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Comparative Study of the Mechanical Performance of Jordanian Fibers and Commonly Used Ones with Polypropylene Composites

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Abstract: The intrinsic mechanical characteristics of natural fibers play a major role in enhancing the fiber composite performance to be implemented in more sustainable functional products. Thus, the proper selection of fibers is of paramount importance for natural fiber composites. This work conducts and demonstrates a comparative study for some of the commonly used fibers worldwide with other potential Mediterranean fibers found in Jordan to reveal their appropriateness for the natural fiber polymeric composites. This was performed as the commonly used fibers for various applications are usually selected upon a limited number of criteria. Here, all flax, hemp, short wood, banana and jute fibers were utilized to compare their mechanical performance with other potential Jordanian fibers including lemon, corn, and fig. The study considered fibers when reinforced with polypropylene as one of the most potential type of polymers for various industrial applications. Results have revealed that Jordanian fiber/polypropylene composites have demonstrated much higher consistency regarding the tensile strength property within 39.1- 46.7MPa. All considered Jordanian fiber based composites have exhibited more steady behavior regarding the tensile strength property and were less sensitive to the fiber content comparable to the commonly used fibers. This in order would enhance their selection for being potential for producing composite materials with reliable and stable properties. This obviously reveals the importance of the Jordanian fibers in reinforcing polymers and opens the door for finding other potential fibers worldwide as well as enhances a better understanding of the role of fiber intrinsic properties in the field of natural fiber composites.

Keywords: Natural fiber; polymeric composite; mechanical performance; polypropylene; fiber selection.

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1. Introduction

Due to the widespread consumption of conventional materials in modern societies, metals as well as man-made (artificially created) materials have come to an end. The usage of naturally accessible constituents in the place of conventional materials is becoming more popular in the twenty-first century [1-4]. Many academic researchers and scientists have advanced their research on natural fiber composite materials. The naturally occurring fibers are used as a raw resource in a variety of applications such as housing insulation, non-woven textures, among others [5, 6]. However, natural fibers are now utilized in producing polymeric based composites for several applications. It is difficult to incorporate them into all types of polymers, and have some technical difficulties in producing such natural fiber composites due to the mismatch between their hydrophilic nature and the hydrophilic traits of polymers [7-9]. However, chemical and physical treatments can reduce the effect of such an issue. Natural fiber-reinforced composites have been used in a number of automotive accessories, including dashboards, rooftop panels and gate panels. In the meantime, various types of fiber have been used in a variety of structural and non-structural installations, including suitcases, post boxes, partition boards, grain storage car interiors, and indoor implementations. Polymer-based composites with such a range of natural fibers have exploded in popularity in recent years all over the world. Coconut, ramie, rice husk, sisal, flax, hemp, banana, kenaf, date, palm and jute are some [10-12]. They are utilized as reinforcements for the polymer matrices to enhance the mechanical performance particularly, the specific ones. Hybridization is a major area in composites that improves their mechanical properties significantly. As a result, it becomes popular to detect various types of natural fiber- composites lead to develop new methods for determining composite qualities as well as proper selection schemes for green products including the analytical hierarchy process [13-22].

The modern world is confronted with the difficult task of developing new advanced technologies and techniques for disposing of or making use of solid wastes, especially non-reversible polymers. The procedures for breaking down those wastes are inept, and as a result, hazardous chemicals will be generated. Given the above conditions, one potential way to reach a solution is to reinforce polymers with natural fibers. Regular fibers need little effort, are recyclable, have a low thickness, and are environmentally friendly. Their tensile characteristics are excellent, and they can be used to replace conventional filaments such as glass and carbon-reinforced plastics. The contrariness, which causes poor adhesion among natural fibers and polymer resins, is a significant drawback of using natural fibers as reinforcements in polymeric materials. Some theories and surface alteration techniques have been developed to strengthen the interfacial bonding among natural fibers and polymers. Moreover, the mechanical characteristics of the natural fibers play a major role in enhancing the fiber composite performance to be implemented in more sustainable functional products [23-27]. Furthermore, the strength and stiffness of natural fiber polymeric materials are highly influenced by fiber loading. Up to a certain point, increasing the fiber mass ratio increases the mechanical characteristics of the composite.

