Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Evaluation of Mechanical Properties of Corn Husk Fiber Reinforced LLDPE Composites

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In light of the growing demand for lightweight, sustainable materials for industrial applications such as automotive components, this study investigates how low reinforcement percentages of corn husk fiber (CHF) can improve the mechanical properties of linear low-density polyethylene (LLDPE) composites. A mass balance is used to determine that the fiber weight percentage of the composite is consistently maintained at approximately 4%, 8%, 12%, and 16% (% wt/wt) in various samples. The process of compression molding is used in the production of the material. Through experimental evaluation, the LLDPE-CHF composite's tensile and flexural properties are evaluated and compared to those of LLDPE. The findings show that up to 12% fiber content in LLDPE can be improved by CHF reinforcement in terms of both modulus and tensile strength. In the composite with the highest percentage of CHF, a decrease in both tensile strength (by 34.29%) and flexural strength (by 29.55%) has been observed. Studies have shown that, in comparison to LLDPE, the tensile and flexural modulus of LLDPE-CHF initially decreases and then rises, while the tensile and flexural strength of LLDPE-CHF initially rises and then declines. When compared to LLDPE, the LLDPE-CHF composite's percentage elongation at break shows a notable decline. This type of behavior is frequently observed in LLDPE natural fiber composites.

Keywords: Corn husk fiber, LLDPE, Polymer composite, Tensile strength, Flexural strength.

1. Introduction

Extensive research in the field of polymer composites has been motivated by the search for lightweight and sustainable materials. Linear Low-Density Polyethylene (LLDPE) is a polymer that has gained popularity due to its excellent mechanical properties, flexibility, and chemical resistance. It is particularly used in the automotive and packaging industries. The durability, surface quality, and environmental tolerance of the composite are mainly the matrix's responsibility. Stress on the matrix prevents damage and cracks from spreading because the external load is evenly distributed among the fibers. This work primarily focuses on petrochemical-derived resins. A petrochemical-based matrix is a chemical composition prepared from petroleum, that is extracted from fossil fuels such as coal and natural gas. A few benefits of natural fibers are their availability, affordability, and biodegradability. The agricultural industry's byproduct corn husk fiber (CHF) offers an alluring substitute for reinforcing polymers. The two main petrochemical-based matrices used in natural fiber composites are thermosets and thermoplastics [1]. Polypropylene, polyvinyl chloride, polystyrene, and polyethylene are the matrix materials used for thermoplastic composites, whereas polyester, vinylester, epoxy, and phenol formaldehyde are used for thermoset composites.

Polyethylene exhibits exceptional chemical resistance and is minimally impacted by acids, bases, or salts. (However, it is significantly influenced by potent oxidizing chemicals.) Polyethylene is widely used due to its various advantageous characteristics, such as its affordability, ease of processing, exceptional electrical insulation properties, durability, and flexibility even in low temperatures. Additionally, it is odourless, non-toxic, and offers acceptable clarity in thin films. Moreover, it exhibits low permeability to water vapour, making it suitable for numerous applications in packaging, construction, and agriculture. Polyethylene is the predominant plastic worldwide, often employed in the production of various things such as transparent food packaging, shopping bags, detergent containers, and automobile fuel tanks. Additionally, it can be severed, transformed into synthetic fibers, or upgraded to acquire the elastic properties of rubber. LLDPE exhibits a markedly superior stress-crack resistance compared to LDPE of identical melt index and density. Puncture resistance, tensile strength, elongation at break, and resistance to extreme temperatures could also be evaluated in a same manner. LLDPE allows the manufacturer to build a product that is more robust at the similar thickness or equally robust at a reduced thickness. LLDPE offers significant advantages due to its lower energy requirements during polymerization and its ability to modify the properties of the polymer by modifying the type and amount of its chemical components. LLDPE is a very suitable material for injection-moulded items used in household goods, closures, and lids due to its favorable flex properties, resistance to environmental stress-cracking, high impact strength at lower temperatures, and minimal warping. LLDPE extruded pipe and tubing exhibit excellent resistance to bursting and stress-cracking.

A few benefits of natural fibers are their availability, affordability, and biodegradability. The agricultural industry's byproduct corn husk fiber (CHF) offers an alluring substitute for reinforcing polymers. Plant fibers have a very complex structure made up of a cell wall and a lumen, which is the central channel. The primary wall, secondary wall, and middle lamella are the three main parts of the cell wall. When it comes to the mechanical characteristics of plant fiber, the middle lamella is the most important part. The primary wall contains a disorganized arrangement of cellulose inside the pectin, hemicellulose, and lignin matrix. The secondary wall contains crystalline cellulose, which is categorized into three categories based on its location inside the fiber. Water transfer occurs via lumens. Figure 1 provides a comprehensive depiction of the intricate composition of plant fiber [].

