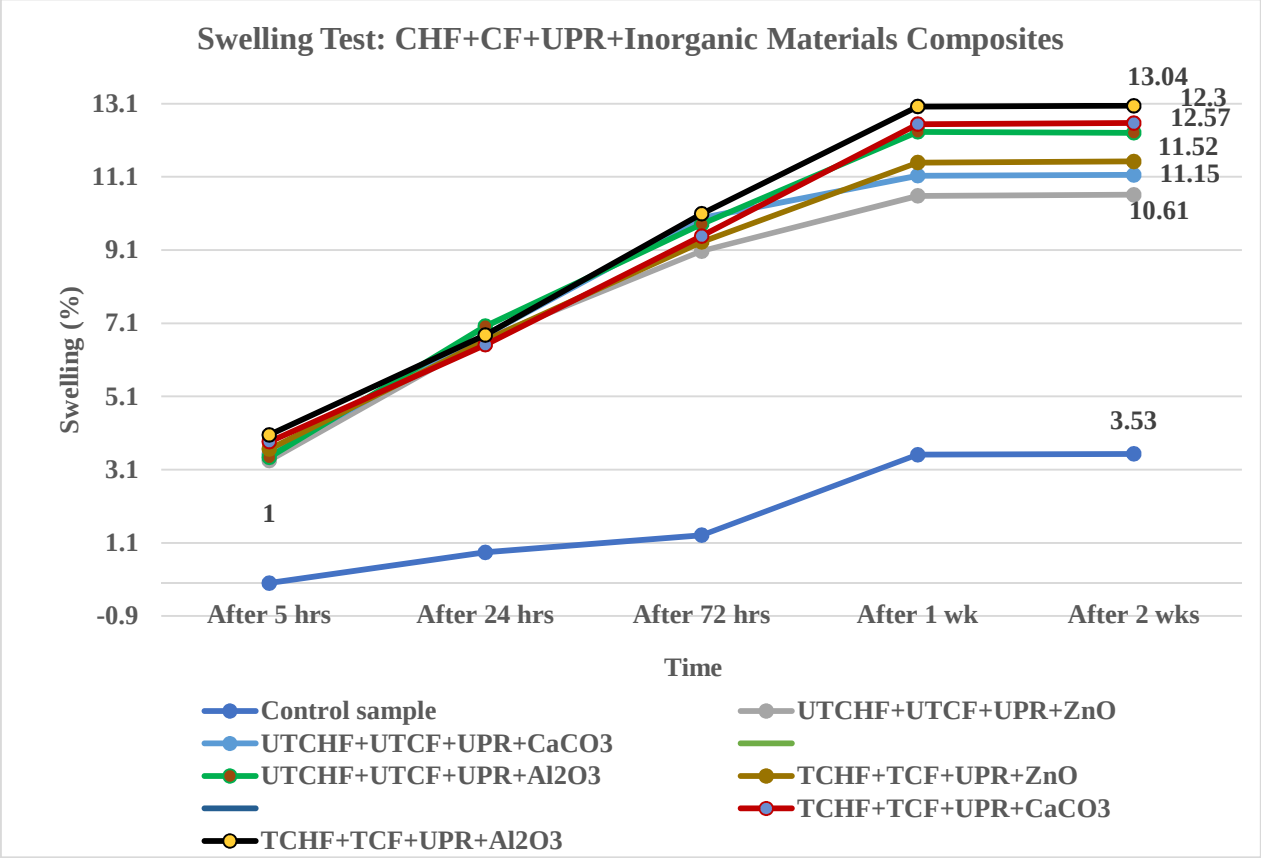


Fig 4.51: Thickness Swelling Test of (cow hair + chicken feather) fiber reinforced UPR composites.

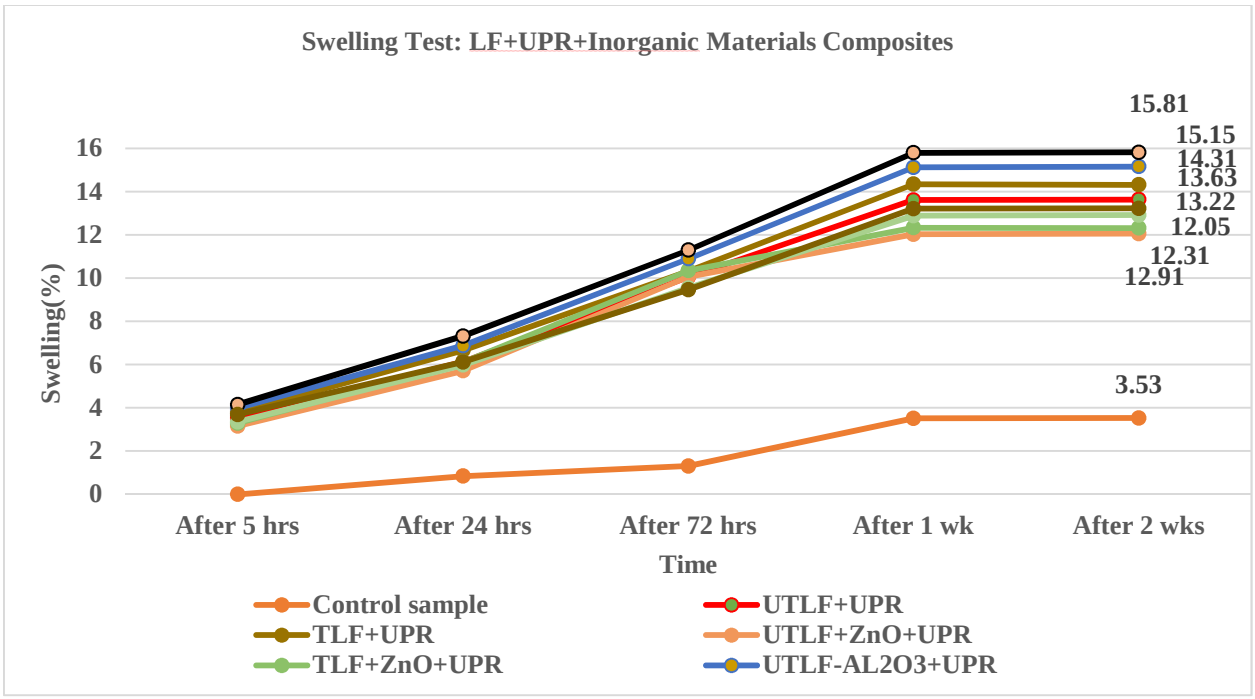


Fig 4.52: Thickness Swelling Test of leather fiber reinforced UPR composites.

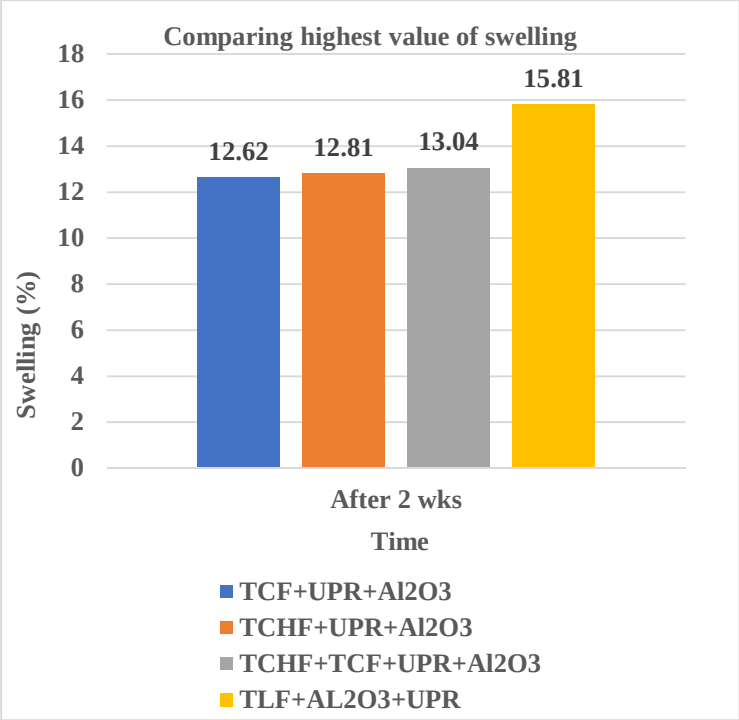


Fig 4.53: Comparing highest value of thickness swelling of the composites.

4.9 Bio-degradation test

The chemical dissolving or breakdown of materials is known as biodegradation.

Percentage weight loss of the composites after degradation was measured as

$$wt = \frac{w_0 - w_{(t)}}{w_0} X\ 100$$

Here, w(t) is the weight after time t, w_0 is the reference dry $w_{(t)}$ of the specimen before biodegradation.

The samples were carefully examined to look for evidence of crazing, heterogeneous surface erosion, or discoloration that are telltale signs of a surface deterioration after 90 days of exposure to the degradation conditions [226, 227–229]. Those submerged in compost showed the most pronounced crazing, followed by those submerged in soil that had been dissolved in saline or water, while samples subjected to air weathering showed the least surface deterioration.

4.9.1 Degradation of the Composites in weather

Short and long-term exposure to environmental conditions such as moisture and humidity, fluctuating temperature, and biological assault can all impair a composite's physical and mechanical qualities. Moisture and temperature are the most critical components studied, and their combination has a large and negative influence on the composite characteristics. To imitate natural weathering circumstances, which necessitate long-term evaluation, test techniques have been improved at a rapid pace, allowing long-term weathering effects to be assessed in less time.

With the fiber loaded, the weather degradation test is conducted at intervals of 30, 60, and 90 days. Figure 4.54–4.57 illustrates how the weight loss % rose along with the increase in fiber loading. owing to the susceptibility of natural fibers to external challenges such temperature, moisture, and light, outdoor weathering may result in oxidation of the composite owing to a photochemical reaction [230, 231]. As a result, the outer surface material of the matrix, which is not directly associated with fibers, may cause weight loss [232].

The highest degradation rate was observed 7.8% for 15% fiber loaded TLF+UPR+Al_2O_3 polymer composite due to highest hydrophilic nature of leather fiber than cow hair and chicken feather fibers and similar case for Al_2O_3 than that of ZnO and $CaCO_3$. The more fiber loaded the degradation rate was increased of the composites. The degradation rate of control sample was 1.4%. From Fig. 4.55-4.57 it was observed that the highest degradation values were 6,4%, 6.1% and 5.7% for 15% cow hair, chicken feather and (chicken feather + cow hair) mixed fiber loaded composites respectively. These degradation values were 21.87%, 27.87% and 36.84% less than that of the treated leather fiber loaded composites. After prolonged exposure to water spraying and the UV radiation continuous cycle, the composites showed significant discoloration owing to animal fibers and UPR breakdown. Because of the deterioration process caused by UV and moisture response, the weathered specimens underwent edge erosion and void formation. Aside from that, the presence of water molecules (which are made up of OH and H ions) stimulated the photo-oxidation reaction, which contributed to the fading effect. The primary mechanism of destruction for a polymer exposed to UV light.

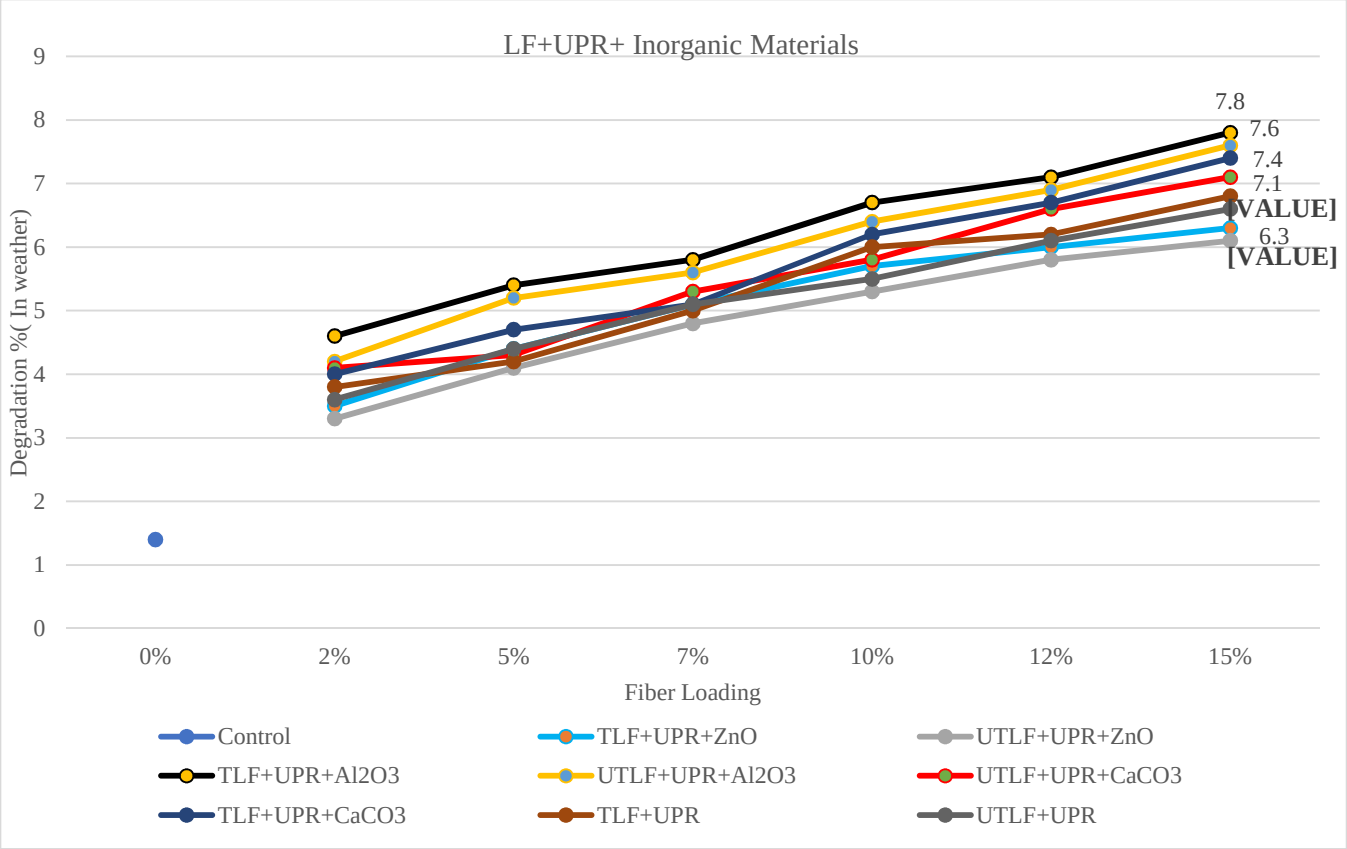


Fig 4.54: Weight loss rate for degradation of leather fiber reinforced UPR composites in weather.

