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INVESTIGATION AND ANALYSIS OF NEW FIBER FROM *ALLIUM FISTULOSUM L.* (SCALLION) PLANT'S TASSEL AND ITS SUITABILITY FOR FIBER-REINFORCED COMPOSITES

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Abstract: Eco-friendly materials receive more attention due to the necessity of addressing pollution and resource depletion in the face of exponential industrial expansion. Natural fibers provide a sustainable substitution, especially in green composites. This study investigated the feasibility of *Allium fistulosum L.* (Scallion) as a fiber resource for composite applications by using its tassel. *Allium fistulosum L.* is derived from a widely available plant and its waste tassels of the plant provide fiber properties and have the potential to be a reinforcing component in composites. The investigation involves characterizing *Allium fistulosum L.* (AfL) fibers through various analyses. The density of the AfL was determined approximately 1.35 – 1.45 g/ cm^3. The percentages of lignin, hemicellulose, and cellulose were found to be 24.31%, 29.73%, and 38.36%, respectively. FTIR and XRD analysis affirm AfL's cellulose, hemicellulose, and lignin presence. SEM images indicate a rough surface, necessitating modification for better matrix compatibility. TGA shows suitable thermal stability, majorly degrading beyond 267°C. Tensile testing demonstrates a tensile strength of 22.19 ±3.75 MPa and 0.87 ±0.16 GPa modulus, exceeding some natural fibers like aerial banyan tree roots and *Cordia dichotoma*. Results show promising features, indicating the viability of AfL fibers in composites with reduced environmental impact and economic benefits.

Keywords: *Allium fistulosum L.*, Tassel, waste fiber, sustainability, composite

Allium fistulosum L. (Yeşil Soğan) Bitkisinin Püskülünden Elde Edilen Lifin İncelenmesi ve Lif Takviyeli Kompozitler İçin Uygunluğunun Analizi

Öz: Çevre dostu malzemeler, sanayinin giderek büyümesi karşısında kirlilik ve kaynakların tükenmesi konularının ele alınması gerekliliği nedeniyle daha fazla ilgi görmektedir. Doğal lifler, özellikle yeşil kompozitlerde sürdürülebilir bir ikame sağlamaktadır. Bu çalışmada, *Allium fistulosum L.* (Yeşil Soğan) bitkisinin püskülü kullanılarak kompozit uygulamaları için bir lif kaynağı olarak kullanımı araştırılmıştır. *Allium fistulosum L.* (AfL) yaygın olarak bulunan, yenen bir sebzedir. Bu bitkiye ait atık püskülleri lif özelliklerini göstermekte olup kompozitlerde takviye edici bir bileşen olma potansiyeline sahiptir. Bu çalışma, AfL liflerinin çeşitli analizler yoluyla karakterize edilmesini ve kompozitlere olan uygunluk analizini içermektedir. AfL'nin yoğunluğu yaklaşık 1.35 – 1.45 g/ cm^3 olarak belirlenmiştir. Selüloz, hemiselüloz ve lignin yüzdesi sırasıyla %38.36, %29.73 ve %24.31 olarak tespit edilmiştir. FTIR ve XRD analizleri AfL'nin selüloz, hemiselüloz ve lignin varlığını doğrulamaktadır. SEM görüntüleri, daha iyi matris uyumluluğu

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için modifikasyon gerektiren pürüzlü bir yüzeye işaret etmektedir. TGA, 267°C'nin ötesinde büyük ölçüde bozunarak uygun termal kararlılık göstermektedir. Mukavemet testi, 22.19 ±3.75 MPa'lık çekme mukavemeti ve 0.87 ± 0.16 GPa'lık bir elastisite modül göstermekte olup, aerial banyan tree roots ve Cordia dichotoma gibi bazı doğal liflerden mukavemetli olduğunu göstermiştir. Sonuçlar, AfL liflerinin kompozitlerde kullanımının çevresel etkiyi azaltabileceği ve ekonomik faydalar ile uygulanabilirliğini gösteren umut verici özellikler göstermektedir.

