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Production, Structural and Morphological Characterization of Feather-Reinforced Epoxy Composites

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ABSTRACT

The use of bird feathers as filler for epoxy offers an environmentally friendly method for developing composites and coatings. In this study, feather-filled epoxy composite coatings have been developed for use in new generation coatings and production. The structural properties of the produced composites were investigated using XRD, F-TIR and surface morphologies using Scanning Electron Microscopy (SEM). With the help of these analyses, the surface properties of the composites such as wettability and morphology were determined. This green approach to the development of an epoxy/feather coating allows for to replacement of metal parts used in many modern industries or to improve the performance and safety of existing parts.

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1. INTRODUCTION

The limitation of the use of pure materials, which emerged as a result of today's technology, has led to alternative searches. As a reflection of this, composite materials with improved properties have been developed and their usage areas have increased. Composite materials are a group of materials that largely constitute the industry's needs. For this reason, to increase the function or effectiveness of composite materials, studies are constantly being carried out to increase their performance with different reinforcement and filler material additions[1].

As a result of the developing technology and visionary perspective, as a result of factors such as improvement of conditions, and high-performance expectations from cheap materials, different searches have occurred in the preferences of reinforcement materials during the production of composites in the industry. Thus, natural raw materials and wastes have been preferred as reinforcement materials. Composite preferences produced with natural raw material reinforcement have emerged based on criteria such as environmental sensitivity, sustainability, and reducing dependence on petroleum and derivative products. Composite production with waste reinforcement is a preferred way to raise awareness by evaluating materials that adversely affect the environment or that are thought to have a negative impact, offering an alternative solution to waste storage problems, and obtaining cheaper reinforcement materials[2].

They are the materials that are formed as a result of combining at least two materials at a macro level, in other words, without dissolving in each other. The purpose of creating composite material; is to enable the development and combination of features that are not available when the components are used alone. [3]

Composites can be classified under different groups by considering criteria such as materials, production methods, areas of use, advantages, and disadvantages. In general, a classification is made according to the type of reinforcement or matrix in its structure. Composites are divided into three main groups according to the matrix type. These; are polymer matrix, metal matrix, and ceramic matrix composites[4].

Polymer materials are materials that have low electrical and heat conductivity properties compared to metals. In addition, polymers have a very low operating temperature range compared to metals and exhibit more plastic properties when placed under a load. In addition, most polymers are resistant to chemicals, but like other materials, polymers cannot resist fatigue. Polymer materials can be colored permanently during production and can be obtained in desired shapes using determined patterns. Thus, they can visually imitate the desired materials and, with these features, they eliminate additional surface and finishing processes. Thanks to their low densities, more economical designs can be obtained by choosing polymers. Due to their high oxidation resistance, repair requirements are lower than metals. In addition, mass production has the advantage of reducing costs in terms of cost per part, and surface treatments such as coating, paint, and joining processes[5].

Polymer materials are the most widely used and widely used materials among composites. The reason for this can be explained as it is easy to produce and raw materials are generally cheap[6].

The reinforcement materials used are; examples such as carbon fibers, kevlar fiber, boron fiber, and glass fiber. The most used methods in the production of polymer matrix composites are; hand spinning, wire wrapping, pouch molding process, pultrusion method, liquid flow technique, reinforced reaction, injection molding, extrusion, and thermo formation methods[7].

The main usage areas of polymer matrix composites are; automotive due to their light weight, marine applications, and sports equipment due to their corrosion resistance, and automotive parts where non-flammability is required can be given as examples[8].

Epoxy resin (ER) is one of the most important thermoset polymers widely used in high-performance composite materials due to its excellent mechanical and chemical properties such as high tensile and compressive strength, good chemical resistance and high heat distortion temperature[9].

Epoxy resins are polyester resins and contain more than one epoxy group that can be converted into a thermoset form. They are formed by epichlorohydrin followed by dehydro halogenation reactions of compounds containing active hydrogen. The reason why epoxy resin, which is the most widely used among thermosets, is preferred; It has excellent chemical and mechanical properties, low shrinkage, and good adhesion with most fibers.