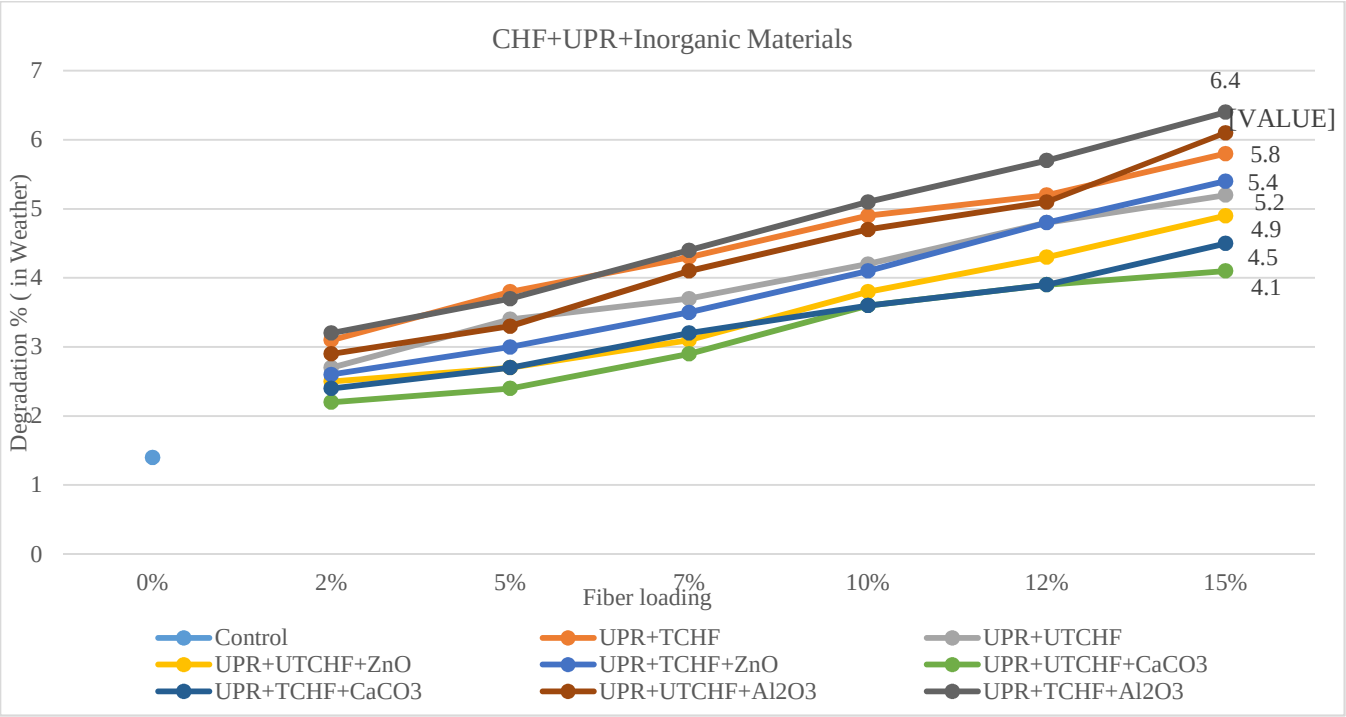


Fig 4.55: Weight loss rate for degradation of cow hair fiber reinforced UPR composites in weather.

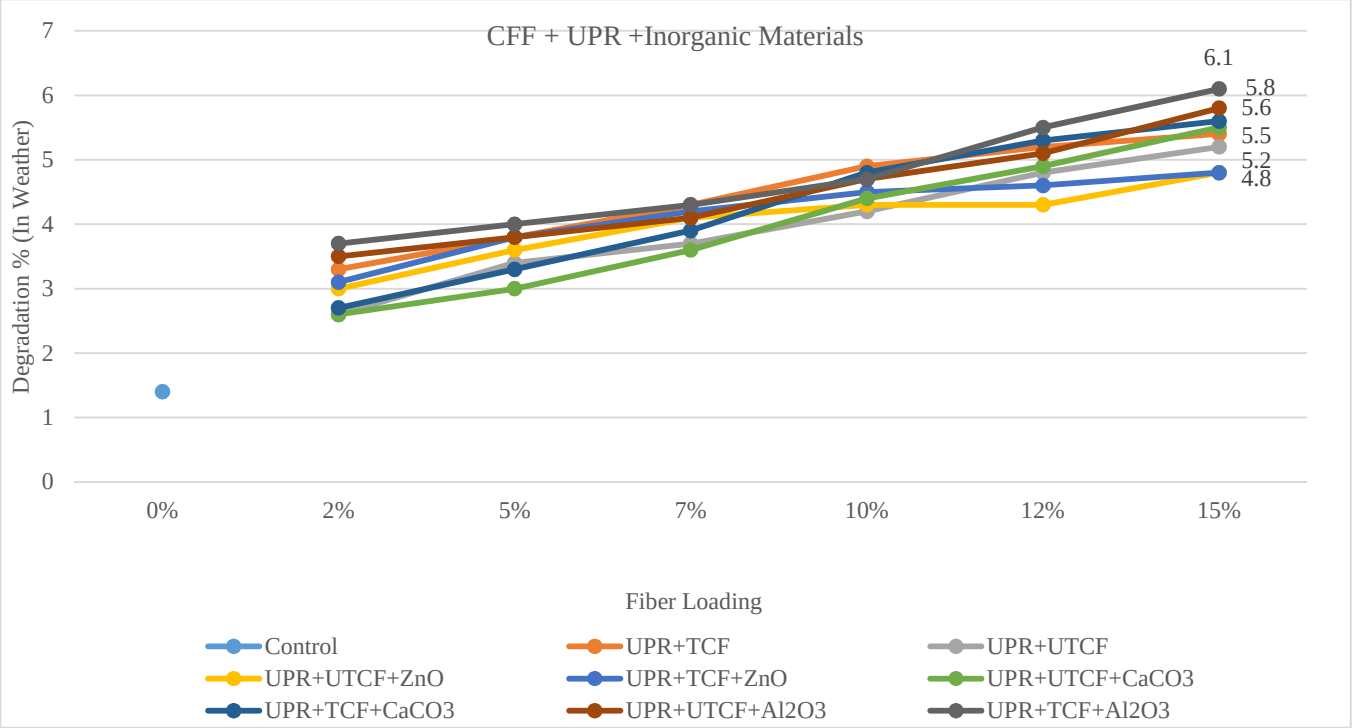


Fig 4.56: Weight loss rate for degradation of chicken feather fiber reinforced UPR composites in weather.

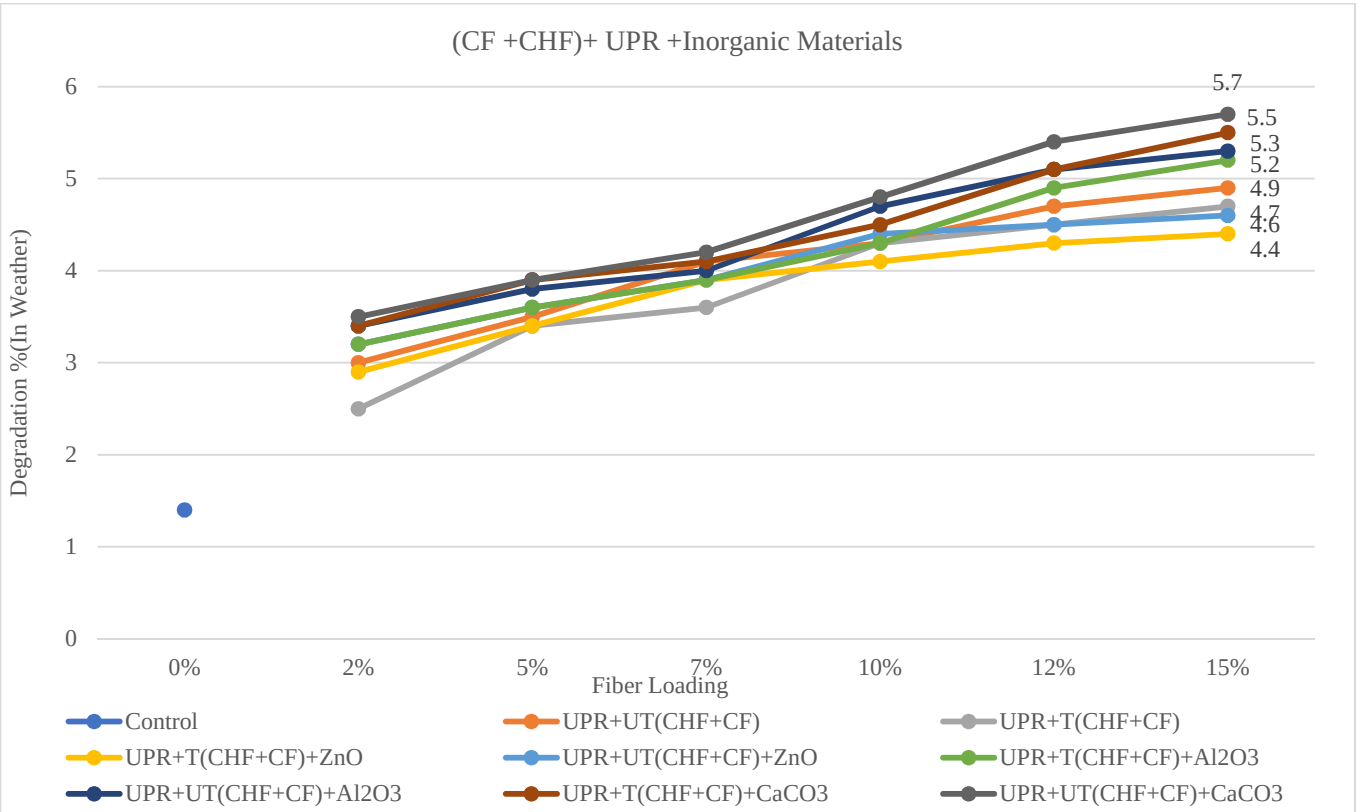


Fig 4.57: Weight loss rate for degradation of (chicken feather + cow hair) fiber reinforced UPR composites in weather.

4.9.2 Degradation of the Composites in water

Water molecules assault the organic side groups as the polymer degrades. The formation of P-OH units and the subsequent migration of the proton from oxygen to nitrogen, which makes the polymer backbone susceptible to hydrolysis, follow the removal of the side groups from the polymer's backbone.

After keeping the sample under distilled water degradation in water was measured. The sample degraded most (12.5%) treated LF+UPR+Al_2O_3 sample because of poor adhesion in matrix interface. Though UPR is not biodegradable material, it showed a slight change of weight loss about 2.1% after 90 days keeping under water. Some cells are not occupied by polymer molecules during the polymer chain formation process. These voids control material porosity and permeability and allow water molecules to penetrate the substance itself [233]. The treated samples were found more biodegradable than the others. So, the addition of Cow Hair Fibers and inorganic materials with UPR has increased the rate of biodegradation. The 15% fiber loaded TLF+UPR+ Al_2O_3 composites' biodegradation in water was increased 495.2% from the pure UPR sample. So, the addition of fibers' increased has increased the rate of degradation in water. The chicken feather fiber loaded composites gave the lower degradation value than that of LF/UPR and CHF/UPR composites. On the other hand, (CFF+CHF)/UPR composites showed the least degradation in water due to its least porosity and voids and less hydrophilic property of cow hair and chic ken feather than leather fiber. Since hydrophilic property of Al_2O_3 is more than that of ZnO and $CaCO_3$, Al_2O_3 incorporated composites showed more degradation.