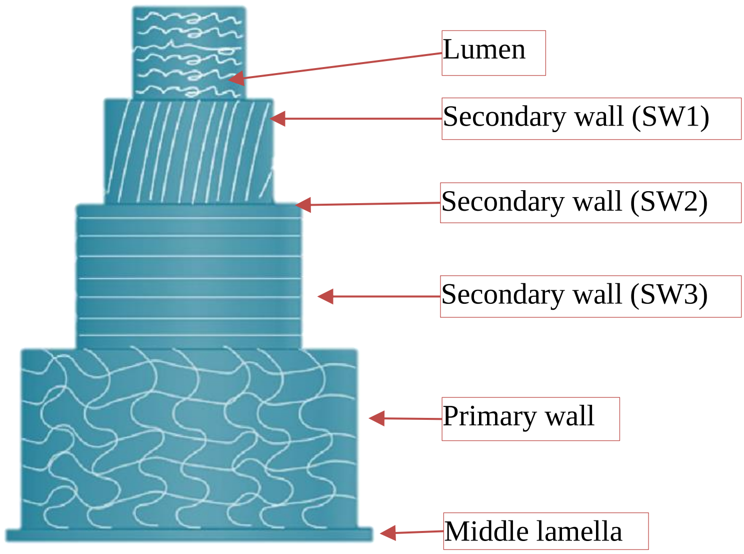

Figure 1 Structure of natural fiber [1].

The tensile properties of the natural fibers can be seen in Table 1 [-4].

Table 1 Tensile properties of popularly utilised natural fibers [2-4].

Fibres	Tensile strength (MPa)	Tensile modulus (GPa)	Elongation at break (%)
Banana	51.6-55.2	3.00-3.78	1.21-3.55
Coir	180	04-06	30
Corn stalks	33.40-34.80	4.10-4.50	1.90-2.30
Hemp	690	30-70	1.5-4.0
Kenaf	930	53	1.6
Oil palm	227.5-278.4	2.7-3.2	2.13-5.00
Sisal	100-800	09-22	3.0-7.0
Sugarcane	257.3-290.5	15-18	6.20-8.2
Wheat	10-200	01-12	2.7

2. Literature review

Previous studies have demonstrated the potential of natural fibers in enhancing the mechanical properties of polymer composites. According to Dirgantara and Kurniati [], it was found that the composite material consisting of CHF and LLDPE at a 30% CHF loading exhibited superior mechanical properties. Specifically, this composite demonstrated a tensile strength of 24.77 MPa, an elongation of 19.10%, and a tear strength of 53.94 N/mm. In comparison, composites with higher fibre loadings of 40%, 50%, 60%, and 70% did not exhibit the same level of mechanical performance. Additionally, it was noted that the greatest modulus of elasticity could be achieved when the fibres were loaded at a concentration of 50%. The modulus of elasticity of the bio-composites is reduced with further increases or decreases in fiber loading. The incorporation of a higher quantity of corn husk material results in an increased level of biodegradability within the composites. Youssef et al. [] conducted a study in which authors developed composite sheets using recycled LDPE and CHF with a particle size of 125 μm. These composite sheets were prepared using different proportions (5%, 10%, 15%, and 20%) of the CHFs, and the fabrication process involved melt compounding and compression moulding. There was no observed substantial alteration in the crystallinity index of the composites while varying the fiber loading, in comparison to recycled LDPE. The amount of reinforcement of 5 and 10% has resulted in the substantial increase in the tensile strength and Young's modulus, as compared to LLDPE. The reinforcement of higher than 10% has resulted in decrement in tensile properties but still those values were higher than the LLDPE.

In a research work, Boujelben et al. [] employed a composite material consisting of LLDPE reinforced with almond shell powder (ASP) formed using compression moulding process. The research findings indicate a gradual decrease in tensile strength as the percentage of reinforcement increases (from 5% to 40%), in comparison to LLDPE. The tensile modulus and hardness (Shore D) of LLDPE/ASP exhibit a notable improvement with higher levels of reinforcement, in comparison to LLDPE. In an investigation conducted by Jirimali et al. [], a composite material consisting of LLDPE of waste eggshell-derived calcium oxide (E-CaO) and hydroxyapatite (E-HAP), was utilized. The composite was produced by using melt compounding and subsequent injection moulding, with varying percentages of reinforcement material: 1%, 2%, 3%, 4%, and 5%. Research findings indicate that the incorporation of reinforcement material in the LLDPE/CaO composite, leads to a notable enhancement in various performance characteristics such as tensile strength, Izod impact strength, and hardness (Shore D). The study conducted by Vishnu et al. [] investigates the utilization of Areca fiber as a reinforcement material in the production of a composite material composed of LLDPE, fabricated by compression moulding with reinforcement of 5% and 25%. The study reveals a notable decrease in the mechanical properties, including tensile strength, Young's modulus, toughness, and percentage elongation, of the LLDPE/Areca composite material as in comparison with pure LLDPE material. The performance of LLDPE/Areca composite material is negatively affected by an increasing amount of Areca fiber.

