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Morpho-anatomical Evaluation of Stem Wood and Bark Fibers of *Solanum dulcamara* and *Genista tinctoria* for Paper Applications

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Research Article

Abstract − As paper remains an essential material in communication, packaging, and various industrial applications, rising demand and the depletion of wood-based raw materials have prompted growing interest in renewable non-wood fiber sources. Alternative fiber sources for paper production have emerged as important non-traditional supply sources due to rising demand for fiber raw materials, a global tree crisis, and growing awareness of sustainability. This study evaluates the morpho-anatomical properties of fibers obtained from the stem wood and stem bark of *Solanum dulcamara* and *Genista tinctoria* in order to investigate environmentally sustainable and renewable non-wood fiber sources. The lengths, widths, lumen widths and wall thicknesses of the fibers, as well as slenderness ratio (related to paper mechanical properties), flexibility ratio (related to fiber bonding potential) and Runkel ratio (associated with pulp quality) were determined. It was determined that the bark samples of both species had longer, thicker-walled and narrower lumen fibers than the wood samples. Overall, the morphological properties of *G. tinctoria* fibers make them suitable for packaging papers that require moderate strength and flexibility. In contrast, the wood fibers of *S. dulcamara* appear suitable for low-strength paper applications due to their short and narrow structure, while its bark fibers show potential for high-strength paper applications, provided that fiber clustering is managed—highlighting both species as promising non-wood fiber sources for diverse paper products.

Anahtar Kelimeler *– Solanum dulcamara, Genista tinctoria, non-wood, paper production, fiber*

Solanum dulcamara ve Genista tinctoria Gövde Odunu ile Kabuk Liflerinin Kâğıt Üretimi Açısından Morfo-anatomik İncelemesi

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Araştırma Makalesi

Öz – Kâğıt; iletişim, ambalaj ve çeşitli endüstriyel alanlarda hâlâ temel bir malzeme olma özelliğini koruduğundan, artan talep ve odun bazlı hammadde kaynaklarının azalması, yenilenebilir odun dışı lif kaynaklarına yönelik ilgiyi giderek artırmıştır. Kağıt üretimi için alternatif lif kaynakları, lif hammaddelerine olan talebin artması, küresel ağaç krizi ve sürdürülebilirlik konusunda artan farkındalık nedeniyle geleneksel olmayan önemli tedarik kaynakları olarak ortaya çıkmıştır. Bu çalışma, çevresel olarak sürdürülebilir ve yenilenebilir odun dışı lif kaynaklarını araştırmak amacıyla *Solanum dulcamara* ve *Genista tinctoria*'nın gövde odunu ve gövde kabuğundan elde edilen liflerin morfo-anatomik özelliklerini değerlendirmektedir. Liflerin uzunlukları, genişlikleri, lümen genişlikleri ve duvar kalınlıkları ile keçeleşme oranı (kağıdın mekanik özellikleriyle ilgili), esneklik katsayısı (lif bağ yapma potansiyeliyle ilgili) ve Runkel oranı (hamur kalitesiyle ilgili) belirlenmiştir. Her iki türün kabuk örneklerinin odun örneklerine kıyasla daha uzun, daha kalın duvarlı ve daha dar lümenli liflere sahip olduğu belirlenmiştir. Genel olarak, *G. tinctoria* liflerinin morfolojik özellikleri, orta derecede mukavemet ve esneklik gerektiren ambalaj kâğıtları için uygun olduklarını göstermektedir. Buna karşın, *S. dulcamara*'nın odun lifleri, kısa ve ince yapıları nedeniyle düşük mukavemetli kâğıt uygulamalarına daha uygundur; kabuk lifleri ise lif kümelenmesi kontrol altına alınabildiği takdirde yüksek mukavemetli kâğıt üretiminde potansiyel sunmaktadır—bu durum her iki türü, çeşitli kâğıt ürünlerinde kullanılabilecek umut vadeden odun dışı lif kaynakları olarak ön plana çıkarmaktadır.