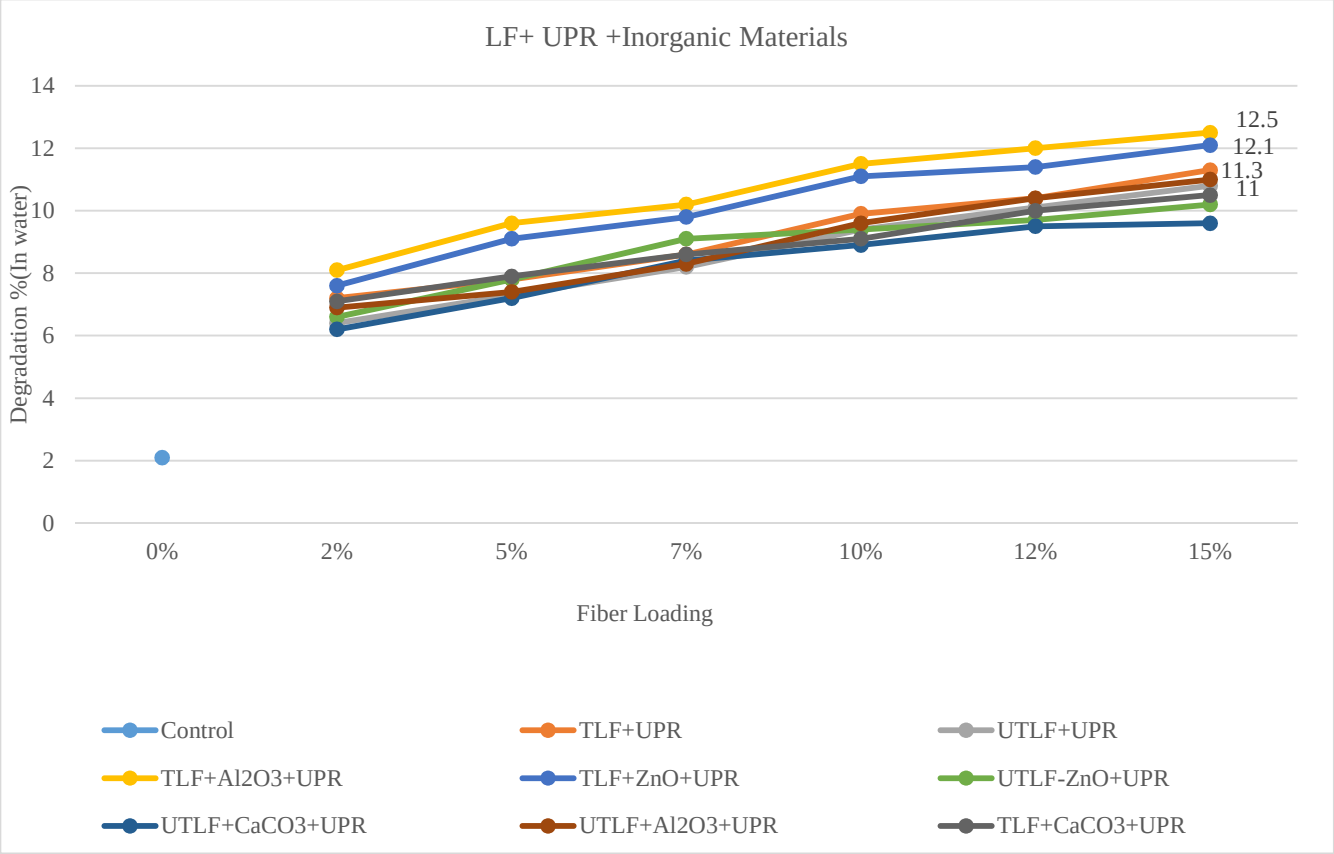


Fig 4.58: Weight loss rate for degradation of leather fiber reinforced UPR composites in water.

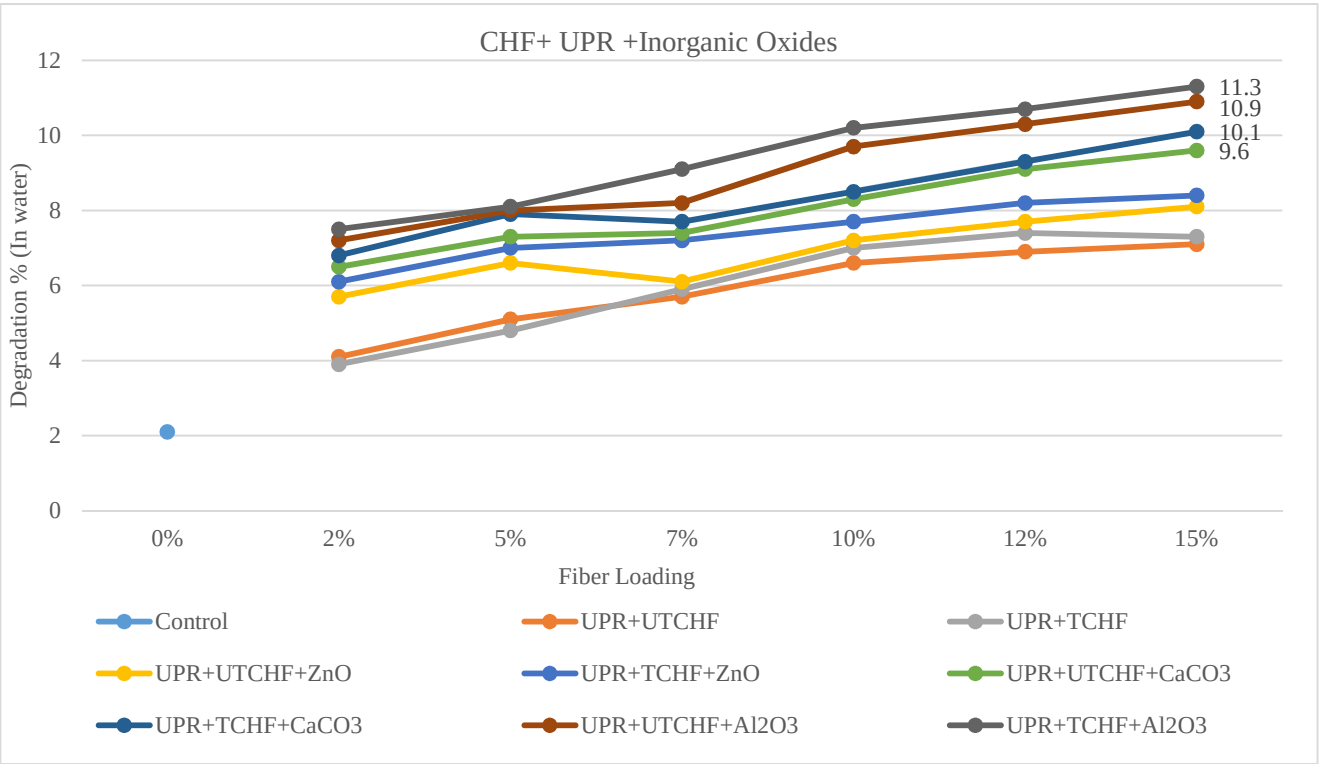


Fig 4.59: Weight loss rate for degradation of cow hair fiber reinforced UPR composites in water.

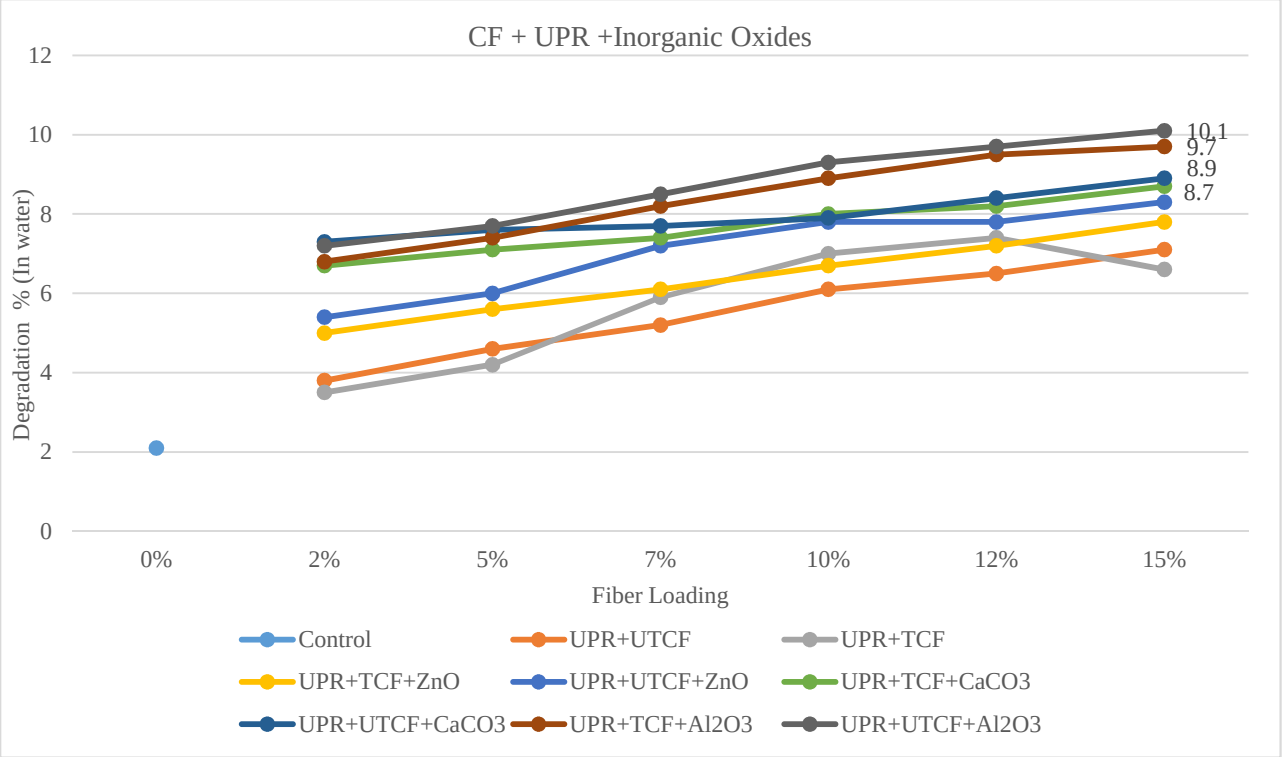


Fig 4.60: Weight loss rate for degradation of chicken feather fiber reinforced UPR composites in water.

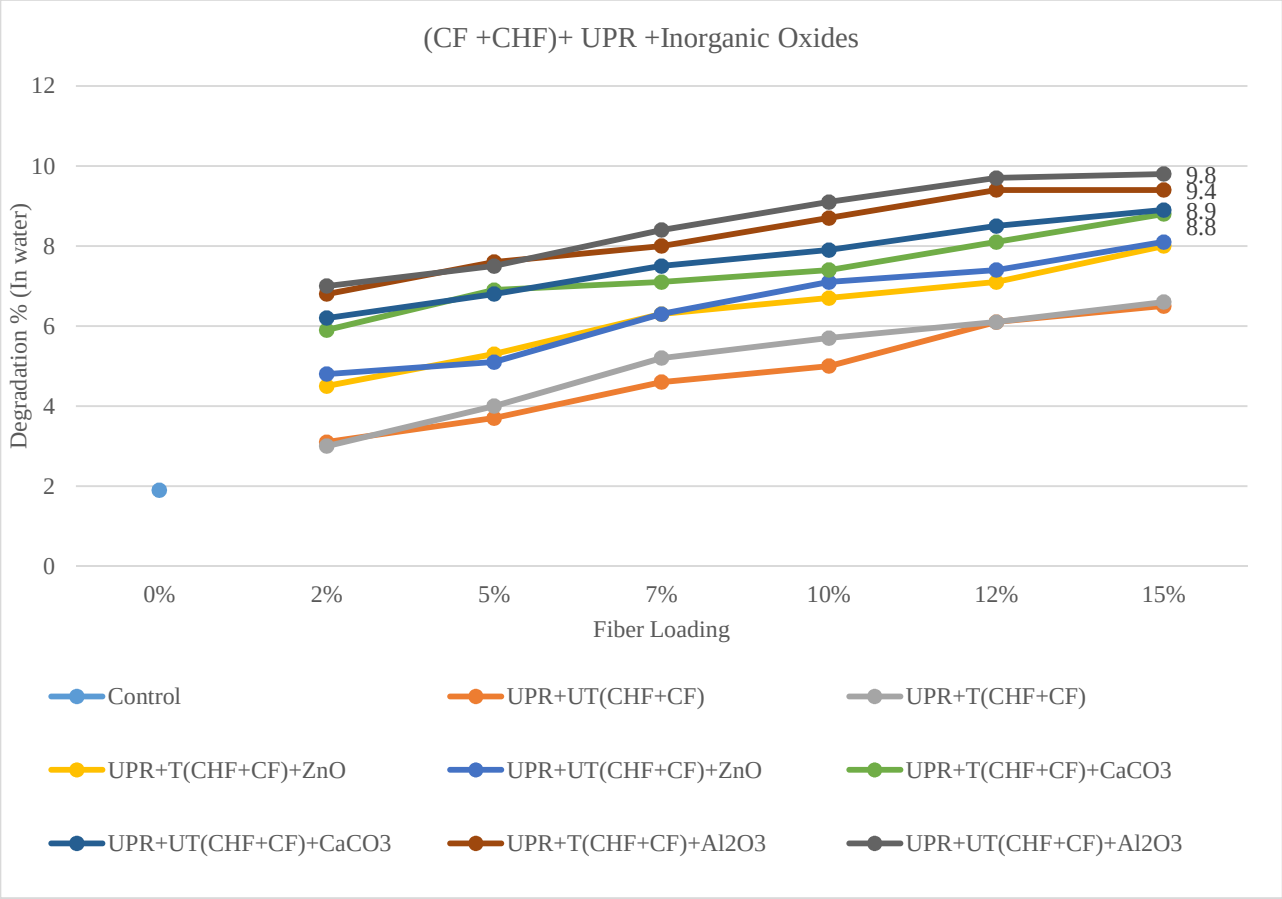


Fig 4.61: Weight loss rate for degradation of (chicken feather+cow hair) fiber reinforced UPR composites in water.