Chun et al. [] conducted a study that uses the composite material of LLDPE formed using Kapok Husk fiber (KH) [], as a reinforcement material, formed by compression moulding with phr (parts per hundred resin) to be 10, 20, 30 and 40. As the amount of reinforcement increased, the tensile strength and the percentage elongation at break slowly decreased, as compared to LLDPE. Upon reinforcement of 10 phr, the tensile modulus LLDPE/KH composite is significantly increased as compared to LLDPE. As the amount of reinforcement increased, the tensile modulus slowly increased, as compared to LLDPE. In a research work, Olusunmade et al. [] conducted an investigation utilizing a composite material consisting of LLDPE reinforced with Oil Palm Mesocarp Fiber (OPMF) formed using hand lay-up moulding process with reinforcement of 5%, 10%, 15%, 20%, and 25%. The study reveals a notable decrease in both tensile and impact strength as the percentage of reinforcement increases, in comparison to LLDPE. The tensile modulus and hardness exhibit a drop following reinforcement, while demonstrating a rise with higher levels of reinforcement, in comparison to LLDPE.

In a study, Balaed et al. [] employed a composite material composed of LLDPE reinforced with Typha Latifolia Fiber (TLF) fabricated by employing compression moulding with reinforcement of 15%, 30%, 45%, and 60%. The tensile strength of the LLFPE/TLF composite was seen to be reduced compared to that of LLDPE. However, the decrease in tensile strength with an increase in reinforcement above 30% was found to be nearly insignificant. When the reinforcing content in LLFPE/TLF composite exceeds 30%, there is a gradual increase in the modulus of elasticity, relative to LLDPE. Mishra and Talele [] have conducted a study that uses the composite material of LLDPE formed using potato starch (PS) [], as a reinforcement material, formed by compression moulding with reinforcement of 5%, 10%, 15% and 20%. The performance of composite is gauged in terms of tensile strength, Young's modulus, percentage elongation at break, and hardness (Shore D). The performance of LLDPE/PS composite, in terms of all the parameters considered in this study, is found to be decreasing with increase in amount of reinforcement, when compare with LLDPE.

A study by Abhilash et al. [] uses the composite material of LLDPE formed using Wood Dust (WD) as a reinforcement material, formed by rotational moulding by adding 5, 10 and 15 wt % of WD fillers. The mechanical properties like tensile strength, flexural strength, impact strength and hardness (Shore D) of LLDPE/WD composite material with 10% WD is found to be higher than other samples. The morphological studies using images from Scanning Electron Microscope (SEM) has indicated the large void formation in case of LLDPE/WD composite material with 15% WD as compared to LLDPE/WD composite material with 5% WD. Khalil et al. [15] examines the thermal and biodegradation properties of solution-cast kenaf/cornhusk fiber reinforced corn starch-based hybrid composites film (CS/K–CH). The CS/K biocomposite film, made from physically blended corn starch reinforced kenaf, degraded faster and lost 96.18% of weight in 10 days, compared to hybrid composites that only lost 83.82%. Al-Talib et al. [16] study used abundant rice husk fiber from agricultural waste to reinforce and improve the mechanical properties of recycled HDPE/PET composite. A two-step extrusion and hot press molding process produced a recycled thermoplastic composite reinforced by rice husk (RH) fibres (70 wt%). The tensile strength and elastic modulus increased by 4.95% and 162.65% over pure recycled thermoplastic blend.

Despite these advances, there is still a gap in research on the use of CHF in LLDPE composites, particularly at lower reinforcement percentages. Corn husk fiber has proven to be a superior natural fiber for improving tensile properties. Also, LLDPE has been shown to be a better matrix material for a wide range of natural fibers. It is also worth noting that there is only one study that considers the composite formed using LLDPE and CHF, with CHF reinforcement exceeding 30%. This study aims to fill this gap by conducting a systematic investigation into the mechanical properties of CHF-reinforced LLDPE composites with fiber content levels of 4%, 8%, 12%, and 16% (wt/wt). The mechanical and flexural properties of this composite are then evaluated and compared with those of pure LLDPE. This study focuses on lower reinforcement levels in order to determine the optimal fiber content that balances improved mechanical properties with material integrity.

