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Exploring the Characteristics of *Aerva javanica* and *Acacia tortilis* as Promising Candidates for Sustainable Industrial Fiber

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Abstract

Background: Green composites, or Natural Fiber-Reinforced Polymer Composites, have emerged as promising alternatives to synthetic polymers due to their biodegradability, renewability, ease of processing, low density, cost, and energy consumption. Natural fibers are created from plants, animals, and minerals, offering higher structural advantages and better performance due to higher cellulose content and microfibril arrangement. The goal of this research is to evaluate the feasibility of using *Acacia tortilis* bark and *Aerva javanica* flowers (natural visible fibers) as a composite by extracting and characterizing their chemical composition and physical characteristics.

Methods: The experiments have been done using standard methods using gravimetrical analysis and calculations.

Results: The initial phase of our studies has shown that *Acacia tortilis* fibers can have competitive chemical composition and tensile properties compared to common natural fibers as well as *Aerva javanica*, is lighter, less dense, and has promising possibilities for utilizing its fiber in developing green composites.

Conclusion: The preliminary findings indicate that *Acacia tortilis* fibers show competitive properties, surpassing common natural fibers and *Aerva javanica*, making them a promising candidate for green composite development. However, further extensive research is required for conclusive insights.

Introduction

Fiber-reinforced polymer composites find widespread application across a variety of sectors thanks to their low weight, high strength, and resistance to corrosion [1]. The United Arab Emirates (UAE) is one of the major importers of glass fiber, according to the statistics [2]. Synthetic polymers, being derived from petroleum, are harmful to both people and the environment. Green composites, also known as Natural Fiber-Reinforced Polymer Composites, have emerged as promising alternatives to synthetic composites due to their biodegradability, renewability, simplicity of processing, low density, low cost, and low energy consumption [3,4]. Natural fibers are derived from plant matter, animal matter, and minerals. Compared to animal-based fibers, natural cellulosic fibers derived from plants are more cost-effective. In addition, unlike mineral-based fibers, they pose no health risks. The character of natural fibers and the environmental conditions of the plants influence the efficacy of the fiber. The increased cellulose content and microfibril arrangement of natural fibers contribute to their greater structural advantages and superior performance. In addition, the chemical composition, growth conditions of the plants, extraction methods, and varieties of treatment influence the properties of natural fibers [5]. Since different plant portions are used to produce natural fibers, they can be extracted using a variety of methods, such as hand extraction, decortication, chemical retting, and water retting. In order to characterize composite materials, their mechanical properties, such as tensile, compression, and flexural properties, as well as wear resistance and failure fracture, must be investigated [6,7].

The *Acacia tortilis* plant, also known as Samar and umbrella thorn, belongs to the family Fabaceae. It is a small to medium-sized tree with an umbrella-shaped canopy that grows slowly. The plant is known to be resistant to drought, salinity, alkalinity, high temperatures, sandy and calcareous soils, and steeply sloping rooting surfaces. Frost resistance has also been demonstrated for elder plants. Therefore, it is indigenous to arid and semiarid regions of the UAE [8-10]. *Acacia tortilis* is highly valuable for reforestation and reclaiming degraded land. It also contributes significantly to the prevention of soil erosion. The plant *Acacia tortilis* is widespread in the UAE [11]. It is utilized in both traditional medicine and animal nutrition. It is traditionally regarded as an important alternative treatment for a variety of conditions, including pharyngitis, diarrhea, congestion, cold, inflammation, and gastric irritation. The investigation of the applications of these organisms has the potential to benefit the economy of the UAE through large-scale application. Several studies were conducted to assess the viability of incorporating *Acacia tortilis* fibers into fiber-reinforced polymer composites. One study revealed that the chemical composition and tensile properties of *Acacia tortilis* fiber are comparable to those of common natural fibers [12]. According to the findings of another study, *Acacia tortilis* fiber reinforced polyester composites have comparable strength and Young's modulus when compared to conventional natural fiber reinforced composites [13]. *Aerva javanica*, also known as kapok shrub and Desert cotton, is a perennial plant belonging to the Amaranthaceae family. It has delicate wood, multiple stems, broad foliage, and a maximum height of 1.6 meters. *Aerva javanica* is a prevalent and widespread plant in the UAE, particularly in the northern Emirates, and it has many traditional applications, including camel saddles and cushions, diuretics, as an antidote for poisoning, and for treating wounds and halting bleeding. *Aerva javanica* fiber, has been shown in experiments to be less dense than conventional fibers, have a lower weight, and provide great potential for use in the creation of eco-friendly composites [14].