Anahtar Kelimeler: Yeşil soğan, püskül, atık lif, sürdürülebilirlik, kompozit

1. INTRODUCTION

Our day is one of fast industrial and technical development, although this development frequently results in the depletion of natural resources and contamination of the environment. In response, researchers have turned their attention to environmentally friendly materials and technology (Eryilmaz et al., 2023). The promotion of sustainability and environmentally friendly production has seen the rise of natural fibers and their composites (Yildiz et al., 2023). Natural fibers like hemp, flax, and jute are combined with polymer matrices like biodegradable plastics to create green composites, which are recyclable and environmentally friendly (Eryilmaz et al., 2021). These materials contribute to waste reduction and the preservation of natural resources, in contrast to typical composites (Eryilmaz et al. 2020). Natural fibers, which are extracted from nature, do not have a negative impact on the environment, but conventional fibers are frequently made from petrochemicals, which pose dangers. Natural fibers have the potential to create sustainable industries because of these qualities. Several companies are already incorporating natural fibers into their composite products, seeking to take the lead in this ecologically responsible path.

In this study, fibers produced from the tassel of *Allium fistulosum L.* (AfL) were assessed for possible use in composite materials. Repurposing natural waste in an environmentally and commercially sustainable way is possible by utilizing AfL fibers as a green resource. AfL fibers have the potential to improve mechanical strength, decrease composite weight, and provide an environmentally friendly substitute for polymer composites. This use promotes the creation of sustainable products by reducing the negative effects of agricultural waste on the environment. *Allium fistulosum L.*, commonly known as scallion, green onion, or Welsh onion, is a member of the Allium genus, including garlic, onions, and chives (Kuo et al.,1990; Wang et al., 2019). *Allium fistulosum L.* is a versatile plant originating from Asia, particularly China. It grows in warm climates and prefers well-draining soil; it is widely grown. Its long, hollow leaves, which grow to a height of 12 to 24 inches, add a subtle onion taste (Kim et al., 2023). Scallions grow quickly, are versatile, and can be cultivated in both warm and chilly areas. They are easily reproduced from seeds by clump division. The tassel of *Allium fistulosum*, or scallion, refers to the flowering head at the top of its stem. Composed of small, clustered florets, the tassel is an ephemeral yet essential part of the plant's reproductive cycle. The tassel of *Allium fistulosum*, or scallion, contains a variety of chemical compounds, including flavonoids, polyphenols, and sulphur compounds that contribute to its characteristic aroma and potential health benefits (Wang et al., 2020). The literature does not contain any research on the characterization of AfL as a usage of fiber reinforcement or its application in the production of fiber-reinforced composites. Because of this, the potential for application in the manufacturing of composites or bio-composite materials was examined in this work through the characterization of fibers derived from the tassel of the *Allium fistulosum L.* (Scallion) plant. Thermogravimetric analysis (TGA), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), and chemical structure analysis (cellulose, hemicellulose, and lignin) were used to analyze the physical and chemical characteristics of

Allium fistulosum L. (Scallion) fiber. Following a discussion of the findings, the suitability of AfL fiber for use in the production of composite or bio-composite materials was evaluated.

2. MATERIALS AND METHOD

2.1. Extraction of AfL fiber

The plants known as *Allium fistulosum L.* are widely accessible in local markets and are native to warm regions such as China, Turkey, India, etc. This plant grows a vegetable with inedible corrugated seeds at the end called tassels. The availability of water and soil fertility affects yield. The tassels of each *Allium fistulosum L.* plant weigh between 10 and 35 grams. As shown in Figure 1(a), fresh tassels are obtained by cutting off the vegetal side, cutting with a knife to the desired length, and soaking in distilled water for effective washing and extraction for a period of two to four days. Each tassel is thoroughly wetted during this procedure, which separates the gum-like compounds from the fibers. Unwanted items are then washed away under running water. Following that, the single fiber is removed by hand peeling. After that, the water content is removed by drying it in the sun for eight to ten hours. The bundle of dried fibers is then gathered, as seen in Figure 1(b), for further investigation.