3. Materials and Methodology

Selection of natural fiber material

The utilization of natural fibers as reinforcement for polymer composites is regarded a viable strategy for eco-reuse, as these fibers are typically considered waste. Natural fibers has superior strength and aspect ratio, making them highly effective in reinforcing composite matrices as opposed to artificial fibers []. Wood plastic composites can be replaced with environmentally sustainable options that utilize polyethylene resins. These alternatives effectively minimize or prevent the release of formaldehyde into the atmosphere. In response to the recent surge in interest in recycling, researchers choose to create composites by utilizing a post-consumer plastic that has been granulated, specifically LLDPE []. Additional substances can also be used to enhance the quality of the composites by removing undesirable characteristics. Various types of fibers, powders, and flours have not been thoroughly investigated for their potential composites with LLDPE. Examples of fillers include different types of discarded grains, brans, or husks, like corn husk, [] as well as natural fibers derived from agro-industrial waste, such as agave fiber []. The structure of corn husk has been found to closely resemble that of cotton fiber []. Nevertheless, its crystallinity is inferior compared to the three predominant natural cellulosic fibers, namely cotton, linen, and jute []. The fibres derived from cornhusk demonstrate enhanced elongation, greater moisture absorption, and increased surface area for chemical reactions due to its reduced crystallinity []. The features of corn husk include moderate strength, increased toughness, lower modulus, and greater elongation, which together provide a unique combination. These characteristics enhance its resilience, flexibility, and smoothness. CHF was chosen due to its abundance as an agricultural by-product, its potential to be repurposed into valuable composite materials, and its alignment with environmental sustainability goals by reducing reliance on synthetic fibers.

Figure 2 Photograph of Corn husk.

The primary components of corn husk are cellulose, hemicellulose, and lignin. Hemicellulose and lignin are tightly bound to the cellulose microfibril bundles. The composition of these components in a fiber changes depending on the age, source of the fiber, and the extraction procedures employed to obtain the fiber [,]. The chemical composition of corn husk, as depicted in Table 2, exhibits variations depending on the source. This phenomenon is commonly observed in most natural materials. This mutation is likely associated with the landraces of corn [].

Table 2 Chemical constituents of corn husk cultivated worldwide [2-4]

Source of corn husk	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash content (%)
Malaysia	45.7	35.8	4.03	0.36
Nusa Tenggara Barat Province, Indonesia	46.5	33.79	13.92	0.33 (silica)
Sonepat, India	49.56	21.24	13	----
Thailand	56.39 ± 0.20	21.93 ± 0.57	7.64 ± 0.27	3.65 ± 0.01
Mumbai, India	50-55	39.39	7.5	1.16
Rajshahi, Bangladesh	45.13 ± 0.87	31.15 ± 0.55	14.32 ± 0.23	----

Studies have indicated that fibers with a greater cellulose content demonstrate superior mechanical characteristics []. The incorporation of CHF has shown a beneficial effect on the characteristics of HDPE composites []. The study focuses on evaluating the impact of CHF, a natural reinforcement material, on the tensile and flexural properties of LLDPE composites.

Experimental Methodology

Compression moulding is a widely used process for manufacturing a variety of valuable polyethylene items. The procedure involves subjecting the polymer to elevated temperatures within an enclosed mould, while applying external pressure by compression moulding. This leads to the creation of products in the shape of sheets. Based on extensive research conducted by multiple researchers, it can be inferred that LLDPE is the preferable choice for compression moulded products among various types of polyethylene. A twin-screw extruder and compression molding were used to create the composites. Compression molding was employed subsequent to the twin-screw extruder to produce the composites. At first, LLDPE and CHF were combined in proportions of 4%, 8%, 12%, and 16% CHF by weight. By means of a hydraulic press, compression molding was applied. 150 kN was the maximum force that was applied during the compression molding procedure. The load was sustained at a temperature of 180°C for a duration of 10 minutes in order to guarantee appropriate consolidation and molding of the composite materials. Compression moulding is the recommended method for shaping LLDPE composites that incorporate natural fibers. The tensile and flexural qualities are commonly regarded as a measure of the utility of any composite material. Hence, the mechanical characteristics of LLDPE composites including natural fibers, such as tensile strength, tensile modulus, percentage elongation at break, flexural strength, and flexural modulus, will be assessed through tests conducted on a Universal Testing Machine.