On the other hand, natural fibers are made up of various chemical components such as cellulose, lignin, pectin, and other materials. Such a chemical composition can dramatically determine the overall fibers unique characteristics and properties that encourage their implementations in the polymeric based composites as a pure polymer does not usually have requisite mechanical strength for applications in various fields [18, 28]. Strengthening polymers with high strength fibers provides the polymer with substantially enhanced mechanical properties that enable the fiber reinforced polymer composites to be suitable for a large number of diverse applications.

Accordingly, the proper selection of fibers is of paramount importance for natural fiber composites. However, the commonly used fibers are usually selected based upon limited number of criteria like availability in a certain region, mechanical properties, and moisture content. This dismisses the selection of much potential fibers worldwide. Thus, this work aims to conduct and demonstrate a comparative mechanical study for some commonly used fibers with other potential Mediterranean fibers found in Jordan to reveal their appropriateness for the natural fiber polymeric composites.

2. Methodology

Here, some of the commonly used fibers worldwide, namely; flax, hemp, short wood, banana and jute, are utilized for comparing their mechanical performance with other potential Mediterranean fibers found in Jordan, like lemon, corn, and fig, fibers when reinforced with polypropylene as one of the most potential type of polymers for various industrial applications. The desired tensile strength, tensile modulus and impact strength for the commonly used fibers are demonstrated with various reinforcement conditions, particularly the fiber content and compared to the Jordanian fibers/ polypropylene composites. The data for the mechanical performance of the commonly used fibers/polypropylene composites were collected from peer reviewed indexed journals and published in the literature [29-35], whereas the mechanical performance data of the Jordanian fiber/ polypropylene composites are gained from experimental work performed by this work. The mechanical performance of the commonly used fibers are demonstrated together according to a particular desired mechanical property to demonstrate their variations in such properties, and the Jordanian based composites are demonstrated separately to discuss their relative behavior. Then, a discussion of the overall behavior of Jordanian based composites relative to the commonly used fiber ones is illustrated to reveal their relative potential regarding the considered properties.

3. Results and Discussion

Some of the benefits associated with the use of natural fibers as reinforcement in plastics are not limited to the commonly used fibers, but for other available ones worldwide. These include being non-abrasive, biodegradability, renewability, low energy consumption and low cost. In addition, several natural fibers are characterized by low density and high-quality properties. Thus, the intrinsic characteristics of natural fibers can meet the demands of the global market and offers a potential alternative to non-renewable synthetic fibers. One way to find out the mechanical properties of materials is using the tensile test. It is used to find out the strength of material that being tested. It is also the measurement of the ability of a material to overcome forces pulling the sample apart and the extent it stretches before breaking. Tensile test can in addition give other important mechanical properties of materials such as modulus elasticity, elongation at break, and so on. The impact test on the other hand, is a method for evaluating the toughness and notch sensitivity of engineering materials and it measures here the energy absorbed by the fractured specimen of the composite materials demonstrating its suitability for the high strain rate applications.

The tensile strength of the considered commonly used fibers worldwide with Polypropylene is demonstrated in Figure1. It can be shown that various tensile strengths are available for different types of fiber base composites. The tensile strength property was also found variable with fiber loading for the same fiber type. This demonstrates that the variation within the composites does not guarantee that all the commonly used fibers are suitable or better than other fiber types available worldwide. It can also be demonstrated that some fibers can properly reinforce the polymer and enhance the tensile strength of the composite like hemp fiber, but other types did not demonstrate potential strength properties. Moreover, the desired tensile property in case of hemp reveals that strength property dramatically varies with fiber content as it was only 32 MPa for the 30 wt.% fiber loading, but reached 100 MPa in case of 55wt.%. However, other fiber types did not demonstrate tensile property more than 38 MPa for any of fiber ladings and some have only 11 MPa like that of 30 wt.% case of banana. This in order illustrates that a super fiber type concept does not exist. Although the chemical composition of natural fibers demonstrates their capabilities, a particular strong fiber may not be suitable in certain conditions to demonstrate superior mechanical properties among other types.