4.9.3 Degradation of the Composites in Brine

It is well understood that brine is a very specialized and intricate natural habitat in which microbes, salt, sunshine, water fluctuation, and other factors all play a role in natural deterioration. The low temperature and alkalinity of brine may have an effect on the activity of psychrotrophic bacteria, which can adapt to changing environments. Despite the fact that the reduced biodegradation rate in brine has been reported in numerous studies, the underlying causes of this result are unknown. In the first stage, UV radiation from the sun may hasten the transformation of materials from big objects to minute pieces. Low temperature and distinct microbial populations continue to be the most important factors of the breakdown rate of polyester resin, resulting in the reverse effect and considerably reduced hydrolysis rates as compared to soil and compost. In contrast to freshwater settings, low temperature and high salinity in the brine environment lead to unique microbial communities, lower total populations of microorganisms, and fewer specific microbial species required for the breakdown of the majority biodegradable chemicals. The sample degraded most (15.7%) untreated LF+UPR+Al_2O_3 composite because of poor adhesion in matrix interface. The presence of a large number of microorganisms capable of degrading the fiber/polyester composites can explain the particularly quick breakdown of animal fiber reinforced UPR composites in brine through surface erosion. The degradation rate of the polymer composites increases as the number of microorganisms increases. The (CFF+CHF)/UPR composites showed least degradation rate due to strong adhesion in fiber-matrix. Significant biodegradation, it is assumed, happened only when microorganisms colonized the polymer composites, a parameter that was reliant on the resident microbial populations. As a result, it is reasonable to assume that lengthy degradation delays would occur in open brine where microorganisms are few.

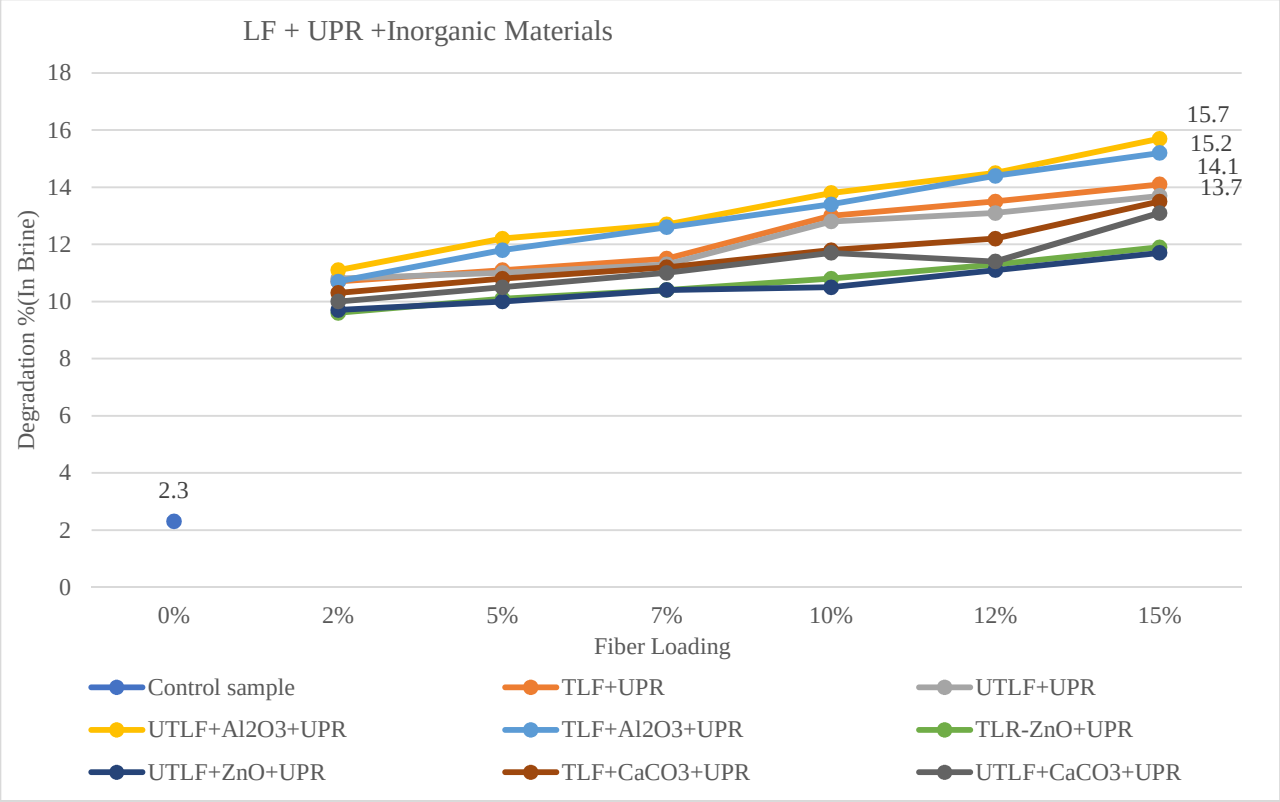


Fig 4.62: Weight loss rate for degradation of leather fiber reinforced UPR composites in Brine.

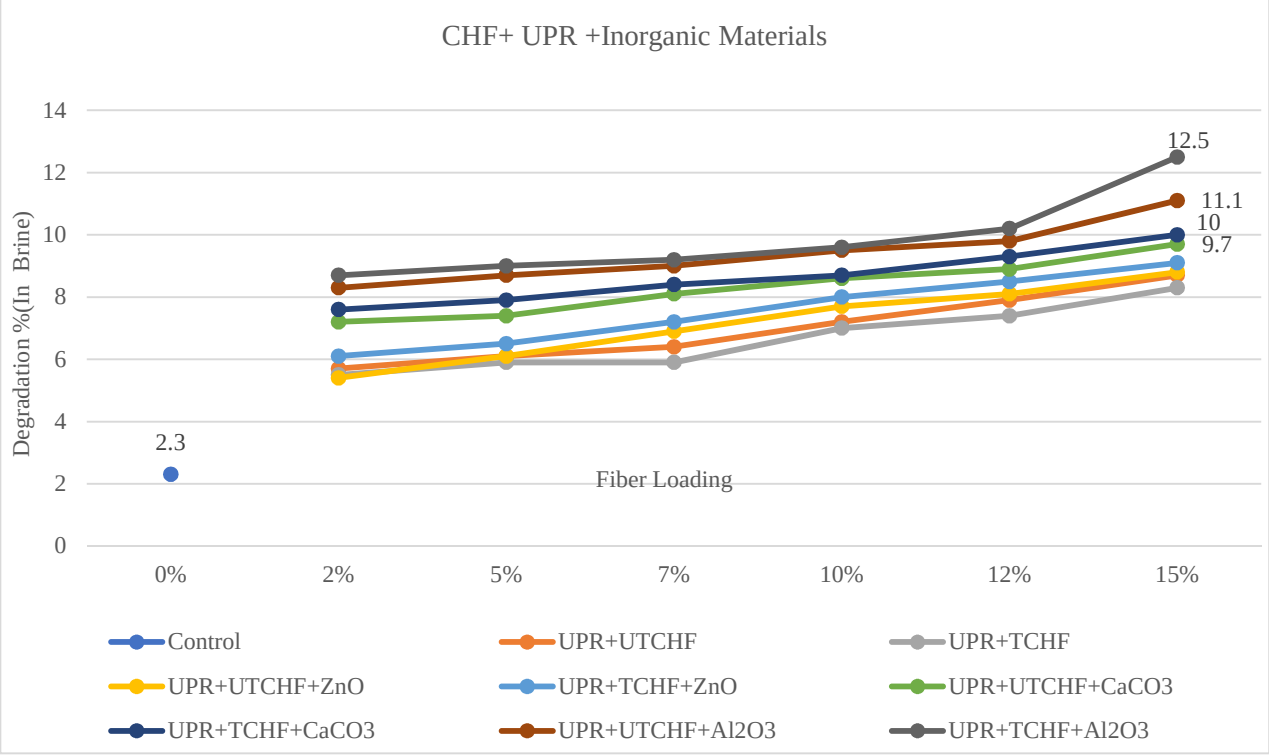


Fig 4.63: Weight loss rate for degradation of cow hair fiber reinforced UPR composites in Brine.

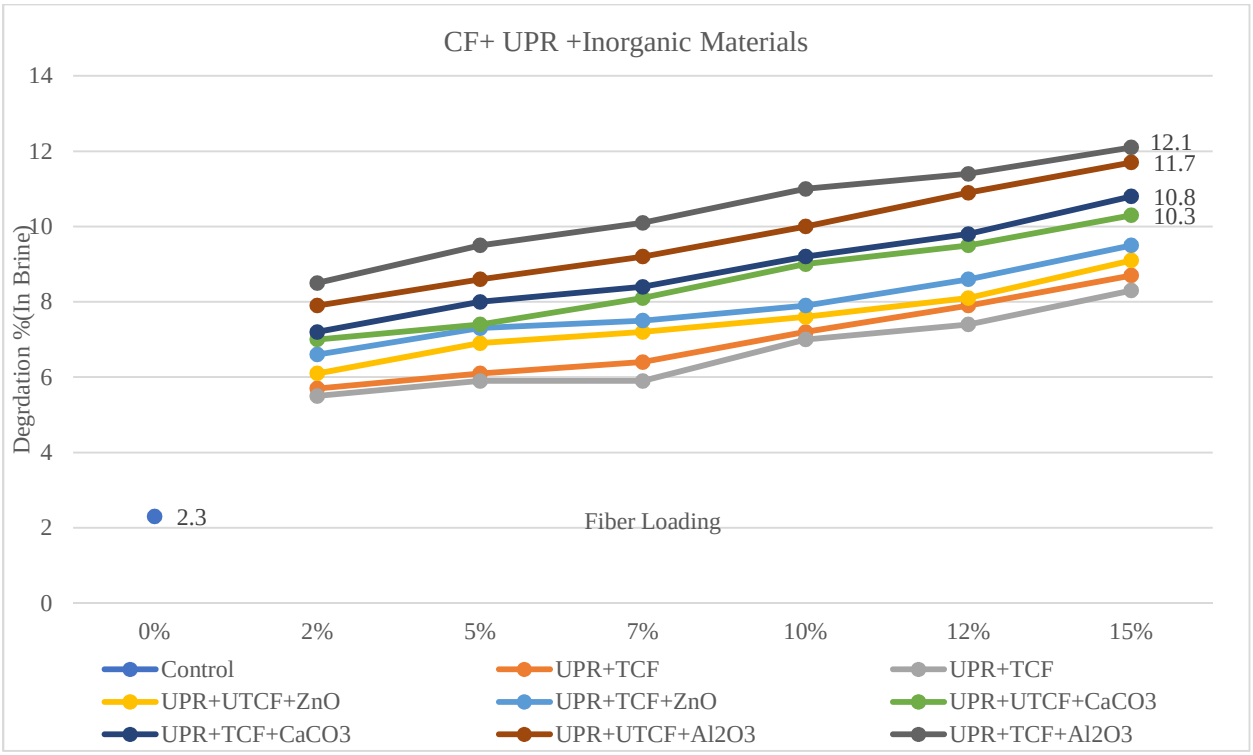


Fig 4.64: Weight loss rate for degradation of chicken feather fiber reinforced UPR composites in Brine.