Experimental Test

The corn husk was dehydrated, pulverized, and sifted to achieve a particle size of 200 μm. The chemical composition of CHFs consists of cellulose (52%), hemi-cellulose (39%), lignin (7%), and ash (2%). While the size of particles in natural fillers might vary, polyethylene powder is characterized by having particles of same size. Most of the polyethylene particles have a size ranging from 200 to 500 μm. The largest CHF particles exhibit a similar size to that of PE particles, however there are also notable quantities of lesser fractions and fillers with large aspect ratios. Numerous investigations are targeted towards the preparation of materials and products using natural fiber composite materials, utilizing transformation techniques such as thermos-compression []. Before mixing, all fibers were dried to a moisture content of 1-2% at a temperature of 80 °C. The LLDPE was initially introduced into the mixer at a temperature of 190 °C and left for a duration of 10 minutes. The blending process occurred at a temperature of 195 °C, using a rotor speed of 60 rpm. Every mixture was extracted from the mixing chamber, allowed to cool, and divided into little fragments appropriate for insertion into compression moulds, resulting in the production of test sample plates with a thickness ranging from 3 to 4 mm. Once the LLDPE matrix had melted, the corn husk fibers were introduced and the mixing process was continued for an additional 10 minutes. The compression moulding process was carried out at a temperature of 170 °C and a pressure of 10 MPa for a duration of 8 minutes. Subsequently, every sample was cooled to the ambient temperature while maintaining the pressure, prior to being extracted from the press. The fiber weight percentage of the composite in different samples is consistently maintained at around 4%, 8%, 12%, and 16% (% wt/wt), as determined by a mass balance.

Natural fibre composites generally exhibit lower mechanical properties as compared to composites constructed from synthetic fibers. Nevertheless, with suitable alterations to the natural fibers and matrices, and by employing the techniques already mentioned, these characteristics can be enhanced. The adhesion at the interface between the resin and fibers greatly affects the tensile properties of natural fiber composites. The fiber and resin can undergo physical and chemical treatments to enhance the tensile qualities of the composites. The tensile strength, tensile modulus, and elongation at break are determined by using universal testing machine (Figure 3).

Figure 3 Universal testing machine

Samples are prepared in accordance with the American Society for Testing and Materials

(ASTM) D638 standard, using samples in the form of dumbbells, as can be seen in Figure 4.

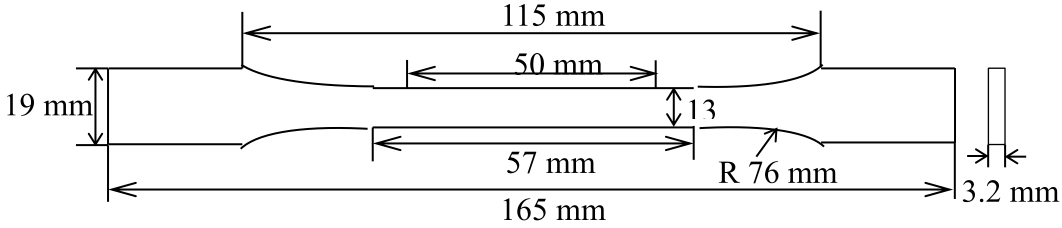

Figure 4 Samples prepared for tensile testing in accordance with ASTM D638 standards

Flexural stiffness is a significant parameter for assessing a composite material's ability to withstand bending deformation. The composite material's modulus and moment of inertia are the primary elements that significantly impact flexural characteristics. Flexural tests are conducted using a universal testing machine in accordance with the ASTM D 790 standards, as can be seen in Figure 5.

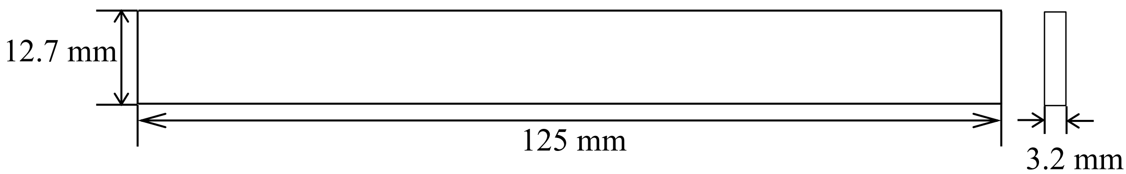

Figure 5 Samples prepared for flexural testing in accordance with ASTM D790 standards.

4. Result and discussion

Tensile strength

Figure 6 indicates the influence of the quantity of reinforcement of CHF on the tensile strength of the LLDPE–CHF composite. It is evident that the tensile strength of the LLDPE-CHF composite increases initially with an increase in the amount of reinforcement, but later decreases. The observed pattern is consistent with the findings of prior research [**Error! Bookmark not defined.**] on composites produced with natural fiber particles as a reinforcing agent. Typically, the aspect ratio of natural filler particles is small, resulting in poor stress transfer. Hence, the inclusion of additional CHF resulted in a decrease in the tensile strength of the LLDPE matrix. The tensile strength of pure LLDPE (0% reinforcement) is around 17 MPa. Tensile strength initially increases with the addition of CHF, peaking at 4% CHF reinforcement at around 19 MPa. As the reinforcement content increases to 8%, the tensile strength remains high, at around 18 MPa. However, beyond this point, a gradual decrease in tensile strength is observed. At 12% reinforcement, the tensile strength drops to about 14 MPa, and at 16% CHF content, it drops to around 12 MPa. The results show that a CHF content of 4% to 8% improves tensile strength in LLDPE composites, making them suitable for applications that require improved mechanical performance without compromising material integrity. Furthermore, the insufficient transmission of stress between the filler and matrix was ascribed to the feeble interfacial bonding between the hydrophilic CHF and hydrophobic LLDPE matrix. Nevertheless, certain polymeric-coupling agents can be employed to augment the characteristics of LLDPE-CHF composites. Past studies have investigated the use of polyethylene-grafted acrylic acid (PEAA) as polymeric coupling agents, and have found that it improves the characteristics of composites [**Error! Bookmark not defined.**].