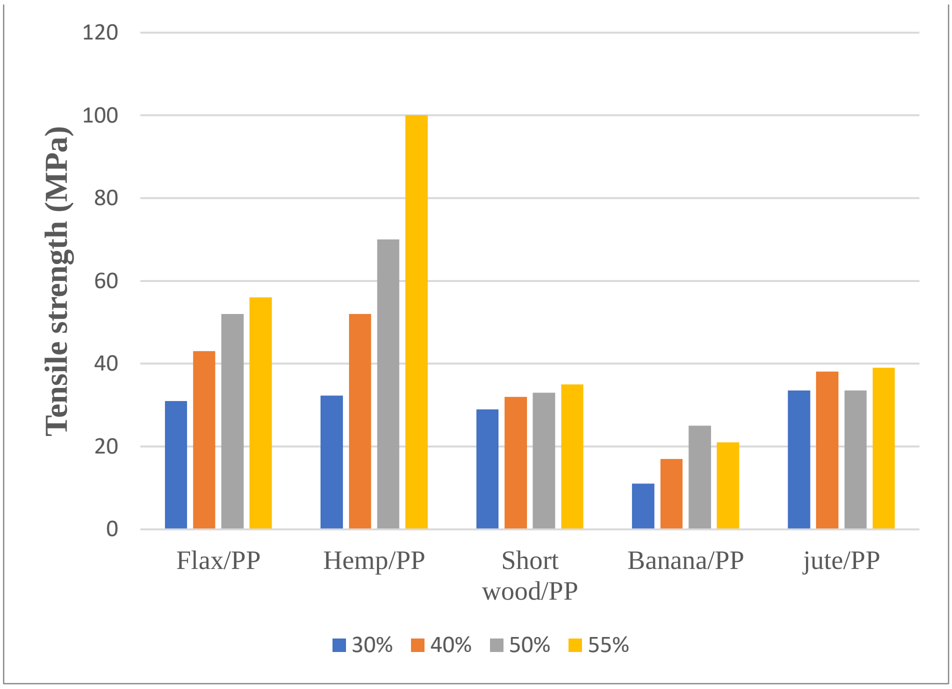

Figure 1. Relative tensile strength behavior of commonly used fiber/polypropylene composites

On the other hand, the tensile modulus property of the commonly used fiber/polypropylene composites is illustrated in Figure 2. It can be demonstrated that hemp shows the best values of the modulus among other fibers except for the 30wt.% case, and jute demonstrates better properties than other fibers and is competitive with flax in most fiber content cases. Also, the tensile modulus property was found to be variable within fiber based composites and dramatically variable with fiber content. This also illustrates that the mechanical properties of the commonly used fiber composites may not be the best among other potential fiber types worldwide.

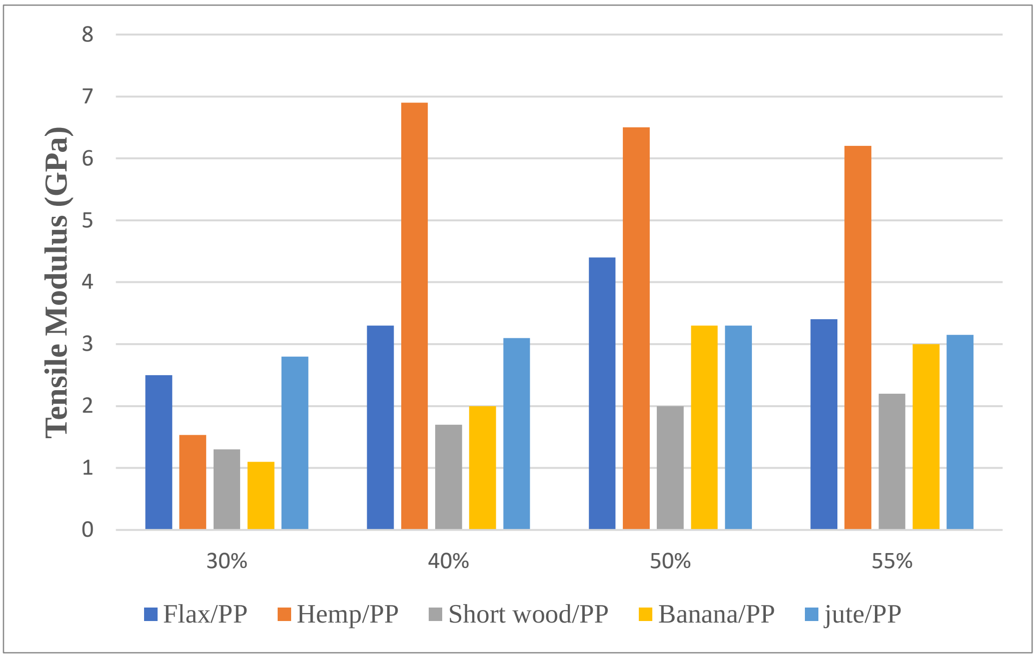

Figure 2. Relative tensile modulus behavior of commonly used fiber/polypropylene composites