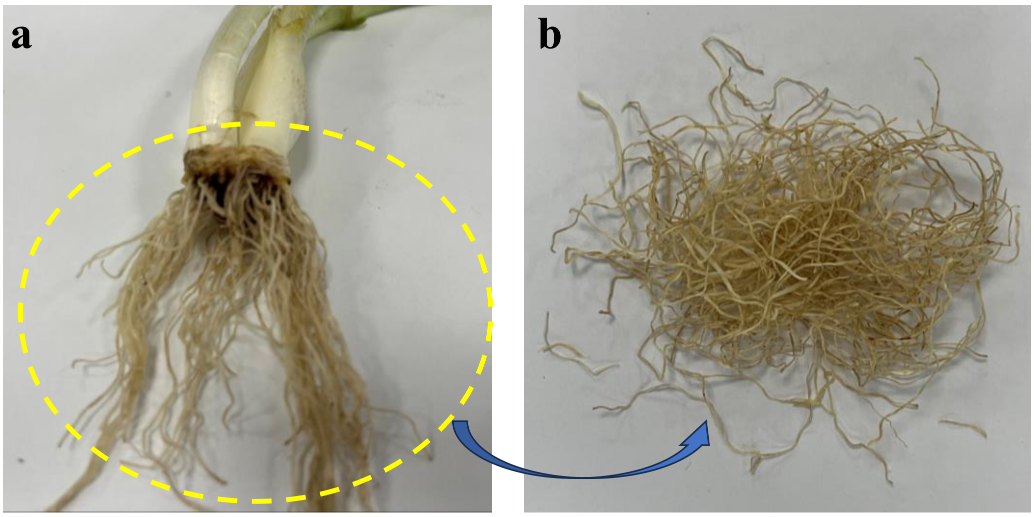

Figure 1.
Fresh Allium fistulosum L. plant and its tassel; ***b.*** *Extracted AfL fiber*

2.2. Determination of AfL fiber's density

The density of AfL fibers was calculated using gas pycnometry and Archimedes Law under ASTM D8171-18 standard. After that, it can be determined using the given equation (1). In this case, the symbols 'd,' 'W_d,' and 'W_s' represent the density of AfL fiber, the weight of the fiber (dry), and the density of the sample in deionized water, respectively.

$$d\ (g/cm^3) = \frac{W_d}{W_d - W_s} \tag{1}$$

2.3. AfL fiber's chemical properties (cellulose, hemicellulose, and lignin)

A weight that was known of AfL fiber soaked in water that had been diluted using a solution made up of a small amount of sulfuric acid and 1.72% sodium hypochlorite. The residue is collected, allowed to dry at room temperature, and weighed after soaking for one hour. Next, the cellulose content as a percentage of the raw fiber is calculated using the following equation (2).

$$\boldsymbol{Cellulose}\ (\%) = \frac{\boldsymbol{W_{residue}}}{\boldsymbol{W_{fiber}}} x100 \tag{2}$$

The AfL fiber samples were hydrolyzed in an ultrasonic bath for one hour at a regulated temperature of 30 °C using 72% percent sulphuric acid. After that, it was combined with methylene chloride and heated to 125 C for one hour in an oven. The following equation (3) was used to determine the percentage of lignin contained in the fiber.

$$\boldsymbol{Lignin}\ (\%) = \frac{\boldsymbol{W_{lignin}}}{\boldsymbol{W_{fiber}}} \boldsymbol{x100} \tag{3}$$

The weight loss technique was used to determine the moisture content of the AfL fiber. For 4 hours, a known weight of fiber was heated to 105 ±5 °C in a hot air oven. After that, the fiber was weighed and removed from the furnace. The fiber's moisture content is determined by the weight differential. Then, the following equation (4) was used to calculate the percentage of moisture content in AfL fiber.

$$\boldsymbol{Moisture}\ (\%) = \frac{\boldsymbol{W_{moisture}} - \boldsymbol{W_{dry}}}{\boldsymbol{W_{moisture}}} \boldsymbol{x100} \tag{4}$$

2.4. Fourier transform infrared spectroscopy (FTIR)

Using FTIR spectroscopy (Perkin Elmer Frontier) with a spectrum of 2 cm^{-1} and throughout a range of 400–4500 cm^{-1} wavenumber, 16 scans/minute were used for each example at the room temperature and 65% humidity to identify the chemical functional substituents attainable in the AfL fiber.

2.5. Crystallinity index (CI) of AfL fiber

Phase identification was performed using X-ray (X-radiation) techniques with a PANalytical XPert Pro MPD system. The X-ray tube produced monochromatic radiation in the 10°–80° range while scanning at a rate of 5°/min. The generator was configured to operate at 30 mA and 40 kV. The formula in Segal equation (5) below was used to compute the Crystallinity Index (CI) of AfL fibers (Segal 1959).

$$CI(\%) = \frac{(I_{200} - I_{am})}{I_{200}} x100 \tag{5}$$

In XRD spectrum, I_{am} denotes the minimum intensity value between the two biggest peaks, which are at a 2θ = 17.82°, and I_{200} represents crystalline peak's intensity, which is linked to the (2 0 0) lattice plane, which is 21.69°.