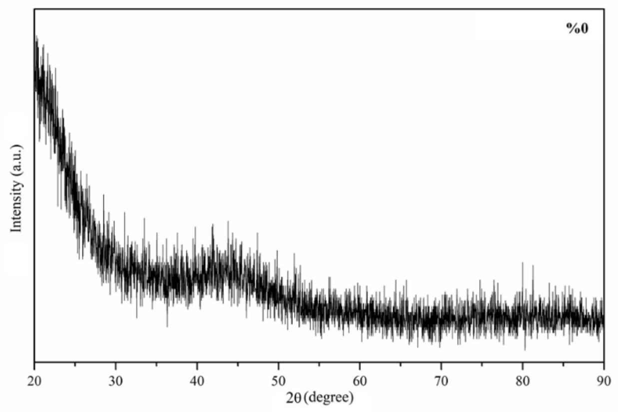
In this study, bird feathers in different mass ratios were ground in different sizes, added to the matrix material epoxy, and the structural and morphological characterization of the produced composites was made[10].

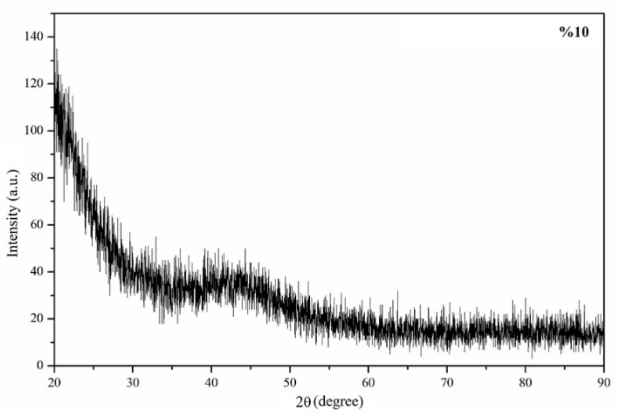
2. MATERIAL AND METHOD

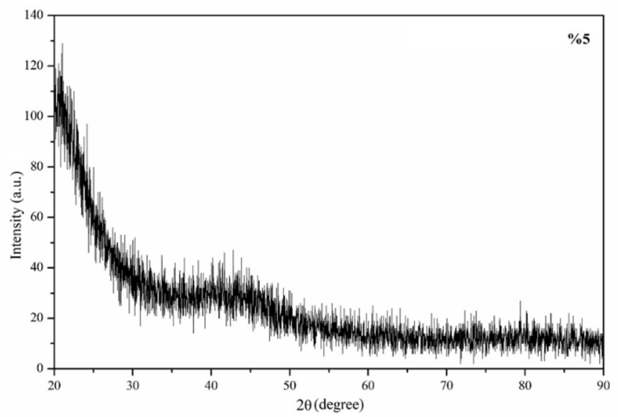
Bird feathers to be used as reinforcement material in the production of composite materials were obtained from various places. The obtained products were first subjected to the cleaning process. The cleaned materials were then ground and passed through a 500 µm sieve, and the under-sieve products were used, and the above-sieve products were ground again and the same process was repeated. “Armor chemical AC520” brand and model epoxy with 16 °C curing temperature, 100 °C burning temperature, casting type ultra-transparent properties was used in the production of composite materials. In the study, the grinding process of bird feathers was carried out in the "IKA" M20 brand and model grinding device. The Ika M20 universal grinder allows grinding of hard and brittle samples up to a maximum volume of 250 mL at 20,000 rpm. In the experimental study, the weighings were made with a "G&G JJ224BC" brand and model precision balance with a capacity of 220 g and an accuracy of 0.0001 g. The crystalline phase of the products was recognized using a BRUKER ADVANCE D8 X-ray diffractometer with Cu Kα radiation (λ = 1.5406 Å) in the 2θ range from 20 to 90° with 0.02 °/min. at room temperature[11]. The morphology of composites were investigated with the a High-Resolution Scanning electron microscope (JEOL JSM-7001F). Nicolet IS5 mark Fourier transform infrared spectrometer with an ID5 ATR sample holder in the wavenumber range from 400 to 4000 cm-1.