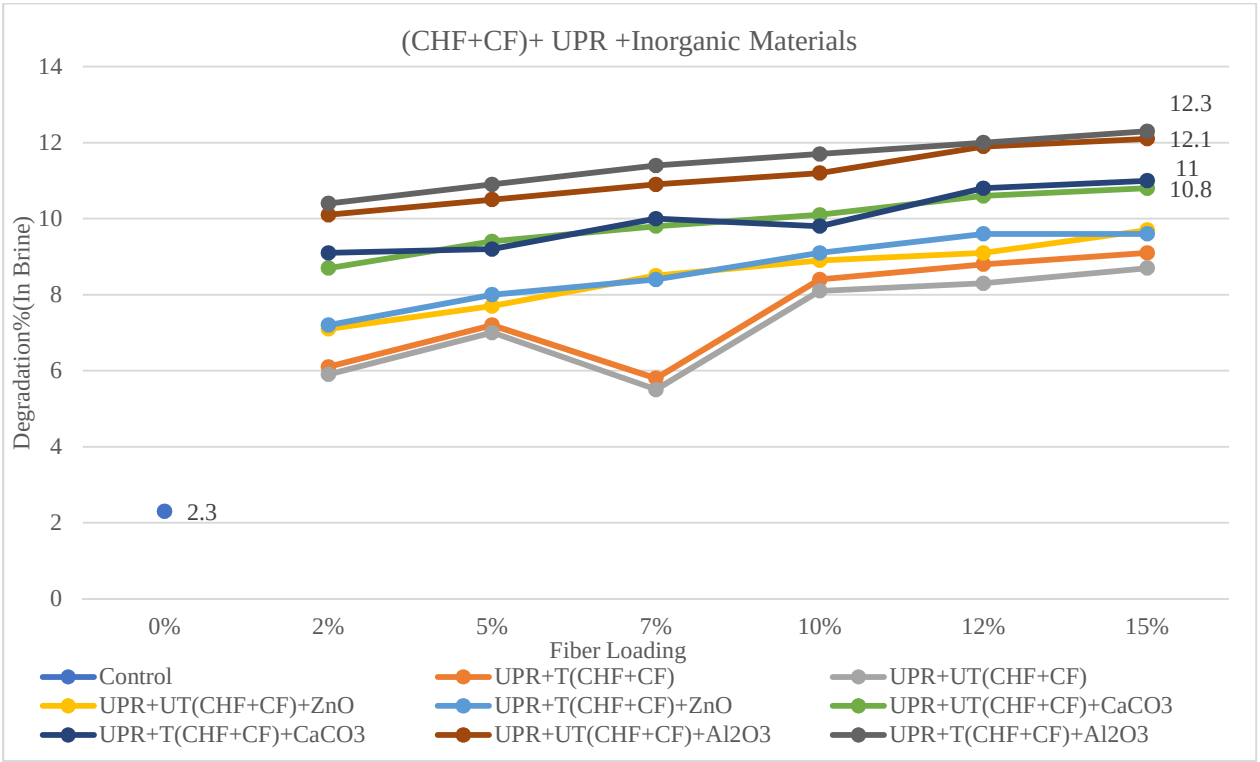


Fig 4.65: Weight loss rate for degradation of chicken feather fiber reinforced UPR composites in Brine.

4.9.4 Degradation of the Composites in soil burial

Figure (4.66 – 4.69) depicts the results of soil degradation tests conducted at intervals of 30, 60, and 90 days in terms of the loss of weight % of the composites. The proportion of weight loss increases progressively as the fiber loading increases. The natural fiber utilized in the composite contains chemical components such as keratin, collagen, and other organic compounds that react with soil microorganisms, resulting in a weight percentage loss of the composite [234]. The hydrolysis of the polymer backbone may induce the degradability of unsaturated polyester resin. The soil contains moisture, which destroys the polyester chain, resulting in smaller composite particles, which microorganisms may exploit as an energy source as they reduce [235]. Hydrophilic, loosely bonded thin films deteriorate quicker than compact thin films. In the lab, researchers looked at how ZnO/ Al_2O_3/ $CaCO_3$ affected how quickly polymer composites degraded. The composites revealed modest aesthetic changes after 30 days in the soil. The LF reinforced UPR composite exhibited 16.1% degradation after 90 days in the soil. Both photo degradation and soil microorganism activity can result in soil biodegradation. Hydrolysis is the primary method by which biodegradable polymers are broken down, however depending on the structure of the polymer, some enzymatic degradation may also occur. The degradation rates of the CHF/UPR, CFF/UPR, and (CFF+CHF)/UPR composites were lower in the soil after 90 days of burial than those of the LF/UPR composite. Hydrophilic, loosely bonded thin films deteriorate quicker than compact thin films. Incorporating inorganic components such as ZnO and $CaCO_3$ into the matrix slowed soil degradation, however Al_2O_3 as a filler loaded composite demonstrated faster degradation due to its higher hydrophilic capacity. SEM findings showed that the (CFF+CHF)/UPR composite was compact, less hydrophilic, and water resistant.

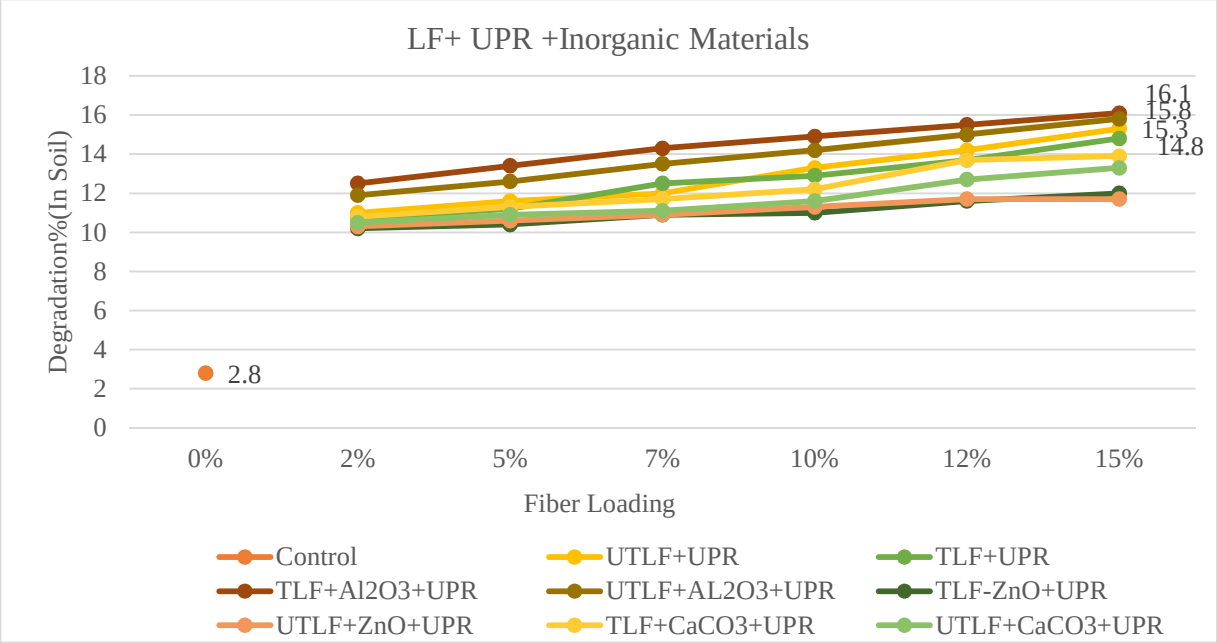


Fig 4.66: Weight loss rate for degradation of leather fiber reinforced UPR composites in soil burial.

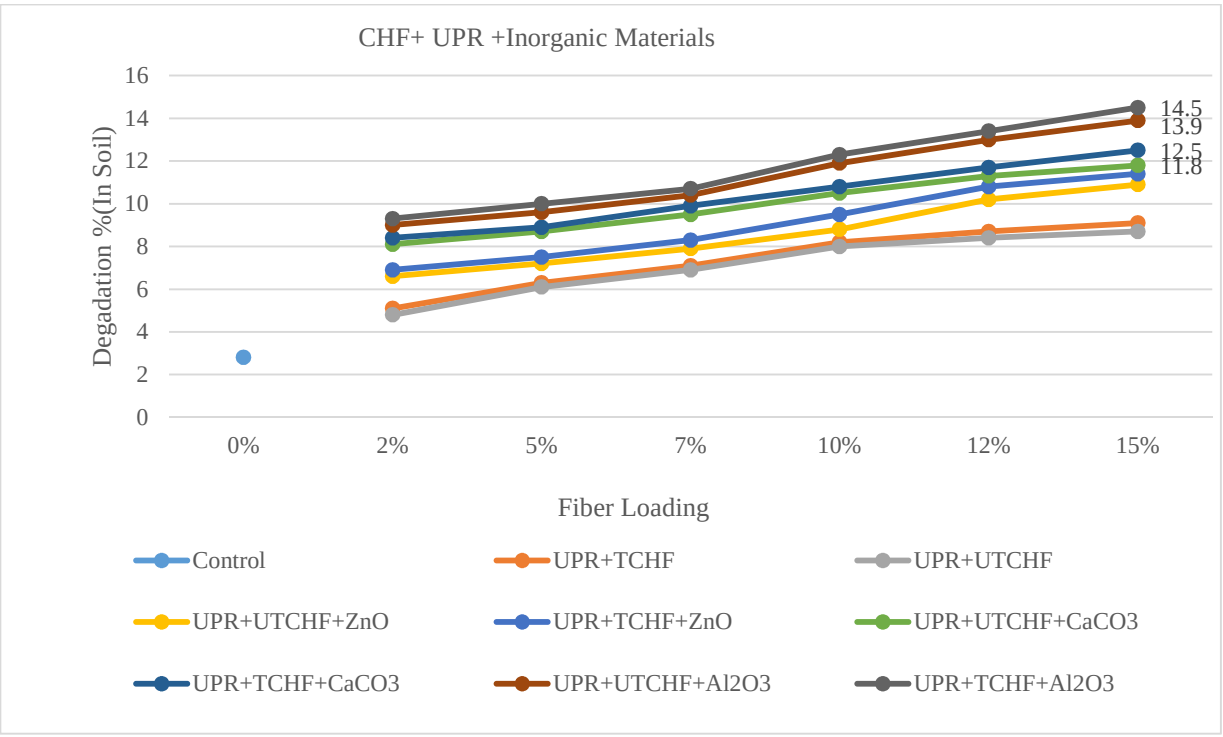


Fig 4.67: Weight loss rate for degradation of cow hair fiber reinforced UPR composites in soil burial.

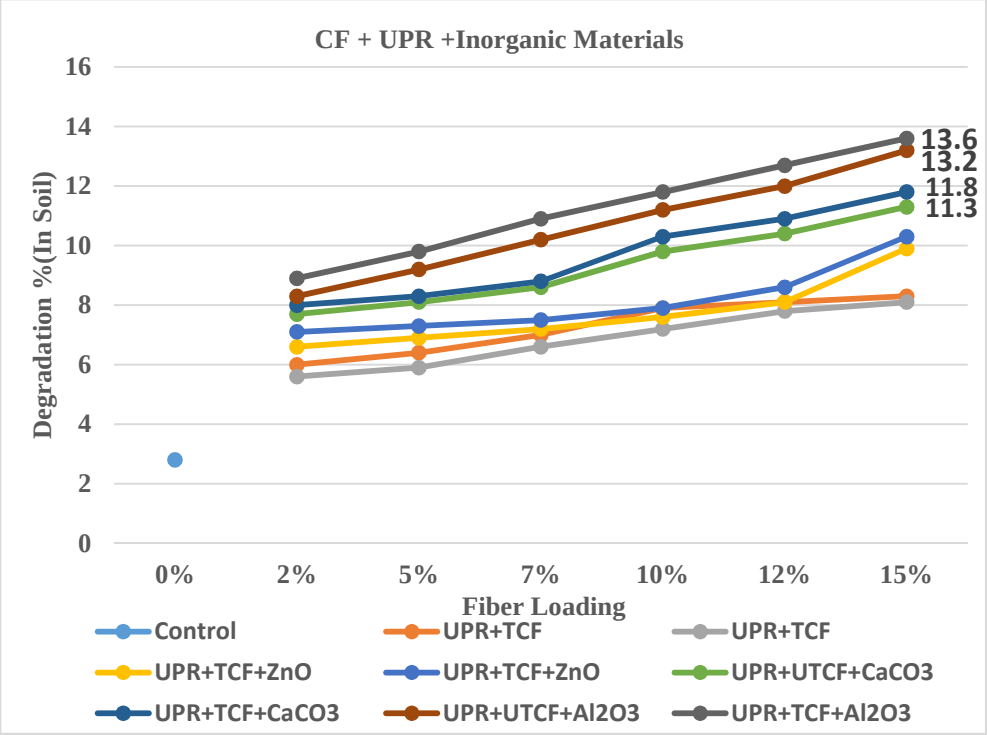


Fig 4.68: Weight loss rate for degradation of chicken feather fiber reinforced UPR composites in soil burial.