2.6. Thermal degradation behavior of AfL fiber with TGA

Utilizing a thermal analyzer (Seiko SII TG/DTA 7200) with nitrogen gas and heating the AfL fiber at a rate of 1°C/min from 30°C to 700°C, thermogravimetric analysis was used to evaluate the thermal behavior of the AfL fiber.

2.7. Surface morphology of the AfL fiber with SEM

The ZEISS/EVO LS10 SEM was used to examine the morphology of AfL fiber. The device used a high-energy electron beam to scan the surface. The SEM generates very detailed three-dimensional pictures, which are highly helpful in comprehending the surface morphology of AfL fiber.

2.8. X-ray photoelectron spectroscopy (XPS) analysis of AfL fiber

The chemical properties of AfL surface have been assessed using X-ray photoelectron spectroscopy (Thermo Scientific Nexsa G2) with a monochromatic Al-Kα, 1486.7 eV, X-ray source, and a 250 µm diameter beam. With a precision of 1 eV and a pass energy of 200 eV, the XPS data was obtained between 1361 and 10 eV. Before performing a surface investigation, the surface of the sample was scattered with ionic gas (Ar), and 20 scans were taken from a single location on the surface to collect the data. (Figure 2).

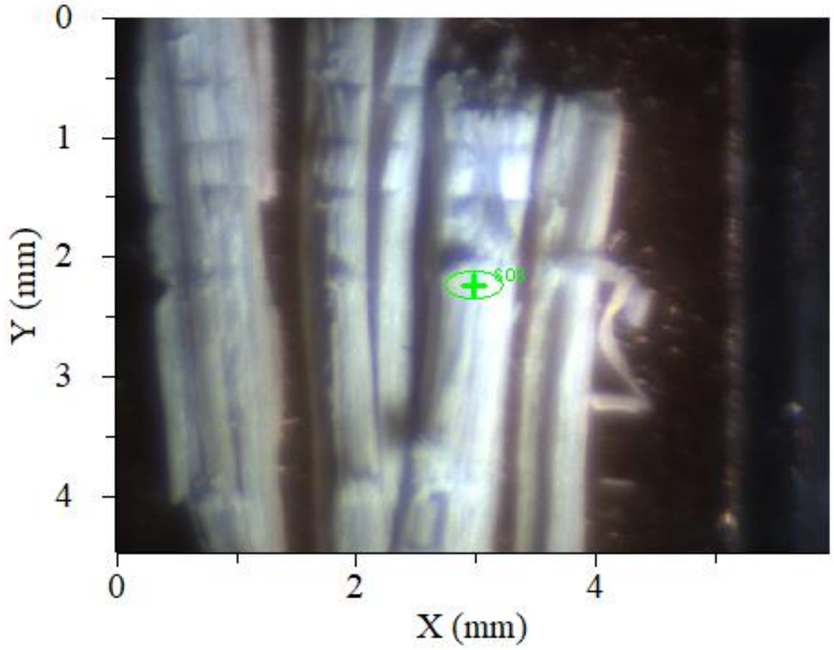

Figure 2.
Image of AfL fiber used in XPS surface measurement

2.9. Tensile properties of single AfL fiber

AfL fiber was used for testing and was determined 1″ (25.4 mm) in length according to the ASTM 3039 single fiber tensile strength standard. The INSTRON 4411 machine was used to determine the mechanical properties of 20 AfL fibers.

3. RESULTS AND DISCUSSIONS

The density of AfL fiber was calculated between approximately 1.35 and 1.45 g/cm^3. It has a density value similar to bamboo (1.40), kenaf (1.45), and hemp (1.48) fibers (Wambua et al., 2003; Holbery et al.,2006). The chemical components (cellulose, hemicellulose, and lignin) of AfL fiber were determined according to standard analytical methods (Balasundar et al.,2018).