The purpose of this study is to extract and characterize the chemical composition and physical properties of *Acacia tortilis* bark and *Aerva javanica* flowers (natural visible fibers) to assess their potential to be used as natural fiber composite [15,16].

Methods

Sample collection

Acacia tortilis bark and *Aerva javanica* flower parts were collected from the Fujairah region in UAE. The gravimeter was used to determine the ash content, density, and moisture.

Chemical composition

To determine the cellulose content of *Acacia tortilis* bark and *Aerva javanica* flower parts, the following formula was used by considering the cellulose as polysaccharides that are carbohydrate basis since we were unable to perform Lignin test determination.

$$(C_6H_{10}O_5)_n$$

Gravimetric analysis was performed to determine the ash content of *Acacia tortilis* bark and *Aerva javanica* flower parts. The sample was weighed and then heated to 600°C for a period of two hours. After ashing the weight of the sample was measured to determine the concentration of ash present. The ash content was determined based on the gravimetric loss. Lastly, the following equation was used to calculate the ash content.

$$Ash\ Content\ (\%) = \frac{Initial\ sample\ weight}{Final\ ash\ weight} * 100$$

Characterization of the physical properties

Moisture content was measured using the gravimetric method. The sample was weighed, oven dried until there was no further mass loss, then reweighed. After, the moisture content was calculated using the following formula.

$$Moisture\ Content\ (\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} * 100$$

The density of *Acacia tortilis* bark and *Aerva javanica* flowers was measured using gravimetric analysis. The samples were weighed once in the air and once in distilled water as an immersion liquid with a known density. Finally, the density was determined using the following relation.

$$\rho_{AT/AJ} = (\frac{m2 - m1}{(m3 - m1)(m4 - m2)})\rho_w$$

where m1 is the mass (g) of the empty pycnometer, m2 is the mass of the pycnometer filled with the bark/flowers, m3 is the mass of the pycnometer filled with distilled water and m4 is the mass pycnometer filled with bark/flowers and distilled water, and ρW stands for the density of distilled water (g/cm3).

Results

The mechanical properties and other properties such as the degree of biodegradability of the natural fibers are influenced obviously by the content of chemical compositions. As described in Table 1 *Acacia tortilis* bark contained cellulose ash, moisture and density with the values 59.78%, 7.27%, 20.12% and 0.982 g/cm3, respectively. Similarly, the *Aerva javanica* flower contained only 29.46% cellulose, 5.41% of the ash contents, 54.80% moisture contents and 0.802 g.cm3 density.

Samples	Cellulose (%)	Ash (%)	Moisture (%)	Density@25°C (g/cm3)
Acacia tortilis (bark)	59.78	7.27	20.12	0.9820
Aerva javanica (flower)	29.46	5.41	54.80	0.08020

Table 1: Chemical composition, moisture and density of *Acacia tortilis (*bark) and *Aerva javanica* (flowers).

The comparison of both plants has been done with the other natural fiber producing plants with properties extracted from literature (Figures 1 to 3). Compared with other common natural fibers, *Acacia tortilis* (59.78%) and *Aerva javanica* (29.46%) have lower cellulose content than Sisal fiber (66.5%) (12), Flax fiber (66.5%), Hemp fiber (71%) and Jute fiber (65%) (13) as illustrated in (Figure 1). The ash content was reported in Tables 1 and 2 to be (7.27%) for *Acacia tortilis* bark and (5.41%) for *Aerva javanica* flowers. As illustrated in (Figure 2), compared with palm leaf fiber (9.0%), *Acacia tortilis* and *Aerva javanica* have lower ash content. The density of the Jute and Flax fibers are 1.25 g/cm3 and 1.5 g/cm3, respectively.

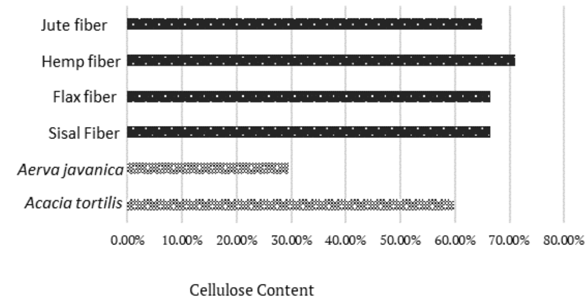

Figure 1: Cellulose content of *Acacia tortilis, Aerva javanica* and common natural fibers.