Keywords *– Solanum dulcamara, Genista tinctoria, odun-dışı, kağıt üretimi, lif*

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1. Introduction

Plant fibers have a wide range of applications in various industries, including textiles, ropes, paper and packaging, furniture, particleboard, insulation panels, food and animal feed, cosmetics, and pharmaceuticals, due to their low cost, biodegradable structure, abundance, and good physical and mechanical properties (Yıldızbaş et al., 2024). Wood and other lignocellulosic raw materials are used in the production of fibers and pulp. On the other hand, the pulp and paper industries require large amounts of wood that must be regularly harvested and delivered to factories. (Thongpukdee et al., 2013; Haile et al., 2021). However, the increase in carbon emissions in recent years have made tree-based carbon sequestration more important; in particular, slow-growing species have an important role to play in slowing down this process by storing more carbon over the long term. Non-wood fibers are therefore increasingly important in the papermaking industry in order to reduce the problems of social, environmental and ecosystem management (Kaul et al., 2010; Haile et al., 2021).

The Solanaceae is an angiosperm family that contains economically, agriculturally, and biologically important plants such as potato (*Solanum tuberosum* L.), tomato (*S. lycopersicum* L.), eggplant (*S. melongena* L.), pepper (*Capsicum annuum* L.), tomatillo (*Physalis philadelphica* Lam.), and tobacco (*Nicotiana tabacum* L.) (Liu et al., 2025; Madlhophe et al., 2025). The family, which is distributed in a variety of habitats ranging from deserts to tropical forests, excluding Antarctica, includes approximately 100 genera and 2700 species. The family exhibits a wide range of life forms, including herbs, shrubs, and even a few trees, all of which have diverse flower, fruit, seed, and embryo morphologies. (Barboza et al., 2016; Huang et al., 2023). The genus *Solanum*, in the Solaneae tribe of the Solanoideae subfamily, is among the ten most species-rich genera of flowering plants, with approximately 1400 species. The taxon *S. dulcamara* L. in this genus is usually called bittersweet or climbing nightshade (Golas et al., 2010; Knapp, 2013). *S. dulcamara* is a woody-perennial plant that has become widely naturalized throughout the entire Holarctic region. It occurs in contrasting habitats, ranging from the moist environments of irrigation channels, riverbanks, and lake shores to the dry areas of dunes and plains (Golas et al., 2010).

Fabaceae (or Leguminosae) is the third largest plant family in terms of species number, following Asteraceae and Orchidaceae, comprising approximately 770 genera and 19,500 species. This family includes plants capable of growing even in nutrient-poor soils due to their ability to fix atmospheric nitrogen, and it is found in nearly every biome worldwide, except Antarctica and the high Arctic. The family includes trees, shrubs, subshrubs, woody vines, climbing annuals, herbs, and aquatic plants. Many members of the family are culturally and economically important throughout the world, used in many areas such as traditional medicines, food, wood, garden ornamentals, dyes, fibers, fuels, gums, and insecticides (Maroyi, 2023). *Genista tinctoria* L., belonging to the Faboideae subfamily, is a woody-perennial shrub with an erect stem measuring 10–200 cm. Research has demonstrated that this taxon exhibits various bioactivities, including antioxidant, anti-inflammatory, and DNA damage-preventive properties (Altınkaya, 2020). Additionally, due to its high genistein content, it has been used for centuries to dye fabrics. While genistein is characteristic of *G. tinctoria*, apigenin and luteolin are also present in this plant (Wozniak et al., 2024).

To date, some taxa in the Solanaceae family that have been studied for their fiber properties are as follows: *C. annuum* var. *accuminatum* Fingerh., *C. annuum* var. *grossum* (L.) Sendt., *N. tabacum S. americanum* L., *S. capsicoides* All., *S. diphyllum* L., *S. lasiocarpum* Ortega, *S. lycopersicum*, *S. mammosum* L., *S. melongena*, *S. sanitwongsei* Craib, *S. seaforthianum* Andr., *S. spirale* Roxb., *S. torvum* Sw., *S. trilobatum* L., *S. violaceum* Ortega, *S. wrigthtii* Benth., and *S. tuberosum* (Shakhes et al., 2011; Thongpukdee et al., 2013; Sharma et al., 2015). Some of the taxa in the Fabaceae family whose fiber properties have been studied are as follows: *Pentaclethra macrophylla* Benth., *Erythrophleum suaveolens* (Guill. & Perr.) Brenan, *Machaerium ferox* (Mart. ex Benth.) Ducke, *Deguelia negrensis* (Benth.) Taub. and *Bauhinia rutilans* Spruce ex Benth. (Nweze et al., 2021; Reis et al., 2018). Despite numerous studies on the fiber properties of certain taxa belonging to the Solanaceae and Fabaceae families, as well as extensive research on the bioactivity, phytochemical content, genomic analysis, and dye properties of *S. dulcamara* and *G. tinctoria* (Kumar et al., 2009; D'Agostino et al., 2013; Amiryousefi et al., 2018; Popova et al., 2021; Gadewar et al., 2024; Altınkaya, 2020; Wozniak et al., 2024), to the best of our knowledge, there is no literature available regarding their fiber properties. In both wood and non-wood sources, when it comes to pulp and paper production, fiber dimensions and the indices derived from them (such as the Runkel ratio, slenderness ratio, and flexibility ratio) are key criteria (Gülsoy et al. 2017; 2021). These indices determine the suitability of the fiber raw materials and the properties of the produced paper (Thongpukdee et al., 2013). In this context, investigating the properties of fibers obtained from potential non-wood sources such as *S. dulcamara* and *G. tinctoria* is of great importance for the paper industry and other industrial sectors.