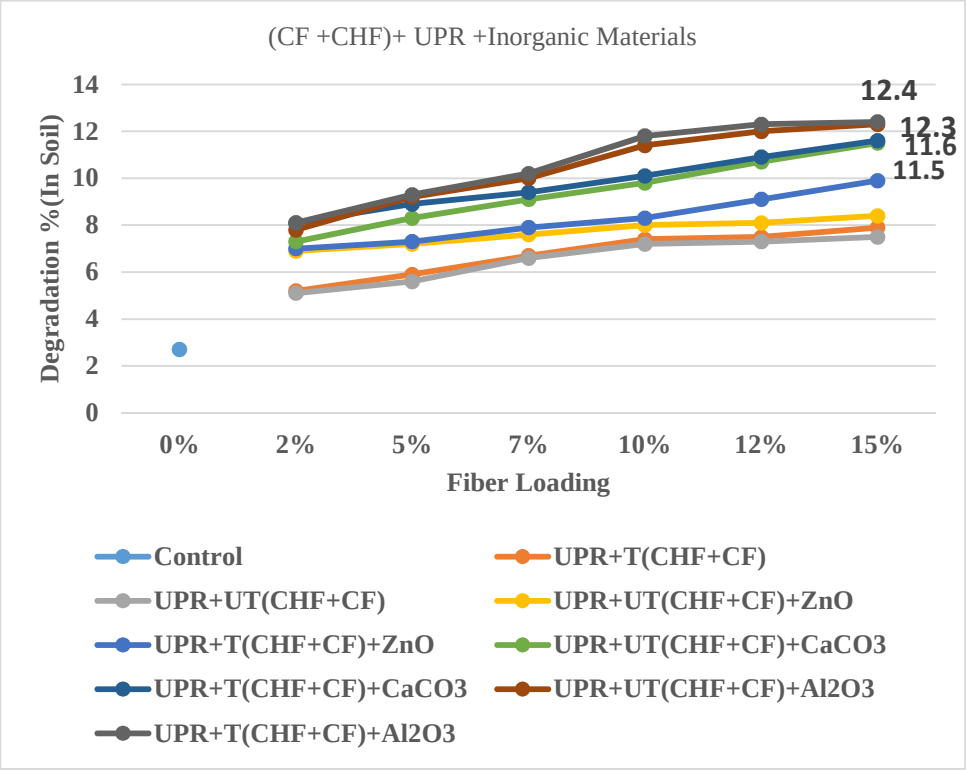


Fig 4.69: Weight loss rate for degradation of (chicken feather+cow hair) fiber reinforced UPR composites in soil burial.

4.9.5 Degradation of the Composites in compost

Samples were placed in a container filled with a compost and soil combination. The temperature of these containers was kept standard. Every day, it received water sprinkles. Samples were removed, cleaned with water, and dried after every 30 days. By evaluating weight loss, the samples' deterioration was examined. The compost is known to have a large population of micro and macroorganisms, with bacteria, actinomycetes, and fungus being the most prevalent [236]. In the composting environment, psychrotrophic acidophilic microorganisms (fungi) might play a major role in the decomposition of composites due to the compost's relatively low temperature (below 20–25ºC) and somewhat acid pH (~6).

Figure 4.70 - 4.73 shows the weight losses of the composites in the compost culture. The treated leather based composites with Al_2O_3 showed the best performance in the compost culture, with a weight loss up to 17.8% after a 90-day degradation. When Al_2O_3 was incorporated in the composites, the degradation performance of the composite was improved than ZnO or $CaCO_3$ incorporated composites. By diffusing from the matrix to the compost, the additional ZnO slowed the rate of compost breakdown, indicating microbial activity in the soil. In the end, the active microbes in compost were decreased, which slows down the rate of compost degradation compared to composites that incorporate Al_2O_3. In a microbiological environment, all composite samples deteriorated. Active compost has microorganisms that use the smaller polymer pieces as a source of energy. The ester and peptide linkages in the polymer backbone of the animal fiber reinforced-UPR composite are hydrolyzed and cleaved, which causes the composite to degrade more quickly. The biodegradable polymers mostly degrade by hydrolysis, however depending on the polymer structure, they may also go through at least some enzymatic breakdown. The higher fiber loaded Composites showed higher rate of degradation.

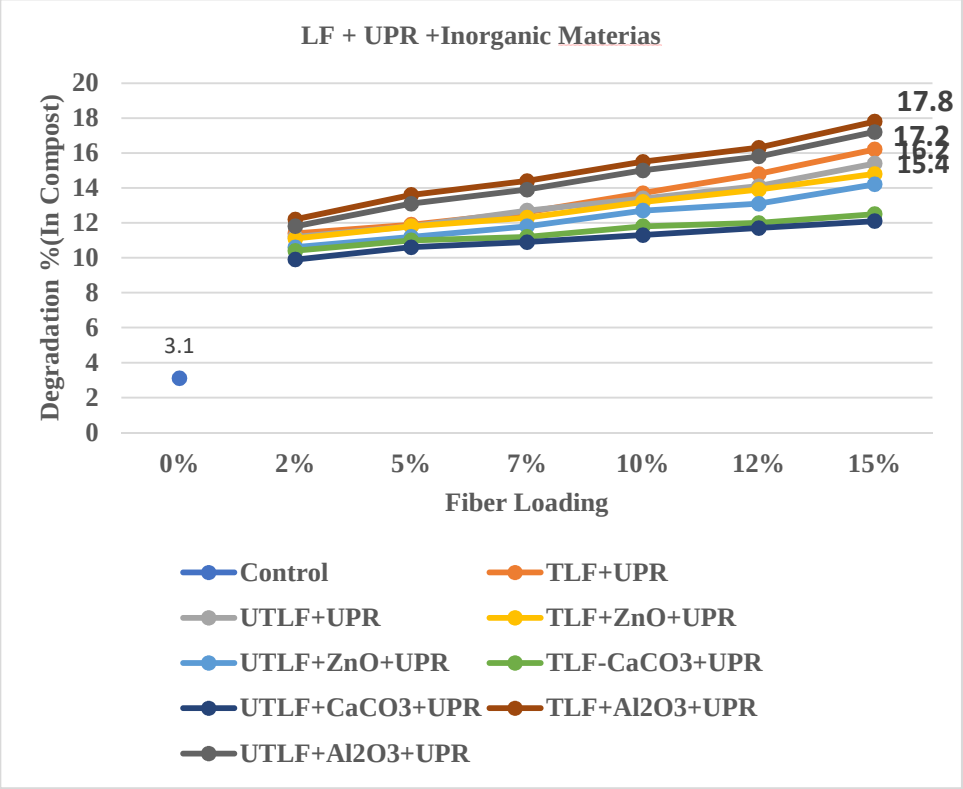


Fig 4.70: Weight loss rate for degradation of leather fiber reinforced UPR composites in compost.

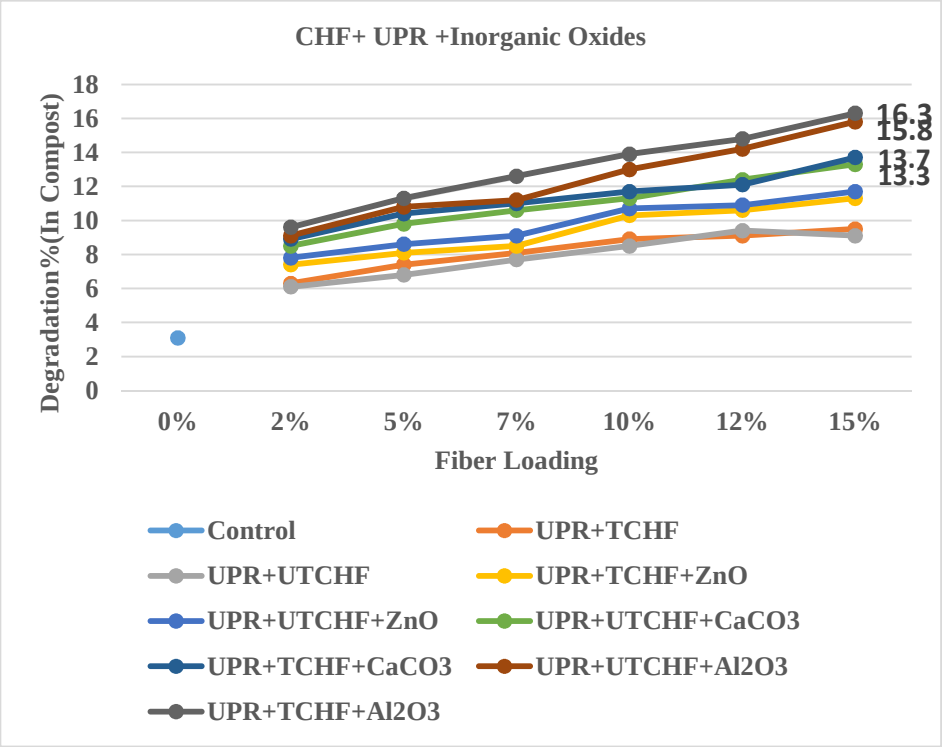


Fig 4.71: Weight loss rate for degradation of cow hair fiber reinforced UPR composites in compost.

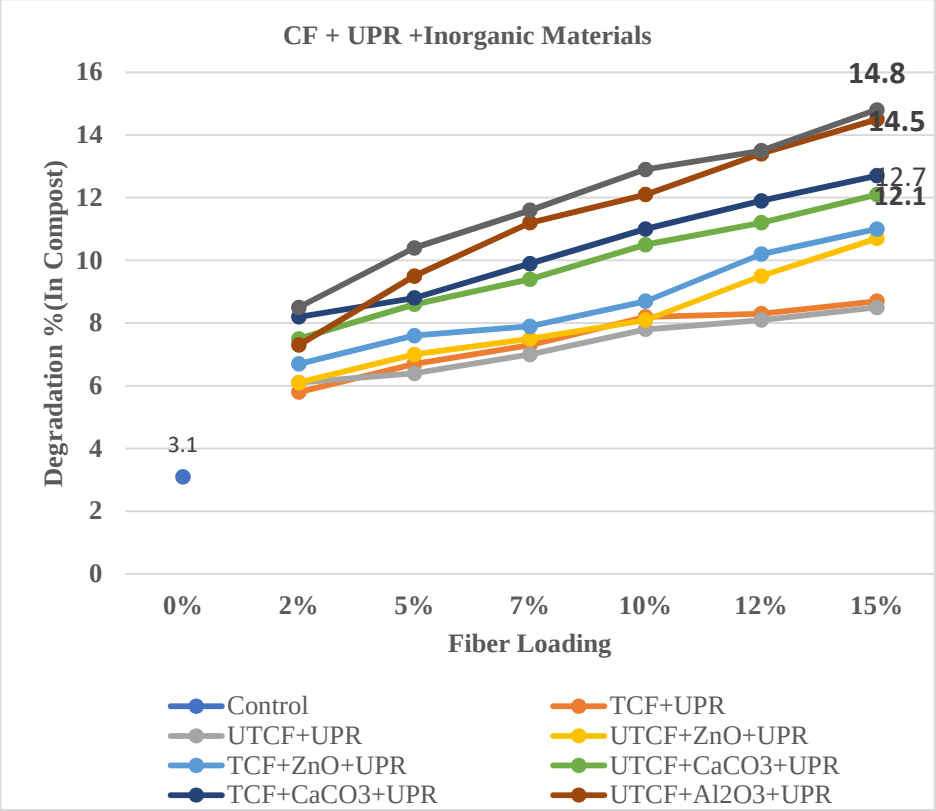


Fig 4.72: Weight loss rate for degradation of chicken feather fiber reinforced UPR composites in compost.

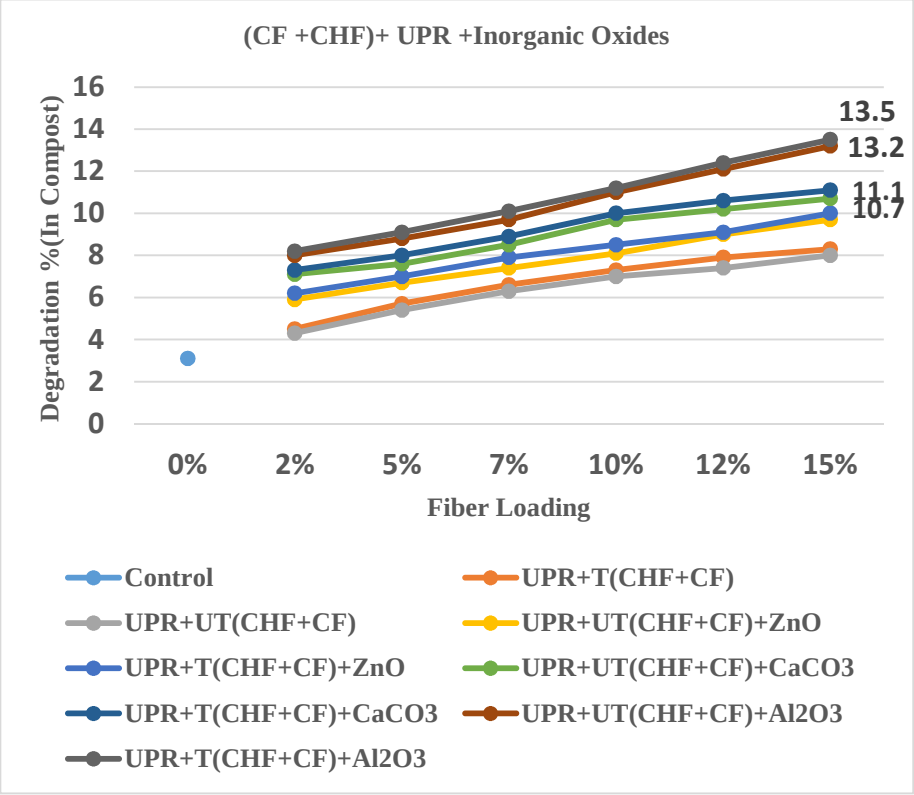


Fig 4.73: Weight loss rate for degradation of (chicken feather+cow hair) fiber reinforced UPR composites in compost.