The impact strength property of the commonly used fiber composites is illustrated in Figure 3. It can be noted that the only consistent composite type with fiber content regarding this property is the jute/polypropylene composite. All the other types of composites are dramatically affected by the fiber content. Moreover, hemp based composites were not the preferable at all regarding the impact strength as they were for the tensile strength and modulus properties. This absolutely demonstrates that there is no preferable fiber type that can maximize all the desired mechanical properties even at particular optimal fiber content. Flax fiber based composites demonstrates the highest impact strength property. However, it was not the best regarding other mechanical properties. Banana fiber composites on the other hand, demonstrate potential behavior regarding the impact property, but it was not recommended type of composites in other evaluations regarding mechanical behavior. This also stressed upon that other fiber types may be potential to the commonly used fibers.

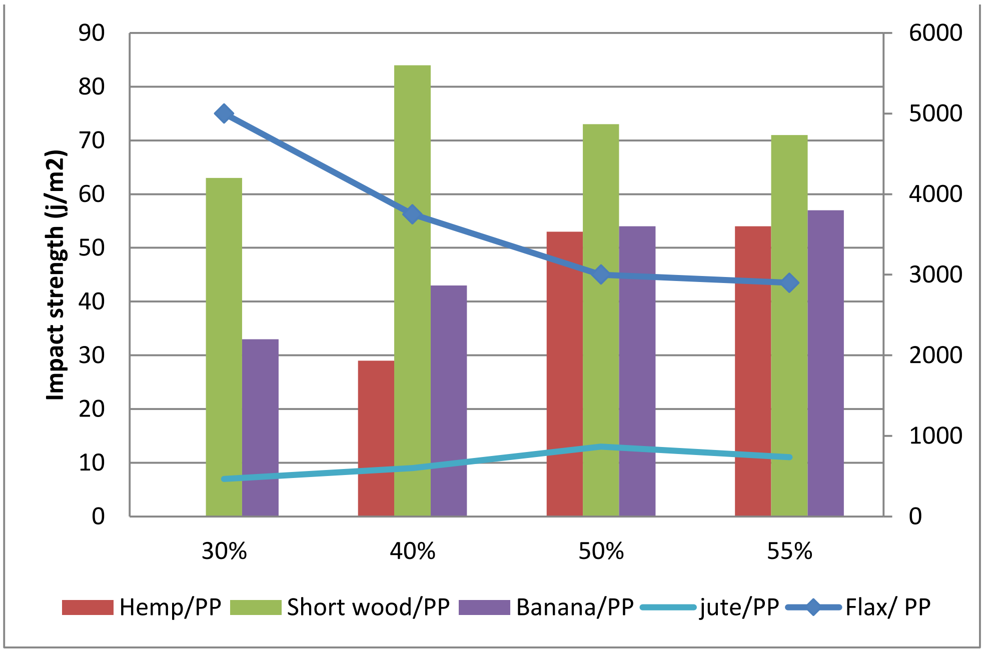

Figure 3. Relative impact strength behavior of commonly used fiber/polypropylene composites. (Right scale is for flax composites)

On the other hand, Jordanian fiber/polypropylene composites demonstrate much higher consistency regarding the tensile strength property as demonstrated in Figure 4. All of the fiber composites demonstrate more steady behavior regarding the tensile strength property as they are not much varied with fiber content as the commonly used fibers did. This in order enhances their selection and potential for producing composite materials with reliable and stable properties. The maximum tensile strength for the composites was 46.7 MPa in case of 40 wt.% corn/polypropylene case and the minimum was for fig at case of 20wt.%. The corn/polypropylene composites were better in this particular mechanical property than most of the considered commonly used fiber composites. Moreover, most of the Jordanian fiber composites were better of than the most commonly used fibers including hemp at 30wt.% case. This obviously reveals the importance of the Jordanian fibers in reinforcing polymers as they can produce composites with much stable properties even at various fiber contents and open the door for finding other potential fibers worldwide as well as enhance better understanding of the role of fiber intrinsic properties in the field of natural fiber composites. Moreover, the relative tensile strength behavior of Jordanian fiber/ polypropylene composites comparable to the commonly used ones is demonstrated in Figure 5. It can be seen that the Jordanian fiber base composites have close behavior regarding their tensile strength property and are not scattered as the commonly used fibers behave. Also, the Jordanian based composite strength seems to be very competitive with other commonly used fibers and less sensitive to variations in fiber content. Figure 6 in addition, illustrates the behavior of Jordanian based composites regarding the tensile strength property relative to those commonly used fiber based composites at common fiber loadings; 30 wt.% and 40 wt.%. It is clear that the Jordanian fibers have better tensile strength property with polypropylene than most of the commonly used fibers. At 30wt.% fiber content, all of the considered Jordanian fibers perform better than all the considered commonly used fibers. Moreover, at 40 wt.% content, Jordanian corn based composite is better than all other commonly used fiber composites except hemp. Also, lemon is better than most of the considered fibers and even fig based composites are competitive and better to some other commonly considered fibers like that of short wood and banana. This tells that there is a potential for other fibers to be better than the commonly used fibers worldwide regarding various mechanical properties and may be viable alternatives to most of the near future sustainable applications considering the long term availability, renewability and cost considerations.