Research on the fibers of various species within the Solanaceae and Fabaceae families has led to the following research question: Are the morphological properties of the wood and bark fibers of *S. dulcamara* and *G. tinctoria* in line with fiber quality standards used in papermaking, and can these species be considered as sustainable non-wood fiber sources? Furthermore, based on previous findings related to species in these families, the following hypothesis has been formulated: The morphological characteristics of *S. dulcamara* and *G. tinctoria* fibers are expected to meet key fiber quality parameters for papermaking, suggesting their potential as alternative and sustainable non-wood fiber sources in the paper industry. Therefore, in this context, the main purpose of the research is to provide new data that will shed light on future paper production and related industrial applications by comparatively examining the fiber properties of species belonging to these two families. In this study, the fiber properties of the stem wood and bark of *S. dulcamara* (yaban yasemini in Turkish) and *G. tinctoria* (dyer's broom in English; boyacı katır tırnağı in Turkish) were investigated, along with their influence on pulp and paper quality as assessed through various industrial indicators such as the Runkel ratio, slenderness ratio, and flexibility ratio. As a result, the potential suitability of *S. dulcamara* and *G. tinctoria* for papermaking, along with their fiber characteristics, has been revealed.

2. Material and Methods

2.1. Plant Material and Preparation

S. dulcamara and *G. tinctoria* were collected in July from Coburlar Village, Zonguldak, Türkiye. The plant identification was carried out by systematic botany expert Avni YILDIZBAŞ. The leaves, twigs and flowers of the plants were removed, and 3–5 cm long pieces were cut from the stem wood and bark.

2.2. Fiber Morphological Characteristics

The 3-5 cm long pieces cut from the stem wood and bark were macerated according to the chlorite method (Spearin and Isenberg, 1947). For this process, approximately 2 g of sample was placed into a 250 mL conical flask containing 160 mL of distilled water. Subsequently, 1.5 g of sodium chlorite ($NaClO_2$) and a few drops of acetic acid were added. The mixture was heated in a water bath at 80 °C for 4–5 hours, with the chemical agents replenished at one-hour intervals. During maceration, lignin was gradually dissolved, leading to the weakening of intercellular bonds and the release of individual fibers. Once the samples appeared visibly lighter in color and softened in texture, they were thoroughly rinsed with distilled water and gently agitated using a mixer to ensure complete fiber separation. The isolated fibers were then filtered through filter paper, preserved in glycerin, and prepared for subsequent microscopic examination. Fiber length (FL) was measured in 100 randomly selected fibers, while fiber width (FW), lumen width (LW), and cell wall thickness (CWT) were measured in 50 randomly selected fibers from both stem and bark samples. Additionally, the length of 50 randomly selected vessel elements (VEL) length was measured from the same samples. The measurements were carried out with an Olympus CX21 light microscope. To measure the lengths and capture general images of very long fibers, a ×4 objective lens was employed. For fibers of standard length, measurements and imaging were conducted using a ×10 objective. Detailed assessments of fiber width, lumen diameter, and cell wall thickness were performed with a ×40 objective lens. The mean values and standard deviations were calculated from measured values. In addition, the measured fiber dimensions were used to determine the slenderness ratio, flexibility ratio, and Runkel ratio (Table 1).