3. RESULTS AND DISCUSSIONS

The crystallinity of down fractions plays an important role in their physical, chemical, optical, and thermal properties. Bird feathers, similar to other animal fibers, have a kind of macromolecular polymer structure between their crystalline and amorphous regions[12]. As can be seen from the crystal diffraction peak, all the plume fractions show a medium diffraction peak and a distinct peak around 2θ = 22°. Also, a diffraction peak trough was observed at 2θ = 14 between the two aforementioned characteristic diffraction peaks, allocated to the amorphous region of plumage structures[13]. The peak density in the diffractograms is indicative of the crystal structure content. The three feather fractions showed a sharp peak at this location originating from the keratin membrane in the feathers. According to the above analysis, down fractions have two types of crystal structures: i.e. a-helix and bsheet[14]. It is well known that keratin is semi-crystalline and macromolecular in nature; XRD profiles confirmed this. The plumage shows two narrow crests around 2θ = 52° and 77°. Besides being narrow, it is the densest at around 52°. These effects are due to the presence of crystal regions in the sample. This was also observed for the entire plumage fraction, albeit with reduced density[15].







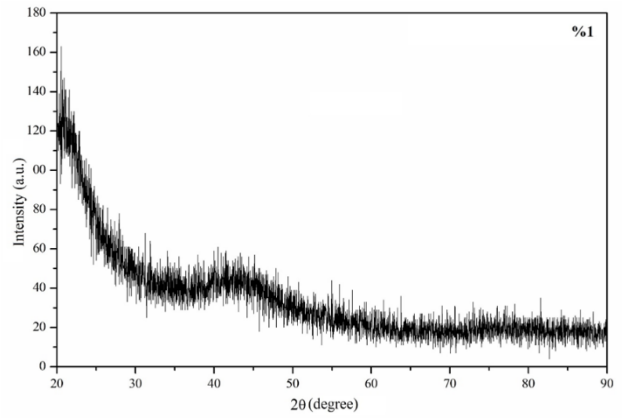


Figure 1. XRD spectrum of Samples

The results of the FTIR analysis applied to pure epoxy and epoxy composites containing feather reinforcement in different mass ratios are shown in Figure 2. C=O bond stretching, N-H bond stretching due to the amide group in the structure, N-H bending due to the protein structure, C-C stretching and C=O bending band are seen in the wave number of the down fibers. The characteristic N-H and OH vibrational movements in the side chains are reflected as broad peaks in the FTIR results[16]. The broad band seen at 700-800 cm-1 represents the covalent S-S bond that connects the two cysteine molecules forming the cystine amino acid in the protein. The peaks in the graph indicate the presence of some bond in the curve at each peak that creates bending or stretching[14]. Different wavelengths have different binding or end groups[17]. It was confirmed from the FTIR results that bird feathers revealed a peak associated with stretching of the NAH amide group. Bands close to 3300 cm-1 were associated with regions characterizing the ordered region of secondary proteins, the α-helix structure[18].

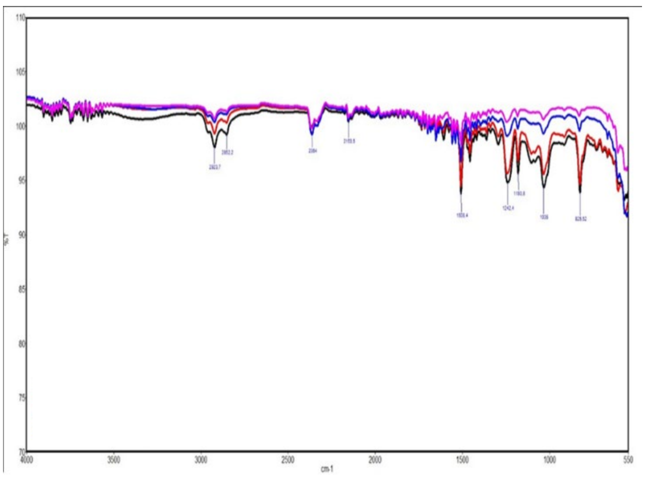
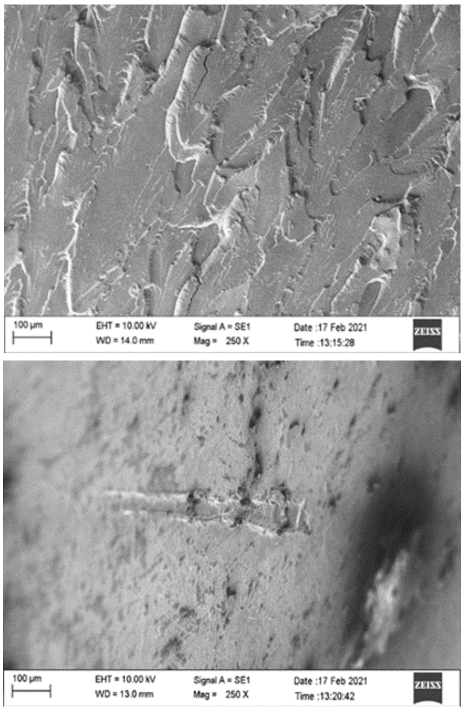