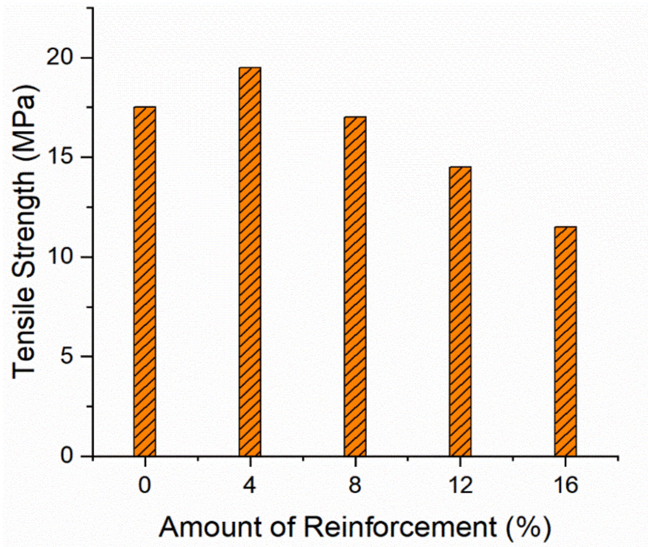

Figure 6 Effect of amount of reinforcement of CHF on tensile strength of LLDPE–CHF composite

Tensile modulus

Figure 7 indicates the impact of the quantity of reinforcement of CHF on the tensile modulus of the LLDPE-CHF composite. It is evident that when the proportion of reinforcement increases, the tensile modulus of the LLDPE-CHF composite initially decreases and then subsequently increases. The tensile modulus is expected to increase with a higher proportion of CHF owing to the filler's increased rigidity compared to the matrix, resulting in stiffer and more rigid composites. Additionally, other researchers have documented a similar result [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. The utilization of palm kernel shell powder as a reinforcement material in LDPE composites has been discovered to boost the tensile modulus when combined with PEAA []. The tensile modulus of pure LLDPE (0% reinforcement) is around 650 MPa. With the addition of CHF, the tensile modulus initially drops to around 600 MPa at 4% reinforcement. As the reinforcement content rises to 8%, the tensile modulus approaches 650 MPa. A significant increase is observed at 12% CHF content, where the tensile modulus reaches approximately 700 MPa. This trend continues with increased reinforcement, reaching a peak of around 750 MPa at 16% CHF content. These results are essential for determining the ideal levels of reinforcement to optimize LLDPE composites' mechanical performance. According to the findings, CHF contents between 12% and 16% offer the best tensile modulus enhancement, striking a balance between increased stiffness and preservation of the structural integrity of the composite.

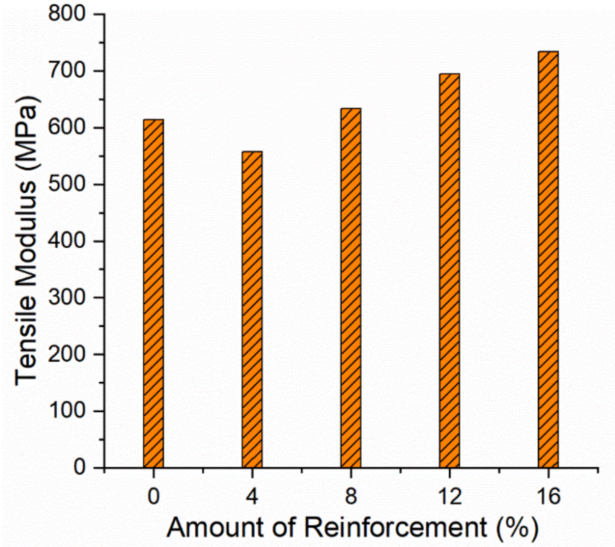

Figure 7 Effect of amount of reinforcement of CHF on tensile modulus of LLDPE–CHF composite