Table 1.
Indices used in the evaluation of fiber properties related to paper and pulp quality

Property	Formula	Reference
Slenderness ratio (SR)	FL/FW	İstek et al., 2009
Flexibility ratio (FR)	(LW/FW) × 100	İstek et al., 2009
Runkel ratio (RR)	(2 x CWT)/LW	Runkel, 1949

FL: Fiber length; FW: Fiber width; LW: Lumen width; CWT: cell wall thickness

2.3. Statistical Analysis

All statistical analyses were conducted using SPSS software. Prior to the comparisons, the data were tested for normality using the Shapiro-Wilk test and for homogeneity of variances using Levene's test. Following the confirmation of these assumptions, independent samples t-tests were applied to evaluate the differences in fiber morphology between bark and wood tissues of each species. Different letters in the same column in Tables 2 and 3 indicate statistically significant differences between groups ($P < 0.05$).

3. Results and Discussion

The fiber of wood and bark of *S. dulcamara* had similar morphological properties with fibers of other Solanaceae species (Table 2). It was found that the wood fibers (0.55 mm) of *S. dulcamara* were approximately 18 times shorter than the bark fibers (10.03 mm). The fiber width (34.55 µm) and the wall thickness (15.46 µm) of the bark fibers were approximately 2 times (16.80 µm) and 3.5 times (4.45 µm) wider than the wood fibers, respectively. When the lumen width of the fibers was compared, it was found that the wood fibers (7.90 µm) had a lumen approximately 2 times wider than the bark fibers (3.63 µm). At the same time, the morphological differences between wood and bark fibers were statistically significant ($P < 0.05$). The biological basis for the remarkable length of bark fibers—particularly primary fibers—lies in their procambial origin and their prolonged cell elongation during development. These fibers are derived from the actively dividing cambial tissue during growth and adapt to the radial expansion caused by the delayed division and enlargement of phloem parenchyma cells. This developmental elongation allows the sclerenchyma fibers, which provide mechanical support to the conducting tissues, to acquire longer and more flexible structures. From a technological perspective, such fiber length offers significant advantages, as longer fibers reduce the number of fiber interfaces, thereby contributing to stronger, more homogeneous, and durable materials, particularly in textile and composite applications. Additionally, their relatively low lignin content facilitates easier processing, while a high proportion of crystalline cellulose makes them ideal for the production of high-strength materials (Gea et al., 2013; Clair et al., 2019).

Slenderness ratio and Runkel ratio values of bark fibers were higher than those of wood fibers. In addition, flexibility ratio of bark fiber was lower than wood fibers. If the slenderness ratio of a fiber is higher than 70 and the flexibility coefficient is higher than 50, the strength of the paper obtained from those fibers will be high. On the other hand, a Runkel ratio lower than 1 indicates that the fibers are ideal for paper production due to their good fiber flexibility and bonding capacity (Yaman and Gencer, 2005; Gulsoy and Ozturk, 2015; Longui et al., 2024). The flexibility ratio, defined as the ratio of lumen width to fiber width, is used to classify fibers into four categories: highly elastic fibers (greater than 75), elastic fibers (between 50 and 70), rigid fibers (between 30 and 50), and very rigid fibers (less than 30) (Gülsoy et al. 2017). According to these results, wood fibers of *S. dulcamara* can be used in papers requiring low-strength and a smooth surface. Bark fibers of *S.*

dulcamara, considering their relatively long fibers, may be suitable for high-strength paper production. However, these fibers cluster during paper formation and negatively affect the formation of the paper. On the other hand, bark fibers have low flexibility ratio and high Runkel ratio values due to their very thick walls, which has a negative effect on fiber-fiber bonding. If these fibers are to be used in paper production, it is considered necessary to mill them to high beating levels to reduce clustering and promote fiber delamination, thereby improving paper formation (Rusu et al., 2011).

The exceptionally long bark fibers of *S. dulcamara* may offer potential advantages for composite applications. In fiber-reinforced composites, longer fibers are generally associated with improved mechanical properties such as tensile and flexural strength, impact resistance, and durability due to their ability to form continuous load-bearing paths and provide greater surface area for matrix bonding (Palanisamy et al., 2023). These properties suggest that *S. dulcamara* bark fibers, owing to their significant length and wall thickness, may serve as reinforcing elements in non-structural composite materials like insulation boards or biocomposites. Therefore, the bark fibers of *S. dulcamara* may be suitable for composite production (such as in insulation panels) rather than for paper production. However, further experimental validation is required to assess their actual performance in composite matrices, including fiber-matrix compatibility and interfacial bonding behavior.