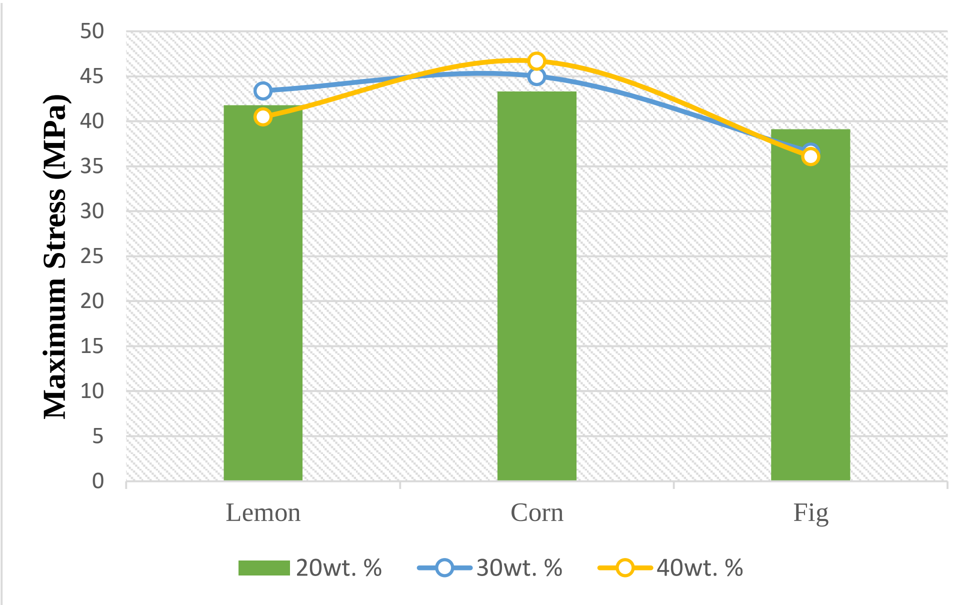

Figure 4. Relative tensile strength behavior of Jordanian fiber/polypropylene composites.