Table 1. Comparison of the physicochemical structure of AfL fiber with other fibers (Indran et al., 2014; Balaji et al., 2017; Shanmugasundaram et al.,2018; Ovalı 2023)

Natural Fiber	Chemical Properties				Physical Properties	
	Cellulose (Wt%)	Hemicellulose (Wt %)	Lignin (Wt %)	Moisture (Wt%)	Density (g/cm^3)	Diameter (μm)
Allium fistulosum L.	38.36	29.73	24.31	3.25	1.35-1.45	190.83
Coconut tree leaf sheath	27	14	27.7	4.7	1.20	140 – 990
Piassava	28.6	25.8	45	-	1.4	-
Areca fruit Husk	57.35–58.21	13–15.42	23.17–24.16	7.32	0.7–0.8	396 – 476
Seagrass	57	38	5	-	1.5	5
Alpha	45.4	38.5	14.9	-	0.89	-
Glycyrrhiza glabra	40.46	15.94	12	9.93	1.43	119 – 158
Wheat straw	51	26	16	-	1.45	-
Flax	64.1	16.7	2.0	3.9	1.5	-
Jute	64.4	12	11.8	1.1	1.3	40 – 350

Table 1 shows the chemical structure of AfL fiber and its comparison with other natural fibers. Coconut tree leaf sheath with approximately 38.36% cellulose content was found to have a higher content than *Piassava* fibers. It contains a cellulose content that can be mixed with other natural fibers. The firm hydrogen bonds that bind cellulose chains together are capable of improving the fibers' strength and crystallinity. (Kumar et al., 2022). Because of its amorphous area, the high amount of hemicellulose is linked to the moisture level of the fiber and can degrade cellulose microfibrils (Saravana et al., 2019). The content of the remaining components, including lignin (24.3%), moisture (3.2%), oils, and waxes, is around in total 28~29%.

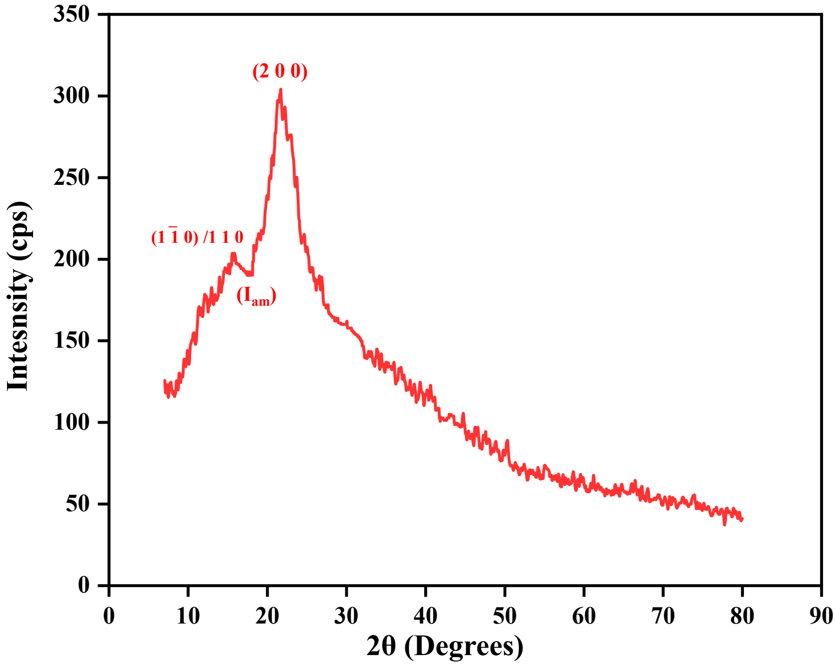

Figure 3.
XRD curve of AfL fiber

Figure 3 shows the X-ray diffraction (XRD) curve of AfL fiber. The intensity seen at I_{am}=17.82° (1 1 0 / 1 1 0) and I_{200} =21.69° (2 0 0) are the characteristic peaks corresponding to Cellulose I (Sreenivasan et al., 2011; (French 2014).) for most of the cellulose-based fibers. It is significant to keep in mind that intensity from both the crystalline and amorphous regions is included in the (2 0 0) peak. The intensity above the horizontal line that the Segal equation assumes crosses the (2 0 0) peak at the I_{am} height and is regarded as the crystalline contribution. Because of its simplicity, Segal's approach for calculating the crystallinity index (CI) is popular. However, it is now understood that the size variations of the microscopic crystallites in cellulose samples have a considerable impact on the crystallinity index (CI) as calculated by the Segal peak height method (Segal et al., 1959). The crystalline index value of AfL fiber was calculated as 38.01%. The determined crystalline index value of AfL fiber is higher than *Grewia tilifolia* (8.8%) and lower than *Althaea officinalis L* (68%) (Maache et al., 2017; Baskaran et al.,2018).