The average vessel element length of *S. dulcamara* wood was 0.27 ± 0.01 mm. In contrast, no vessel elements were detected in the bark section. The photos of the fiber and vessel elements of *S. dulcamara* wood and bark are presented in Figure 1.

Table 2.
Fiber properties of wood and bark of *S. dulcamara*, with comparative data from other *Solanum* taxa.

Species	FL (mm)	FW (µm)	LW (µm)	CWT (µm)	SR	FC	RR	Reference
S. dulcamara wood	0.55±0.04a	16.80±1.13a	7.90±0.35a	4.45±0.49a	33.14	47.02	1.13	Present study
S. dulcamara bark	10.03±0.62b	34.55±2.92b	3.63±0.38b	15.46±1.54b	290.52	10.50	8.52	Present study
Stem tip of *S. torvum* Sw.	2.48	25.76	15.40	4.88	96.27	56.37	0.76	Thongpukdee et al.. 2013
Stem base of *S. torvum*	2.89	26.68	14.16	6.36	108.32	53.07	0.89	Thongpukdee et al., 2013
Stem tip of *S. lycopersicum*	4.06	46.48	35.68	5.84	87.34	70.35	0.34	Thongpukdee et al., 2013
Stem base of *S. lycopersicum*	4.49	45.52	29.04	8.16	98.63	63.79	0.36	Thongpukdee et al., 2013
Stem tip of *S. melongena*	2.93	21.60	10.20	5.28	135.64	48.79	0.97	Thongpukdee et al., 2013
Stem base of *S. melongena*	2.11	26.36	13.20	6.08	80.04	50.07	0.92	Thongpukdee et al., 2013
Stem tip of *S.capsicoides*	2.84	26.40	11.92	5.76	107.57	36.55	1.17	Thongpukdee et al., 2013
Stem base of *S.capsicoides*	4.27	31.60	9.28	9.64	135.12	29.36	2.08	Thongpukdee et al., 2013
N. tabacum stalk	1.23	24.31	15.38	8.93	50.59	63.26	1.16	Shakhes et al., 2011

±: Standard deviation.