Figure 2 FT-IR spectra of producted epoxy composites

SEM creates a high-resolution image of the scanned surface in micrographic view. Here the results of epoxy resin are compared with 1%, 5%, 10% filler by weight of composites. Figure 3 shows the SEM micrographs of the samples. When SEM micrographs are examined, discontinuities can be easily marked due to the contribution of down. In contrast, samples containing 5% and 10% down show nearly perfect bonding between spine and matrix as shown in the figures[19]. Also, there are no internal and micro cracks on the cracked surface[4]. This is mainly due to the uniform distribution of down particles throughout the area and the absence of clumping or clumping of these particles, indicating the optimum amount of down in the sample[9]. Therefore, increasing the amount of down particles above a certain limit has a detrimental effect on the interfacial bonding ability with the matrix[10]. However, down fiber based on keratin and consisting mostly of hydrophobic groups can be considered as compatible with a more hydrophobic polymeric matrix than cellulose-based jute, which is mostly hydrophilic[3]. To obtain good fiber reinforcement, it is important to have high modulus fibers and good interaction with the polymer[20].



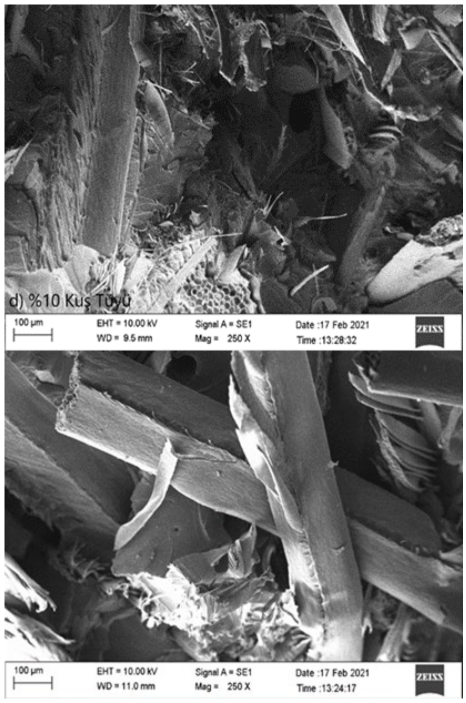


Figure 3. Scanning Electron Microscopy photographs of the composites

4. DISCUSSION

In this study, bird feathers were used to produce natural raw material reinforced composites. First of all, these natural materials were ground to different grain sizes. Then, it was made into composite with epoxy and the structural (physical and chemical) properties of these composites were determined by performing XRD, SEM and FT-IR analyzes.

The measurement results showed that when these composite materials are evaluated as waste and natural raw materials, a material that is less costly and less harmful to natural life will be produced in applications where lower tensile strength is required. It has been observed that the functionalization process increases the surface bonding properties of natural fiber reinforced composite materials. For this reason, it has been seen that natural fiber reinforced composites can be used instead of taking into account the costs of commonly used composite materials according to the desired feature at the place of use. It has been predicted that different results can be obtained by using composite combinations with different ratios of reinforcement material and matrix material and by changing parameters such as mixing homogeneous structure.

The test results also show that natural fiber reinforced composite materials can be preferred to conventional composite materials according to the place of use. Considering that the wastes are increasing and the natural raw materials are in very high amount, research and development studies should be carried out on low cost, environmentally friendly and recyclable composite materials and they should be brought to industrial use.

The authors declare that they have no competing interests.

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