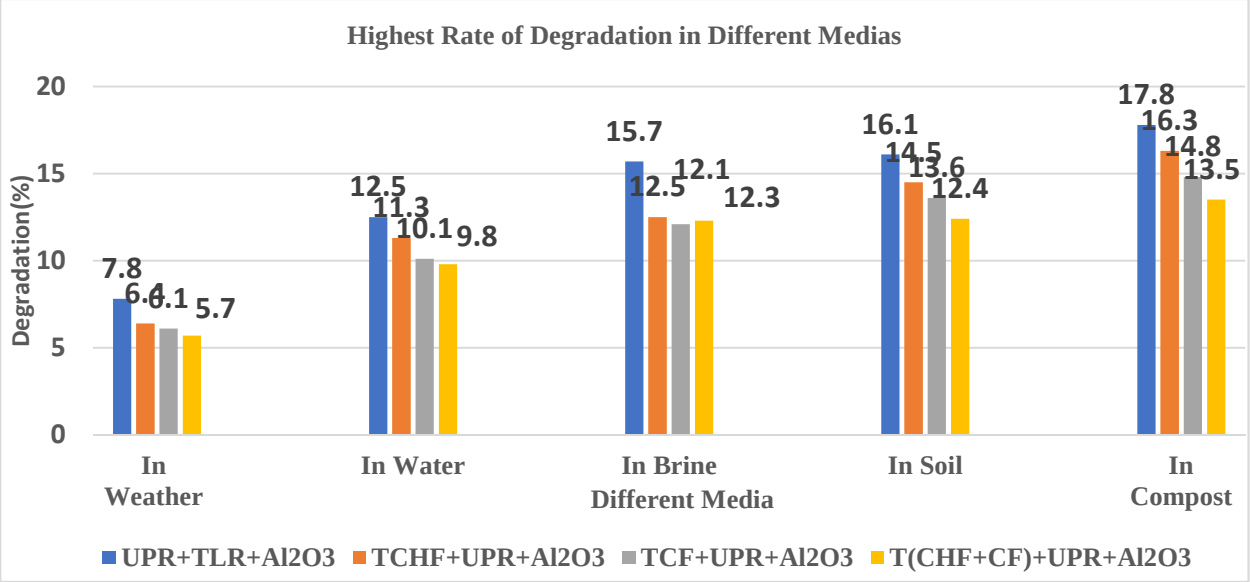


Fig 4.74: Comparing the highest rate of degradation in different medias of the composites

4.10 Abrasion Test analysis

Three circular specimens of diameter 16 ± 0.2 mm and thickness 6 ± 0.2 mm were cut from each of the composites. A piece the standard composite sample was placed in the test specimen holder on the carriage so that 2 ± 0.2 mm is protruding from the opening. The carriage was moved to its starting position at one end of cylinder and it was started the cylinder rotating. The piece of specimen was brought into contact with the abradant, simultaneously applying a force of 10 ± 0.2 N and started the carriage moving at a speed of 4.20 ± 0.2 mm for every revolution of cylinder in a direction parallel to the axis of the cylinder. After 84 complete revolutions of the cylinder, the specimen was lifted away from the abradant and removed the specimen from the test holder.

The difference between before and after abrasion was used to calculate abrasion resistance.

Weight Loss = wt. of the sample before abrasion – wt. of the sample after abrasion

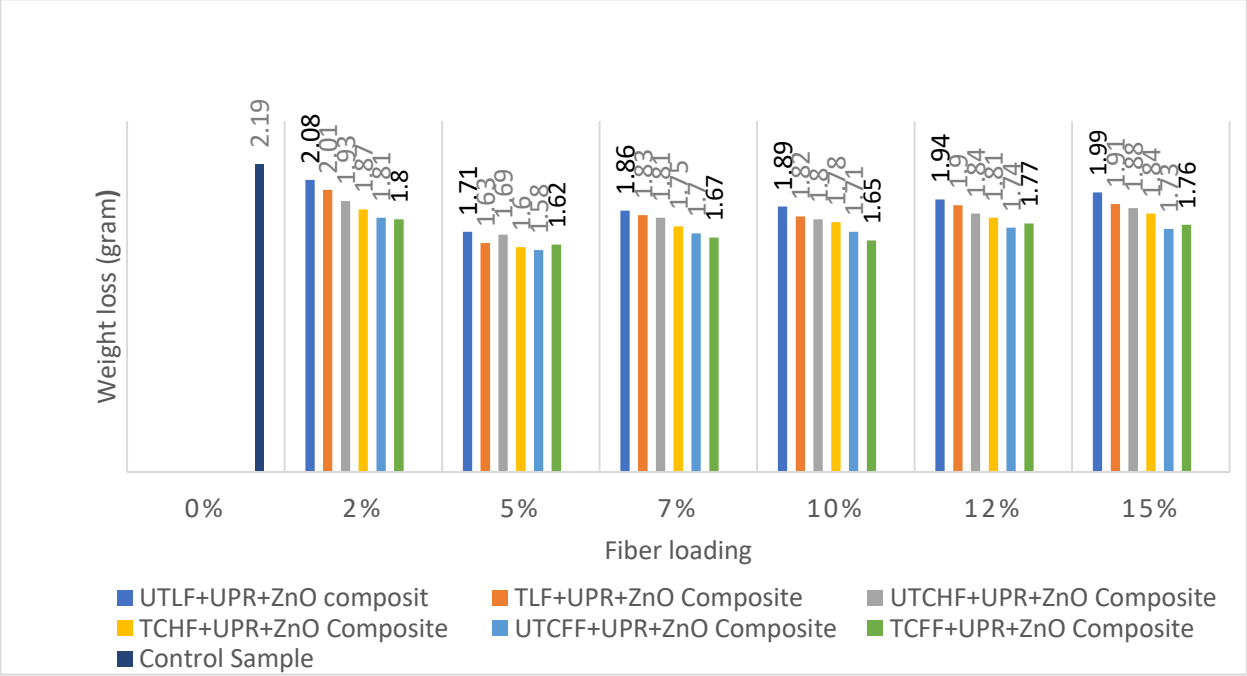


Fig 4.75: weight loss (in gram) of the composites after abrasion.

The abrasion resistance of treated and untreated chicken feather, cow hair and leather fiber composites added by ZnO, Al_2O_3 and $CaCO_3$ is shown in Fig.4.75. It was observed that 5% fiber loaded composites incorporated ZnO significantly improved the wear resistance of the animal fiber/UPR composites where chicken feather fiber added composite showed the highest resistance. From Fig.4.75, it was found that the composites with additional 2 wt% and 15 wt% fiber loaded composites revealed lower specific wear resistance than the other composites. As shown, due to the effective reinforcing and self-lubricating effects, CFF/UPR composites showed lower the friction and improved the wear resistance of UPR polymer.

4.11 Effect of gamma radiation on tensile properties of the composite

The animal fibers/UPR-based composite's TS values increased after exposure to gamma radiation. The no-sucrose-based composites' TS values were raised until a certain dose was achieved, after which they were lowered. The greatest tensile strength value of each utilized 5% fiber based composite was disclosed by the application of Gamma radiation doses to the treated and untreated fiber loaded composites. The best result was obtained for the 5.0 kGy gamma dose and the improvement was 9.57%, 4%, 5.11% and 3.16% for UTLF+UPR+ZnO, UTCHF+UPR+ZnO, UTCFF+UPR+ZnO and UT(CHF+CFF)+UPR+ZnO composite respectively. Although the TS for the alkaline treated animal fiber/UPR-based composite fell by a minor amount after a 7.50 kGy dosage, no significant results were identified when the material was exposed to gamma radiation. The chain scission of alkaline-treated animal fiber/UPR-based composites may be to blame. Gamma radiation's impact on the hide. Cow hair and chicken feather fiber/UPR-based composite is shown in Figure 4.76.

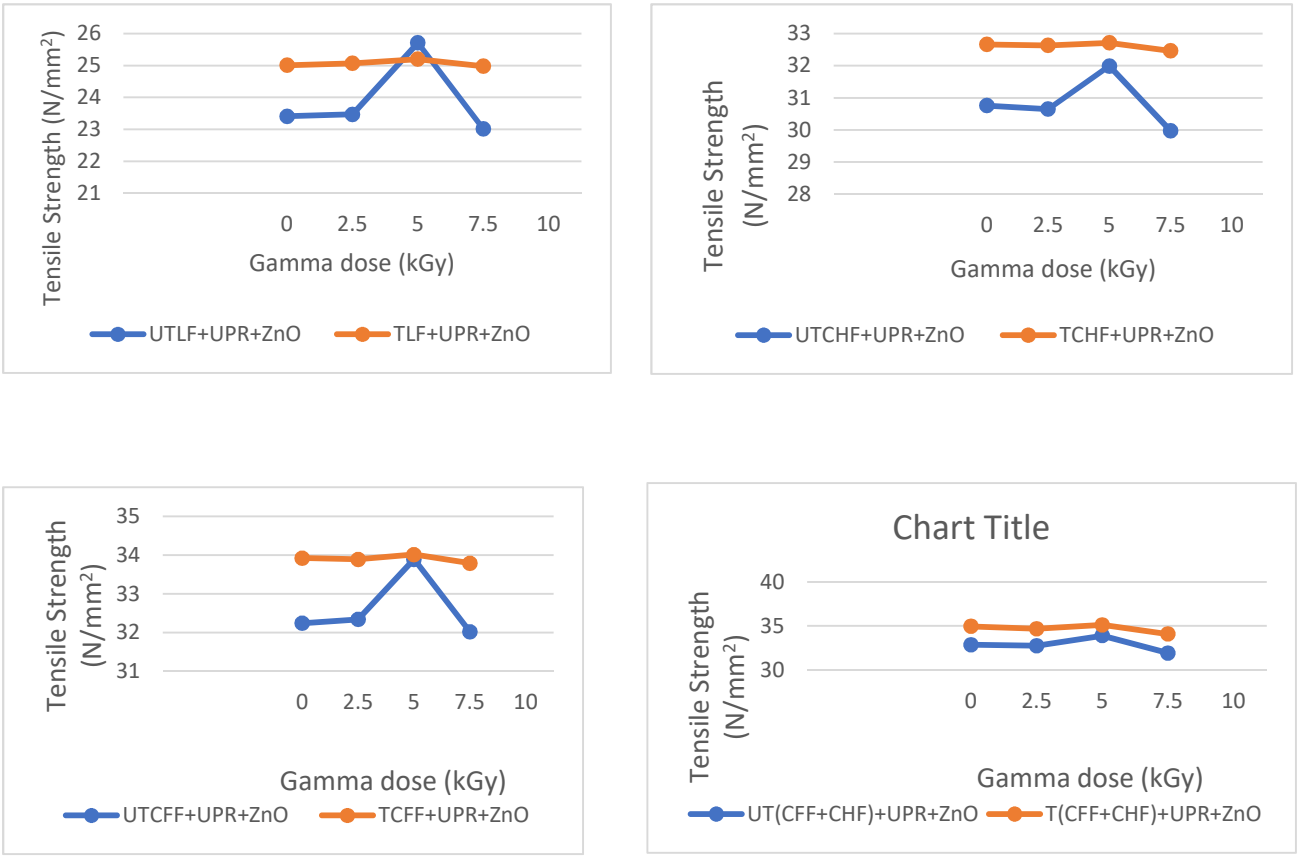


Fig 4.76: Effect of gamma radiation on tensile strength of different animal fibers/UPR-based composites.

Until a particular dosage of gamma radiation was applied to the composite made from untreated animal fiber/UPR, the TM values rose. With a gamma dosage of 5.0 kGy, patients had the greatest improvement 4.78%, 2.91%, 3.89% and 2.98% for UTLF+UPR+ZnO, UTCHF+UPR+ZnO, UTCFF+UPR+ZnO and UT(CHF+CFF)+UPR+ZnO composite respectively. Under gamma radiation, the TM values of the chemically treated animal fibers/UPR-based composite dropped in a linear way, with the largest decrease being 1.34 percent of the TM at a dose of 7.50 kGy. One reason could be that the 7.5 kGy gamma dose caused the chemically treated fibers/UPR-based combination to break apart in a longer chain. Figure 4.77 shows how gamma rays affect a combination made of fibers and UPR.