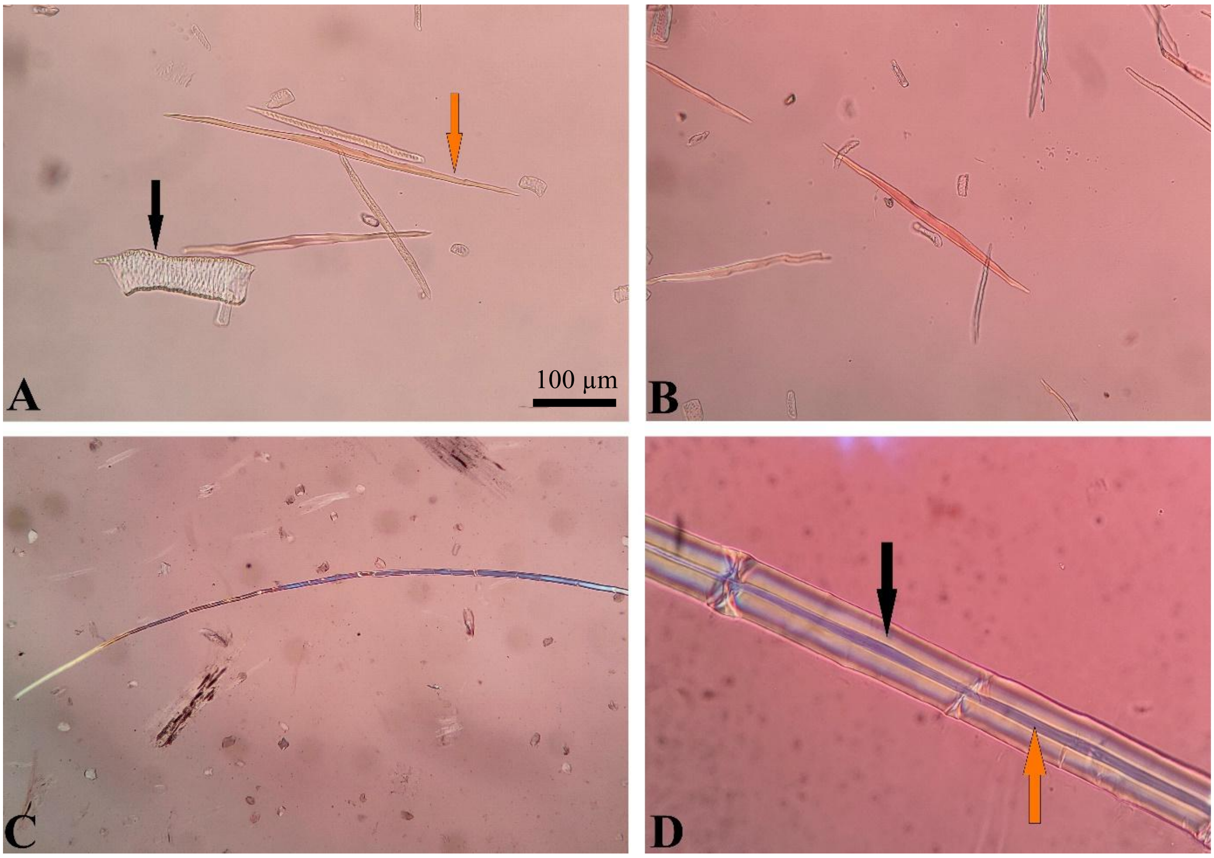

Figure 1. The fiber and vessel elements of *S. dulcamara* wood and bark. **A** and **B** wood, black arrow is vessel element, orange arrow is fiber (×10 objective lens); **C** (×4 objective lens) and **D** bark, black arrow is cell wall, orange arrow is lumen (×40 objective lens).

The fiber properties of *G. tinctoria* wood and bark are presented in Table 3. It was found that wood fibers of *G. tinctoria* were shorter (0.60 µm) and slightly wider (15.00 µm) than bark fibers (length 0.97 µm; width 13.35 µm). Furthermore, the lumen width of wood fibers (6.30 µm) was more than twice that of bark fibers (2.75 µm), whereas the cell wall thickness of bark fibers (5.30 µm) was higher than that of wood fibers (4.35 µm). On the other hand, these morphological differences were found to be statistically significant ($P<0.05$). These dimensional distinctions are further reflected in calculated indices: bark fibers showed a substantially higher slenderness ratio (72.65) than wood fibers (40.00), suggesting a more favorable morphology for reinforcing applications. However, the bark fibers also exhibited a notably lower flexibility ratio (20.60) and a considerably higher Runkel ratio (3.85), indicating limited collapsibility and inter-fiber bonding potential during paper formation. In contrast, wood fibers displayed a more balanced fiber profile, with a flexibility ratio of 42.00 and a Runkel ratio of 1.38—values approaching the acceptable thresholds for papermaking.

When compared to other members of the Fabaceae family that have been evaluated for fiber utilization, *Genista tinctoria* exhibits intermediate anatomical characteristics in terms of fiber morphology. Specifically, its fiber length and flexibility ratio suggest a moderate suitability for pulp and paper applications. For instance, species such as *Deguelia negrensis* (Benth.) Taub. display notably longer fibers (1.15 mm) and a high slenderness ratio (SR = 95.06), both of which are considered desirable for enhancing paper strength and flexibility. Similarly, *Bauhinia rutilans* Spruce ex Benth. possesses relatively long fibers (0.91 mm) and a favorable slenderness ratio (SR = 79.30), indicating potential for higher-grade pulp applications. In contrast, species such as *Erythrophleum suaveolens* (Guill. & Perr.) Brenan and *Pentaclethra macrophylla* Benth. exhibit considerably shorter fibers (0.40 mm and 0.56 mm, respectively), coupled with lower flexibility ratio (FC = 68.01 and 53.20) and higher rigidity (RR = 0.61 and 1.12), which may limit their use to lower-strength paper products or as filler materials. The fiber characteristics of *Machaerium ferox* (Benth.) Ducke., with a fiber length of 0.62 mm and relatively moderate FC and SR values, are more comparable to those of *G. tinctoria*. Thus, the bast and wood fibers of *G. tinctoria*, while not as mechanically advantageous as those of *D. negrensis* or *B. rutilans*, present better fiber quality than species like *E. suaveolens* or *P. macrophylla*, suggesting its potential use in medium-grade pulp production or as a supplementary fiber source for composite applications (Nweze et al., 2021; Reis et al.,). Nevertheless, further investigation is required to assess their compatibility with polymeric matrices and overall performance in composite systems.