Elongation at break

Figure 8 demonstrates the impact of varying levels of CHF reinforcing on the elongation at break of the LLDPE-CHF composite. The increase in filler concentration in LLDPE-CHF composites led to a significant drop in the percentage of elongation at break, as is commonly observed in thermoplastic composites with natural fillers, due to disruption of the polymer's crystallinity. For pure LLDPE (0% reinforcement), the elongation at break is about 220%. The elongation at break is significantly reduced with the addition of CHF. The elongation decreases to roughly 40% at break at 4% reinforcement. Elongation at break decreases further with increasing CHF content to 8%, 12%, and 16%; for the higher reinforcement levels, this stabilization occurs around 30%. The influence of CHF reinforcement on the ductility of LLDPE composites is demonstrated by the trend shown in Figure 8. The addition of CHF significantly reduced the elongation at break, indicating a reduction in the composite's ability to undergo plastic deformation prior to fracture. When stiff natural fibers are introduced to a flexible polymer matrix, typical behavior is seen. The fibers limit the mobility of the matrix, which results in less elongation. The presence of bigger voids in the LLDPE-CHF composite leads to fracture occurring at very low elongation. As a result, the percentage of elongation, which is typically large for LLDPE, is lowered by a considerable 90% in the LLDPE-CHF composite. This is a common occurrence observed in thermoplastics containing bio-fillers [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. The CHF particles, when subjected to stress, serve as stress concentrators and can potentially induce the formation of micro-cracks. Consequently, the LLDPE-CHF composites have a tendency to fracture readily after a certain amount of initial elongation, reaching the point of break.

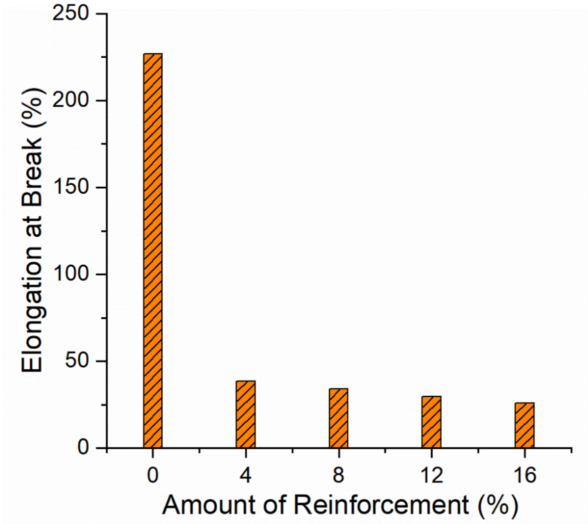

Figure 8 Effect of amount of reinforcement of CHF on elongation at break of LLDPE–CHF composite

Flexural strength

The flexural strength of the composite is enhanced by the initial addition of CHF to LLDPE, as seen in Figure 9, indicating an efficient load transfer between the matrix and the fibers at lower reinforcement levels. The increased irregularity of the composites containing CHF filler is responsible for the reduction in bending strength, leading to a decrease in flexural strength for composite with higher CHF. As expected, the use of fiber fillers resulted in increased rigidity of the LLDPE polymeric matrix. The flexural strength increase at 4% reinforcement shows that the material's resistance to bending forces can be improved by adding a small quantity of CHF. Pure LLDPE (zero reinforcement) has a flexural strength of about 22 MPa. The peak flexural strength of CHF at 4% reinforcement is increased to approximately 24 MPa. However, the flexural strength drops to about 21 MPa, 18 MPa, and 16 MPa, respectively, as the CHF content is raised to 8%, 12%, and 16%. The results hold special significance for materials subjected to bending forces in other fields, such as automotive components. Higher CHF content causes the flexural strength to initially increase before declining, indicating that there is an ideal range of reinforcement where the advantages of fiber addition are maximized without degrading the performance of the material.

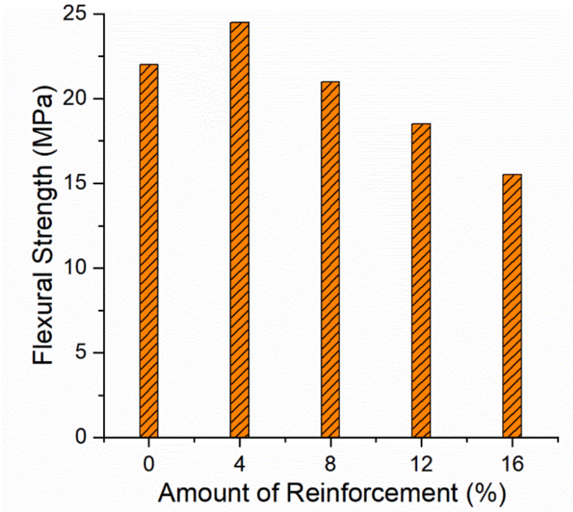

Figure 9 Effect of amount of reinforcement of CHF on flexural strength of LLDPE–CHF composite