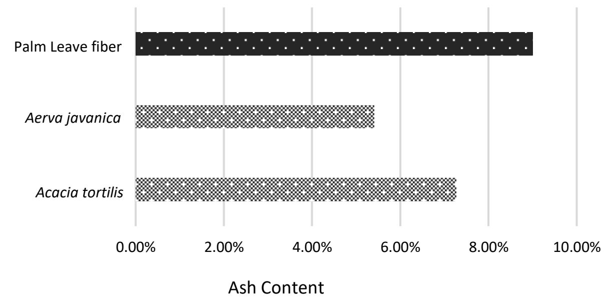

Figure 2: Ash content of *Acacia tortilis, Aerva javanica* and Palm leaf fiber.

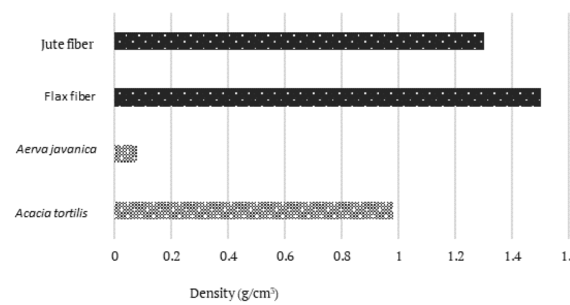

Figure 3: Density of *Acacia tortilis, Aerva javanica,* Flax and Jute fibers.

Discussion

These results provide valuable insights into the composition and characteristics of *Acacia tortilis* and *Aerva javanica* plant samples.

Cellulose is a complex carbohydrate and a major component of plant cell walls. *Acacia tortilis* bark contained a higher concentration of cellulose content which enhances the tensile strength and rigidity of the fibers and provides enormous mechanical strength contributing to the structural strength of the fiber. The comparison of *Acacia tortilis* (bark) with other plant samples, such as Jute fiber, Hemp fiber, Flax fiber, Sisal fiber, and Palm leaves, reveals variations in cellulose content, ash content, and density. *Acacia tortilis* (bark) exhibits a lower cellulose content compared to Jute fiber, Hemp fiber, Flax fiber, and Sisal fiber. These differences can be attributed to various factors, including the origin of the plant, plant type, and structural characteristics [17,18]. Cellulose content varies among these samples, suggesting differences in the composition of plant cell walls and their respective roles in providing strength and support. The ash content of *Acacia tortilis* (bark) is comparable to that of Palm leaves. The ash content discrepancy indicates variations in the accumulation of minerals or inorganic components within the plant tissues, potentially influenced by the soil composition and nutrient uptake. The low ash content has a significant effect on the flexural properties of composites. Density determines the application of natural fiber with other properties. Similarly, the density comparison also exhibits slightly lower, but comparable results. The differences in density can be attributed to the density of plant cell walls, cellular arrangement, and the presence of additional components within the tissues.

On the other hand, *Aerva javanica* (flower) has a significantly lower cellulose content compared to Jute fiber, Hemp fiber, Flax fiber, and Sisal fiber. Overall, *Aerva javanica* shows a lower amount of content than other plants in the study. These variations in values can be attributed to the different parts of the plants used for analysis, as well as variations in the plant species and their structural composition.

These variations emphasize the diverse nature of plant species and highlight the unique properties and applications of each plant sample in different industries, such as textiles, construction, and agriculture. Soil plays a critical role in nutrient uptake of the plant. The arid soil of UAE, despite its challenging conditions, has proven to be capable of producing comparable nutrient levels necessary for plant growth and development. This study provides a base for the extensive assessment of both the plant's *Acacia tortilis* and *Aerva javanica* to be used as green fiber composites. Future studies include extraction of the fibers from different parts of the plants, and evaluation of their strength using alkali and non-alkali treated fibers which would lead to further assessment.

Author Contributions

Aisha Mohamed Ahmed Alkaabi involved in the experimental work and drafting the manuscript. Shaher Bano Mirza carried out the design of the overall project and prepared the final manuscript and Fouad Lamghari Ridouane participated in the overall design of the project and manuscript proofread.

Conflicts of interest

The authors declare no conflict of interest.

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