The average vessel element length of *G. tinctoria* wood was 0.14 ± 0.05 mm. In contrast, no vessel elements were detected in the bark section. The photos of the fiber and vessel elements of *G. tinctoria* wood and bark are presented in Figure 2.

Table 3.
Fiber properties of wood and bark of *G. tinctoria* with comparative data from other Fabaceae taxa.

Species	FL (mm)	FW (µm)	LW (µm)	CWT (µm)	SR	FC	RR	Reference
G. tinctoria wood	0.60±0.05a	15.00±0.47a	6.30±0.35a	4.35±0.27a	40.00	42.00	1.38	Present study
G. tinctoria bark	0.97±0.06b	13.35±0.52b	2.75±0.24b	5.30±0.31b	72.65	20.60	3.85	Present study
Heartwood of *P. macrophylla*	0.56	23.70	8.60	4.70	34.05	53.20	1.12	Nweze et al., 2021
Heartwood of *E. suaveolens*	0.40	17.40	10.90	3.20	25.16	68.01	0.61	Nweze et al., 2021
Wood of *B. rutilans*	0.91	12.01	5.59	3.21	79.30	46.71	1.21	Reis et al., 2018
Wood of *D. negrensis*	1.15	13.22	3.41	4.91	95.06	25.95	3.28	Reis et al., 2018
Wood of *M. ferox*	0.62	14.37	8.50	2.93	44.00	58.98	0.76	Reis et al., 2018

The length of woody-perennial (for shrubs and subshrubs) plant fibers varied between 0.31-4.49 mm on average, fiber widths varied between 12.01-46.48 µm, lumen widths varied between 5.59-35.68 µm, and fiber wall thicknesses varied between 2.59-9.64 µm. Slenderness ratio derived from fiber dimensions of woody-perennial plant is between 17.27-264.20, flexibility ratio is between 44.44-74.66, and Runkel ratio is between 0.34-2.08. According to these results, the wood fibers of *S. dulcamara* and wood and bark fibers of *G. tinctoria* are similar to the morphological properties of woody-perennial plant fibers (Rodriguez et al., 2016; Celis et al., 2014; Maiti et al., 2015; Shaltout, 1992; Abd-ElGawad et al., 2022; Reis et al., 2018; Thongpukdee et al., 2013; Zumaya-Mendoza et al., 2019).