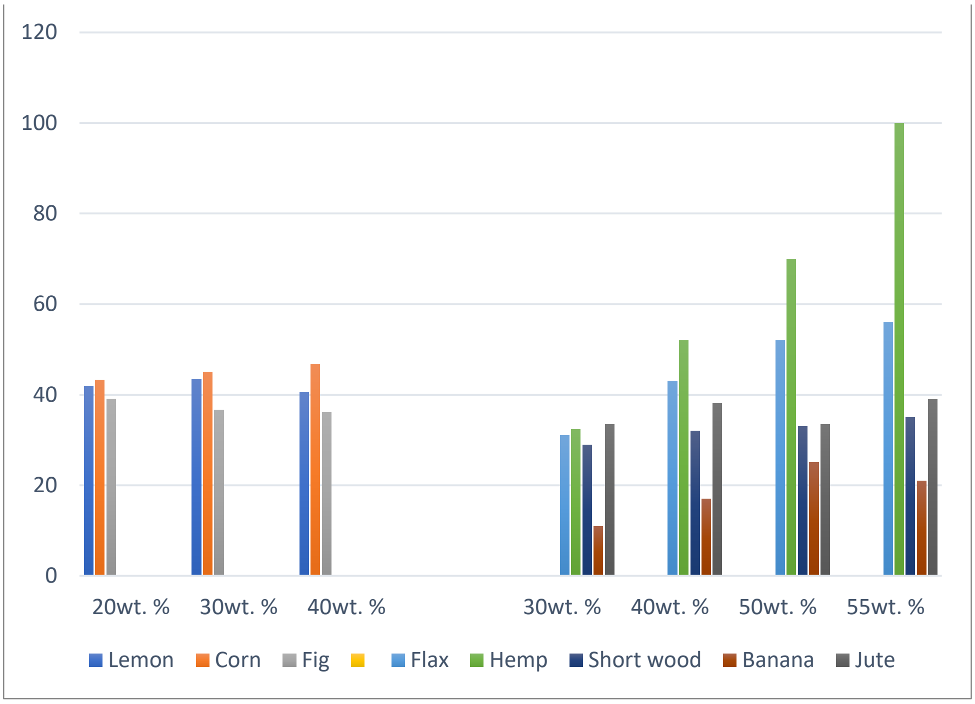

Figure 5. Comparative tensile strength behavior of Jordanian fiber/polypropylene composites with commonly used fiber ones.

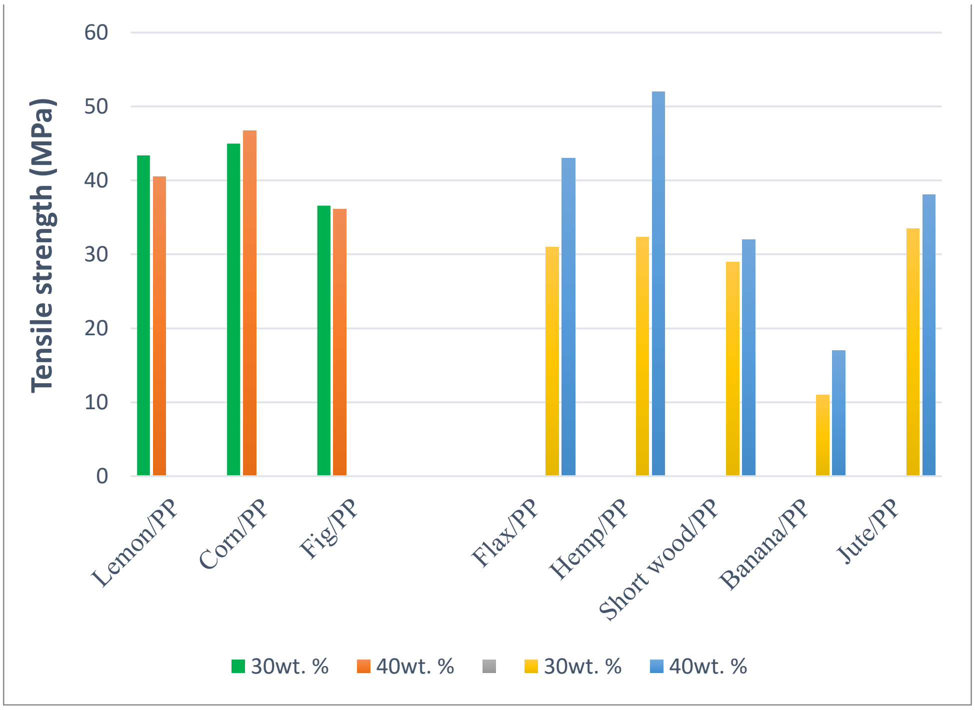

Figure 6. Relative tensile strength behavior of Jordanian and commonly used fiber/polypropylene composites at 30 wt.% and 40wt.%

4. Conclusions

This work successfully demonstrated a comparative study between the commonly used fibers and fibers found in Jordan regarding mechanical properties. The work considered the polypropylene polymer matrix for all of the considered fibers to demonstrate the relative behavior of the commonly used fibers and Jordanian ones. It was demonstrated that Jordanian fibers had confirmed more consistent tensile strength with fiber loadings comparable to the commonly used fiber.

Moreover, the Jordanian/ polypropylene composites were better than the considered commonly used fibers at 30 wt.% fiber content regarding the tensile strength property. Moreover, Jordanian fibers were found competitive to all the considered commonly used fibers at various fiber contents that enable them to be potential for more reliable and steady composite material behavior for various green products. section is not mandatory but can be added to the manuscript if the discussion is unusually long or complex.

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