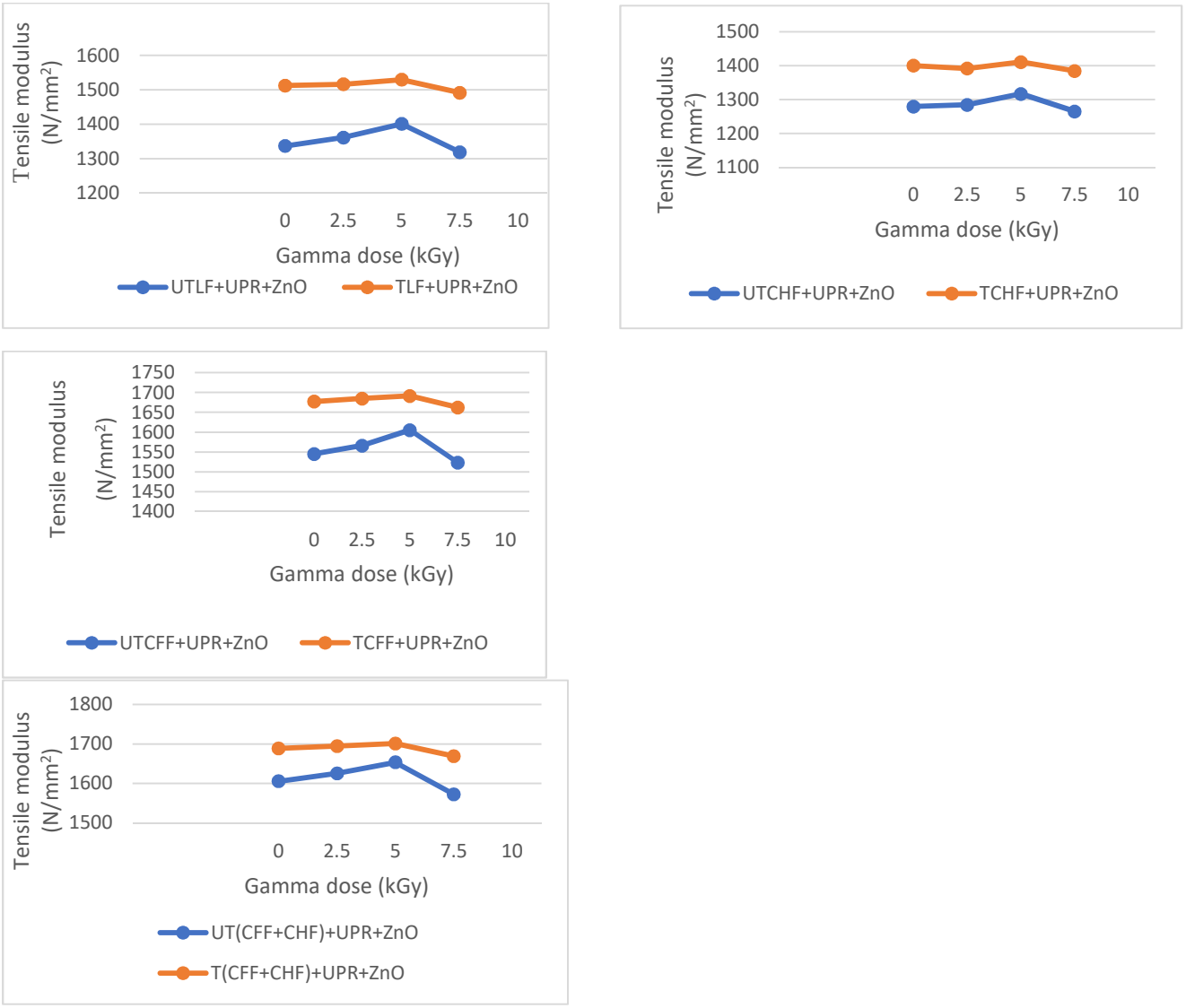


Fig 4.77: Effect of gamma radiation on tensile modulus of different animal fibers/UPR-based composites.

The Eb values decreased after a gamma radiation dosage was administered in the case of the chemically treated animal/UPR-based combination, but they then increased again. The Eb values were initially elevated and subsequently decreased for the materials that weren't chemically treated. The fiber-based material that hadn't been exposed to chemicals responded best to the 5.0 kGy gamma radiation. The improvements were 15.1%, 14.28%, 11.43%, and 9.09% for the respective composites of UTLF+UPR+ZnO, UTCHF+UPR+ZnO, UTCFF+UPR+ZnO, and UT(CHF+CFF)+UPR+ZnO. The largest reduction in the chemically treated fiber/UPR-based composite was found at 18.10% of the Eb for TCFF+UPR+ZnO composite at 7.50 kGy dosage. Figure 4.78 illustrates how gamma radiation affects the Eb of an animal fiber/UPR-based composite.

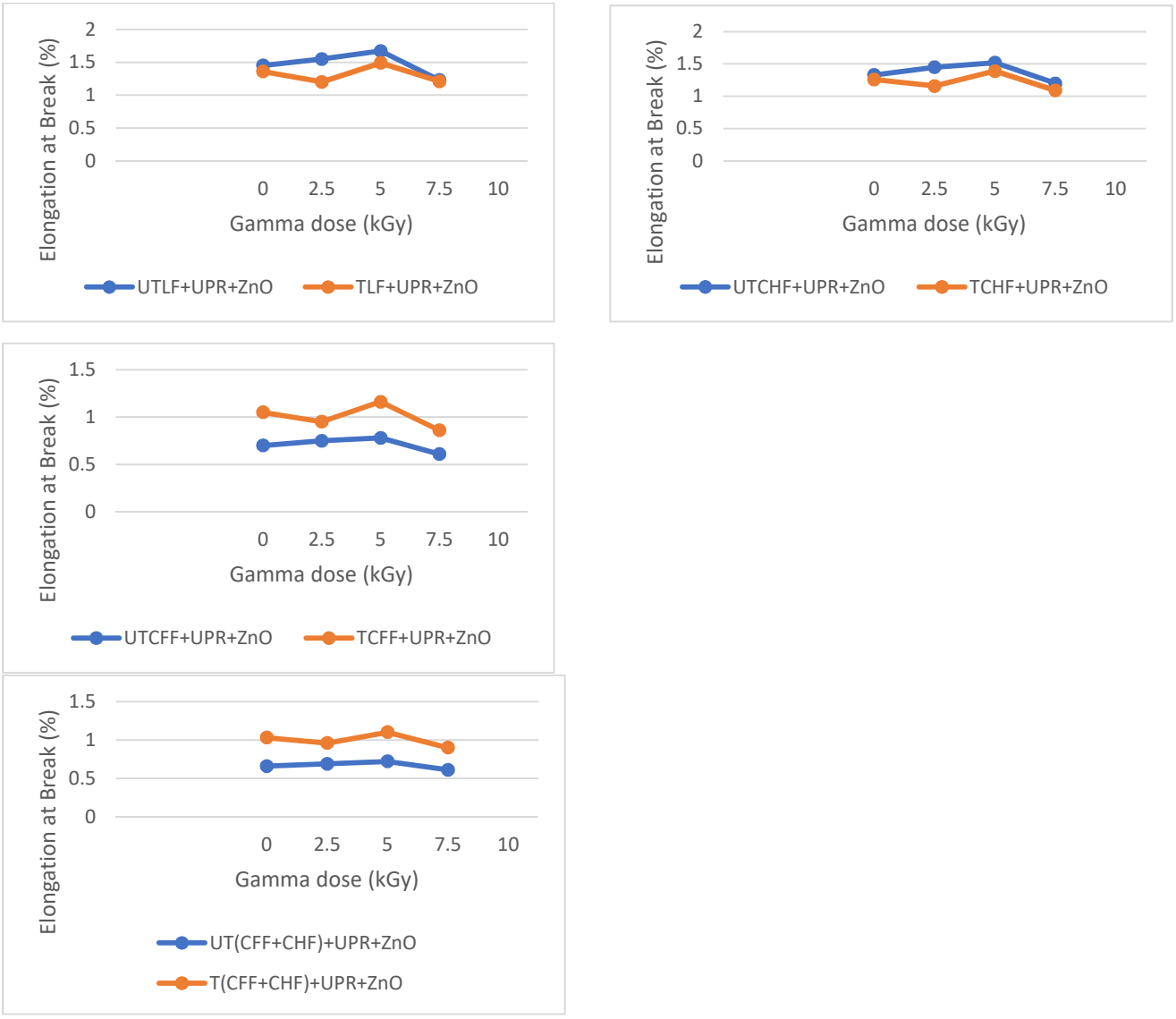


Fig 4.78: Effect of gamma radiation on elongation at break of different animal fibers/UPR-based composites.

It is generally known that gamma radiation may leave energy deposits in solids by the photoelectric effect, Compton scattering, and pair creation. The Compton scattering is believed to be the main mechanism for energy transfer by gamma radiation at intermediate energy doses. In the fiber, free radicals are created by gamma radiation. The characteristics of the fiber and composite materials alter as a result of this newly produced radical. Since gamma radiation is a high-energy radiation, no photo-initiator is required for the mechanism of gamma radiation in animal fiber/UPR based fabrics or composite materials.

Chapter 5

Conclusion and recommendation for future work

Conclusion

Chicken feathers, cow hair, and scraps of leather were the materials of choice for this investigation since they are readily available, biodegradable, and environmentally benign. Composite items made with these fibers were employed to make a significant dent in pollution levels. This research examined the mechanical characteristics of UPR composites including either chicken feathers, cow hair, or waste leather fiber as a reinforcing material. Using treated and untreated CFF, CHF and LF that had undergone UPR and that hadn't, together with the fillers ZnO, Al_2O_3, and $CaCO_3$, composites were produced by hand lay-up method. The structure was investigated internally using the SEM. Thermal properties were measured using thermo gravimetric analysis (TGA). The sample's structure was examined using an FTIR spectrophotometer. Numerous experiments involving water absorption, thickness swelling, and biodegradation were performed on composite materials. The following conclusions are reached in light of the experimental findings:

1) The purpose of this research is to develop composite goods that decrease environmental pollution and may be utilized in a broad variety of contexts by making use of biodegradable, eco-friendly, and

readily available materials including chicken feather fibers (CFF), cow hair fibres (CHF), and waste leather fibers (LF).

2) Due to their easy accessibility, cheap production costs, minimal environmental impact, and light weight, sustainable animal fibers present a promising opportunity for the creation of sustainable bio-composite materials.

3) The enormous environmental threat posed by climate change may be mitigated, in part, by using waste by-products like cow hair, chicken feathers, and buffing dust-trimming dust for sustainable applications.

4) This study offered a natural fiber thermosetting reinforcement option that is high-performing yet less priced. Compared to the other two fibers, chicken feather fiber produced superior results. For composites constructed using mixed fibers of chicken and cow hair with ZnO as the filler, mechanical characteristics such as tensile strength, tensile modulus, bending strength, and bending modulus were optimal. The UTLF+UPR + ZnO composite, on the other hand, excelled in the elongation at break.

5) Composites were made utilizing UPR and fillers ZnO, Al_2O_3, and $CaCO_3$ in a manual lay-up process employing both treated and untreated CFF, CHF, and LF. ZnO was discovered to be the optimal filler for these fibers during the UPR reinforcing stage.

6) When comparing the mechanical parameters of untreated and chemically treated animal fibres reinforced with unsaturated polyester resin composites, the former showed substantial improvement.

7) There is strong evidence from the Fourier transform infrared (FTIR) and scanning electron microscopy (SEM) that the fiber and UPR matrix are mechanically bonded rather than chemically bonded.

8) This research shows that the composites can be successfully applied with only a few degradation values across five distinct media. Even though the deterioration performance was measured for just

90 days, it can be prolonged for more study. The commercial consumption of these waste products, which would otherwise be harmful as environmental pollution agents, is justified by this effort.

9) ZnO with 5% treated (chicken feather fibers+ cow hair fibers) reinforced-UPR composites can be employed in engineering applications where increased mechanical characteristics are sought.

10) Fabricated composites have drawn a lot of interest as potential replacements for synthetic fiber-reinforced polymer composites because of their accessibility, lack of toxicity, and resistance to corrosion.

11) The degradation values in five distinct media, including compost, soil, brine and weather over 90 days, can result in useful applications of the composites.

This work successfully illustrates the recycling and proper disposal of a once-useless material, such as chicken feathers, cow hair, or leather fibers.

Recommendation for future work

Although the findings of the current study are noteworthy, the following recommendations are made for more research:

1. The current research should be expanded upon employing fiber from various animals from various sources.

2. To increase the ideal state of modification for fiber and composite, the existing modification system has to be improved.

3. For the composite to exhibit the best mechanical characteristics, the weathering behavior of the raw and modified animal fiber should be assessed.

4. For a clean and healthy environment, it is advised to use waste animal fiber-reinforced composite rather than synthetic UPR alone, according to this research. Synthetic polymers are sold in quantities of nine billion metric tons annually. It will be a significant step toward a sustainable environment if waste chicken feather, waste cow hair, and waste leather fiber can help to cut down on the usage of synthetic polymers just a little bit.

5. Nanofiber might be employed as a reinforcing ingredient in composites at a lower proportion.

6. Complete animal fiber utilization systems could be set up with the help of many stakeholders, reducing solid waste and environmental issues, benefiting people on a social and economic level, and relieving pressure on other non-renewable resources and fossil fuels that could be saved for future needs.

7. It's important to inform the public about the advantages of using animal fibers as well as secure collection and utilization methods.

8. Based on the environmental effect, business needs, and market reach of different applications of animal fibers, laws and regulations can be passed as well as support structures developed.

9. Even though the degradation performance was only assessed for 90 days, it can be prolonged for additional study.

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