Figure 4 shows the Fourier transfer infrared spectrum of AfL fiber in which the chemical functional groups and related chemical composition are determined. Fourier transfer infrared spectrum is shown. In the spectrum given in Figure 4, peaks at 3341, 2921, 1634, 1423, 1373, and 1033 cm^{-1} were detected. The peak at 3341 cm^{-1} is the peak corresponding to the hydrogen-bonded OH stress vibration of hydroxyl groups in cellulose and hemicelluloses. The C-O stretching vibration of lignin is shown by the peak at 1634 cm^{-1}, the CH symmetric vibration of cellulose is represented by the peak at 1423 cm^{-1}, the C-O stretching vibration of polysaccharides and lignin is represented by the peaks at 1373 cm^{-1} and 1033 cm^{-1}. The C≡C stretching vibration is represented by the peak at 2921 cm^{-1} (Maache et al.,201; Kumar et al., 2022).

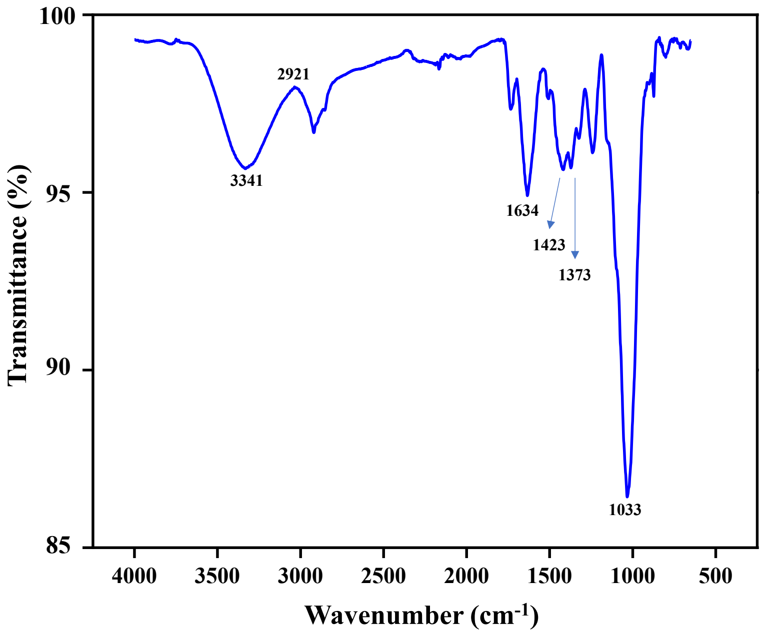

Figure 4.
FTIR curve of AfL fiber

The atomic percentages of the elemental compositions forming the AfL fiber surface were determined as carbon (C1s) 59.24%, oxygen (O1s) 22.2%, nitrogen (N1s) 1.74%, and silicium (Si2p) 0.5% by using XPS. The surface chemical constituents of AfL are given in Table 2. In general, a high C/O ratio is associated with hydrophobic surface characteristics of the fiber and this parameter is important for cellulose based fiber reinforced composite materials. It can be said that AfL fiber has a more hydrophobic surface than jute (2.09) and kenaf (2.38) fibers with a C/O ratio of 2.66 (Šernek et al., 2004; Sgriccia et al., 2008).

Table 2. Surface chemical constituents of AfL fiber

Fiber	C1s (%)	O1s (%)	N1s (%)	Si2p (%)
Allium fistulosum L.	59.24	22.2	1.74	0.5

XPS curves given in Figure 5 for C1s and O1s peaks were used to determine the content of functional groups. The main peak C-C/C-C-H of AfL fiber at 284.88 eV indicates the presence of cellulose or ether, the peak (C=O/O-C-O) carbonyl groups C-OH at 286.38 eV, O-C=O at 288.8eV indicates carboxylic acid or lignin (Kılınç et al., 2018; Ilaiya et al., 2020).