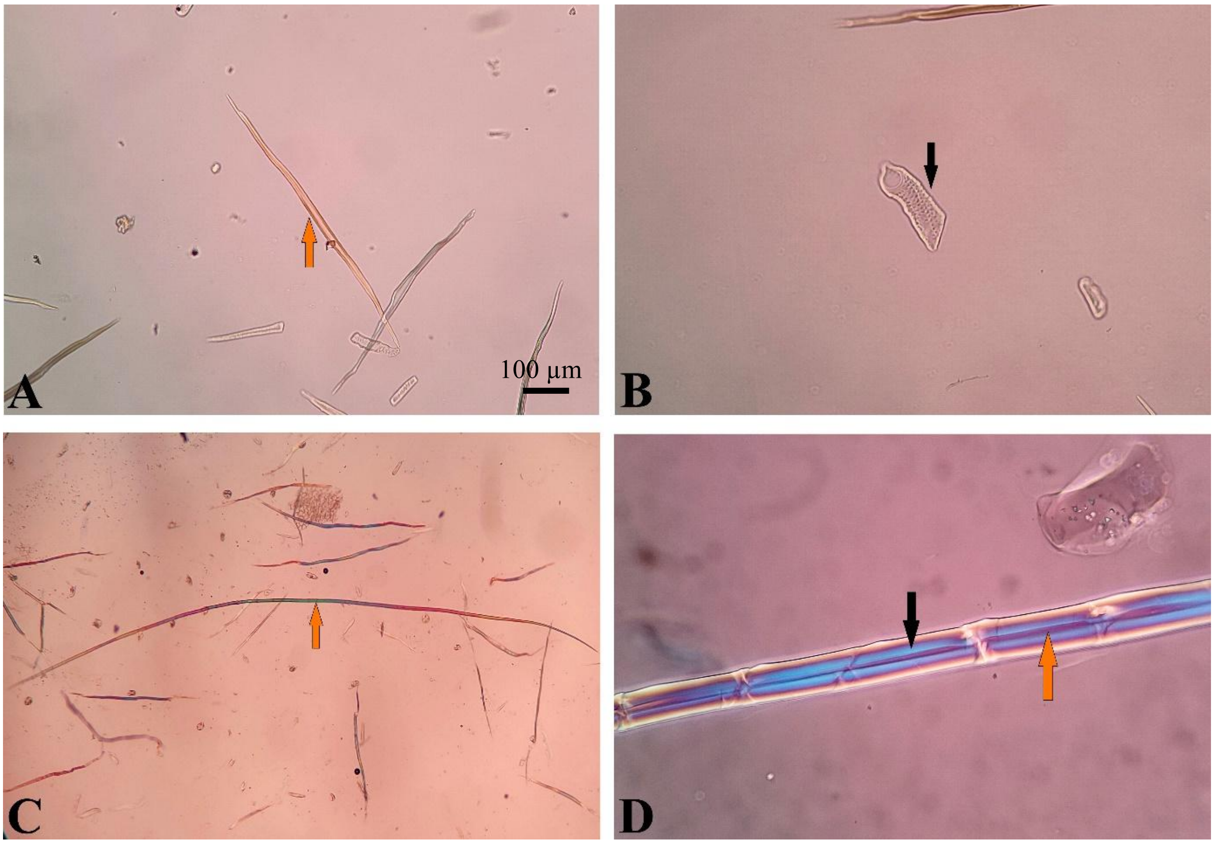

Figure 1. The fiber and vessel elements of *G. tinctoria* wood and bark. **A** and **B** wood, orange arrow is fiber, black arrow is vessel element (×10 objective lens); **C** (×4 objective lens) and **D** bark, black arrow is cell wall, orange arrow is lumen (×40 objective lens).

4. Conclusion

This study highlights the distinct morphological properties of *S. dulcamara* and *G. tinctoria* fibers, providing insights into their potential industrial applications. According to the study's findings, the fibers of *S. dulcamara* and *G. tinctoria* show promise as sustainable natural resources due to their sufficient quality and natural abundance. Because of the fibers' morphological properties, they can be used to produce pulp and paper or biodegradable composite materials. The wood fibers of *S. dulcamara*, being significantly shorter and narrower than the bark fibers, are more suited for the production of low-strength paper, which requires a smooth surface and does not demand high mechanical strength. In contrast, the bark fibers of S. dulcamara with their longer lengths and thicker walls, show promise for composite materials, their clustering tendency during paper formation poses a challenge for high-strength paper production. On the other hand, the wood and bark fibers of *G. tinctoria* demonstrated a different set of characteristics, with the wood fibers being shorter and wider than the bark fibers, and having a lower Runkel ratio and higher flexibility ratio. These properties make both the wood and bark fibers of *G. tinctoria* more suitable for producing packaging papers that do not require high strength, offering a potential alternative for such applications.

In conclusion, while *S. dulcamara* fibers, particularly the bark fibers, show promise for composite materials like insulation panels, their potential in high-strength paper production is limited by their morphological characteristics. The fibers of *G. tinctoria*, with their more favorable flexibility and bonding properties, are more appropriate for low-strength paper applications, such as packaging, where strength requirements are less critical. Despite these promising morphological features, the application of these fibers in paper and composite production requires further experimental validation, particularly concerning fiber processing and compatibility with other materials. Additionally, there may be financial and environmental advantages to considering these plants as agricultural waste. Future research should focus on the industrial-scale production of these fibers, along with a detailed exploration of their chemical composition and paper properties. Additionally, studies should assess their integration into various application areas to evaluate performance and potential benefits, while ensuring both environmental and economic sustainability.

Author Contributions

Author Avni Yıldızbaş: Literature reviewed and summarized it, conducted laboratory studies, took the photos, and wrote the article.

Author Sezgin Koray Gülsoy: Conducted the statistical analysis of the study, and designated and wrote the article.

Author Abdullah İstek: Literature reviewed and summarized it, and designated and wrote the article.

Conflict of Interest

The authors declared no conflict of interest.

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