The composite experiences a partial loss of elasticity due to the increased volume of the interphase layer in relation to the volume of the polymer, which is caused by the lowered mobility of the polyethylene macromolecule links at the fiber-polymeric matrix interface. This phenomenon is properly understood, particularly at large (16 wt%) filler concentrations. Figure 10 demonstrates the impact of varying levels of CHF reinforcement on the flexural modulus of the LLDPE-CHF composite. Pure LLDPE (0% reinforcement) has a flexural modulus of about 900 MPa. The flexural modulus first drops to about 850 MPa at 4% reinforcement when CHF is added. The flexural modulus stays constant at about 850 MPa when the reinforcement content rises to 8%. At 12% CHF content, there is a noticeable increase, with the flexural modulus reaching roughly 950 MPa.At lower fiber contents, it might be difficult to achieve ideal fiber dispersion and interfacial bonding, as indicated by the initial decrease in flexural modulus at 4% reinforcement. Higher CHF contents (12% and 16%), however, cause an increase in flexural modulus that suggests enhanced fiber-matrix interaction and improved load transfer efficiency.With a further increase in reinforcement, the trend continues, peaking at roughly 1000 MPa at 16% CHF content. Flexural modulus increases significantly at 12% and 16% reinforcement levels, indicating that CHF reinforcement is an effective way to increase the stiffness of LLDPE composites. This improvement is probably the result of the well-dispersed CHF's reinforcing action, which limits the polymer matrix's ability to deform when stress is applied. The rationale behind the enhancement of the flexural modulus is essentially identical to that described for the enhancement in the tensile modulus. The enhancement in flexural modulus may be attributed to the improved dispersion of filler inside the polymer matrix.

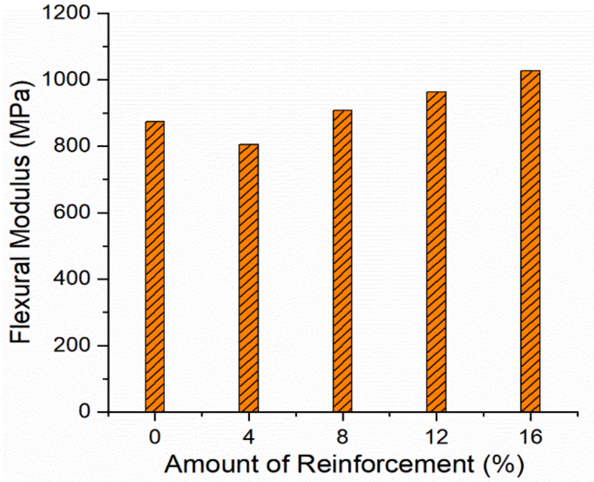

Figure 10 Effect of amount of reinforcement of CHF on flexural modulus of LLDPE–CHF composite

The rationale behind the enhancement of the flexural modulus is essentially identical to that described for the enhancement in the tensile modulus. The enhancement in flexural modulus may be attributed to the improved dispersion of filler inside the polymer matrix.

5. Conclusions

This study examined the mechanical characteristics of linear low-density polyethylene (LLDPE) composites reinforced with corn husk fiber (CHF), with a particular emphasis on different reinforcement levels of 4%, 8%, 12%, and 16% (% wt/wt). The compression moulding process produces a composite material made of LLDPE and CHF. When CHF was added, the tensile strength of LLDPE first increased and peaked at 4% reinforcement with a pressure of about 19 MPa. The tensile strength declined after this, reaching its lowest value at 16% reinforcement (about 12 MPa). This suggests that tensile strength is improved by a moderate CHF content (4–8%), but that higher contents result in diminishing returns because of poor dispersion and fiber agglomeration. The mechanical and flexural properties of this composite are then assessed and compared to those of pure LLDPE. A decline in both tensile strength (by 34.29%) and flexural strength (by 29.55%) has been noted in the composite with a highest proportion of CHF. This suggests a decrease in the amount of stress that the material can endure before failing under tensile and bending loads. A similar pattern was seen in the flexural modulus, which started at about 900 MPa for pure LLDPE and increased to 1000 MPa at 16% CHF content. This indicates that, especially at higher reinforcement levels, CHF greatly increases the stiffness of the composites. The composite with a higher proportion of CHF exhibits a rise in both tensile modulus (by 16.35%) and flexural modulus (by 14.90%), indicating an enhanced stiffness of the material in resisting tensile and bending loads. The drastic decrease in elongation at break (by 88.55%), which is a commonly recognized phenomenon in natural fiber composites, is also exhibited in LLDPE-CHF composites. By employing various moulding processes like as rotational moulding and injection moulding, one can monitor alterations in the pattern and characteristics of mechanical properties.

Conflict of interest

- The authors declare that they have no conflict of interest.
- The data used in the work will be made available upon the request to author with justification.

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