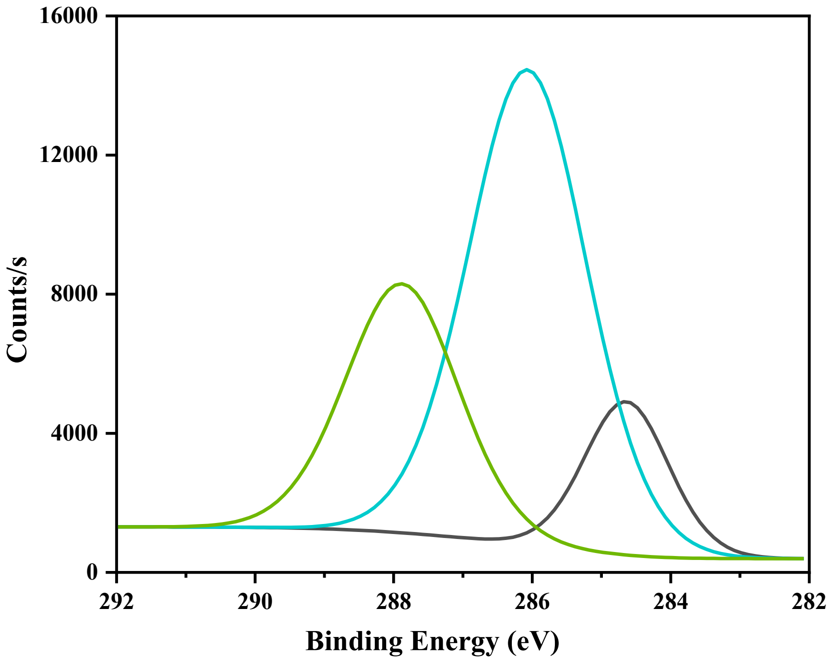

Figure 5.
XPS (C1s) spectrum of AfL fiber

Figure 6 shows the mass loss of AfL fiber as a result of TGA analysis. The analysis was carried out between 30-620 °C. It is known that cellulose, hemicellulose, and lignin degrade at 240-350 °C, 200-260 °C, and 280-500 °C, respectively (Belouadah et al., 2015). The first degradation of AfL fiber was observed at 72.52 °C with the evaporation of water (Gopinath et al., 2016). 267.46 °C corresponds to the decomposition of hemicellulose and lignin. Thermal stability is directly related to the hemicellulose ratio (Manimaran et al., 2019). The peak at 315.72 °C shows the decomposition of cellulose and the maximum degradation value. It is understood that there will be no change in the structure of the AfL fiber-reinforced composites at temperatures below 267.6 °C.

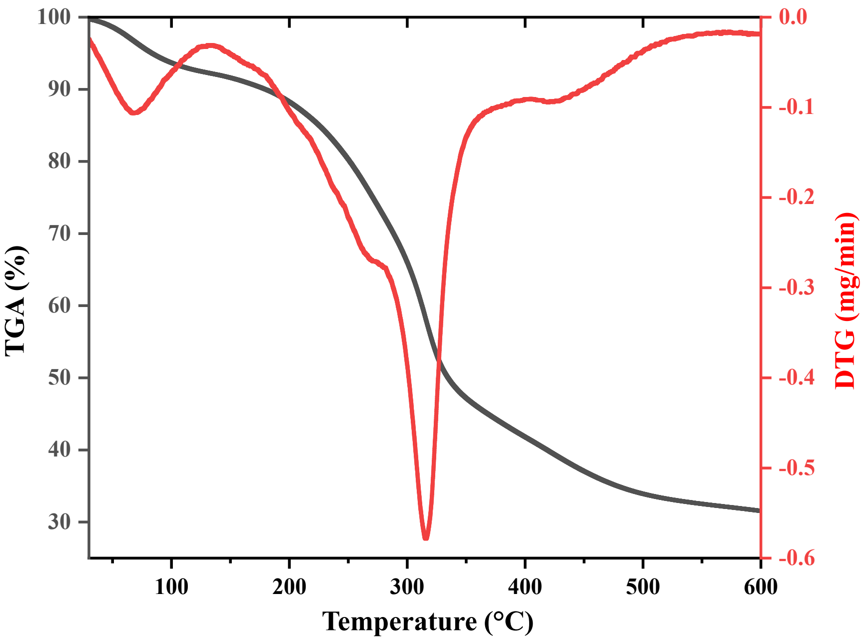

Figure 6.
TGA-DTG curve of AfL fiber

Figure 7 shows SEM images of the transverse and longitudinal sections of AfL fiber at 100X and 2000X magnification. In the longitudinal section image of the fiber, the surface is rough and fiber cells containing lignin and hemicellulose are seen. Surface modification processes are required to improve fiber/matrix surface compatibility. In this way, fiber polymer surface compatibility can be increased.

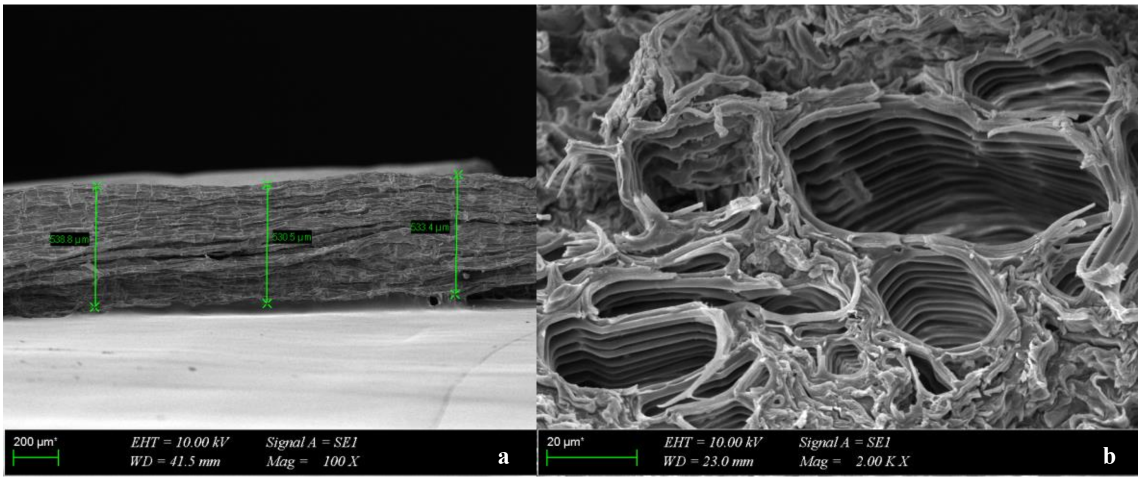

Figure 7.
SEM images of AfL fiber; (a) longitudinal view, (b) cross-section view

The mechanical properties of cellulosic-based fibers vary according to the content of cellulose, lignin, and hemicellulose in their structure as well as the soil, climate, and environmental conditions. The tensile strength, modulus, and elongation values of 22.19 ± 3.75

MPa, 0.87 ± 0.16 GPa, and 9.92 ± 2.7%, respectively, were determined for AfL fiber. The tensile strength value (22.19 MPa) of AfL fiber is higher than the Aerial roots of the banyan tree at 19.37 MPa (Ganapathy et al., 2019), *Cordia dichotoma* at 16.9 MPa (Jayaramudu et al., 2011), and lower than the Coconut tree leaf sheath at 46.4 MPa (Reddy et al., 2010), *Grewia tiliifolia* at 65.2 MPa (Jayaramudu et al.,2010) fibers.

4. CONCLUSIONS

This study investigates the feasibility of using *Allium fistulosum L.* (scallion) tassel fiber as a reinforcement material for green composites. The fiber characterization procedure determined the properties that were physical, chemical, mechanical, morphological, and thermal characterizations. The distinctive characteristics of the AfL fiber were attributed to a variety of chemical constituents (cellulose, hemicellulose, and lignin) which together demonstrated a density that was comparable to that of established natural fibers.

It was found that its low density of 1.35 – 1.45 g/cm^3 could be advantageous for the manufacturing of composites. In addition, it was determined that it has a density value similar to fibers known such as jute and flax. With a crystallinity index of 38.01%, the XRD examination showed that the material was in a region that was useful for fiber reinforcing. FTIR analysis identified essential chemical functional groups in AfL, and XPS data indicated a hydrophobic surface, a crucial factor for cellulose-based fiber-reinforced composites. TGA analysis displayed a thermal stability up to 267.46 °C, showing its suitability for composite heat processing. SEM images highlighted the need for surface modification to enhance fiber/matrix compatibility. The tensile properties of AfL fiber with a tensile strength of 22.19 MPa and a modulus of 0.87 GPa place it in a weak position among natural fibers. Nevertheless, even in this state, AfL fibers can offer an alternative for use as filling material in composites in order to enhance sound absorption properties due to pore characteristics. However, when it is intended to be used as a fiber, these mechanical properties have the potential to be improved in combination with surface treatments and coupled with its environmentally friendly origin, can make AfL fiber a promising candidate for the green polymer composites using waste fibers.

As a result, *Allium fistulosum L.* (scallion) tassel fiber presents a promising, readily available, and environmentally friendly alternative to conventional composite reinforcements. Further research on surface modification and composite fabrication is needed to fully realize its potential in sustainable fiber-reinforced composite applications.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTION

Oğuz ERYILMAZ: Configuration of paper, Analyzing Data, Writing, Visualization, Editing

Sabih OVALI: Literature Review, Experimental Investigation, Editing, Writing

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