Mechanical Properties of Acrylic Laminations Resin (PMMA) Reinforced by Natural Nanoparticles and Hemp Fibers

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Abstract. The current research uses the chopped hemp fibers (HF) with a length of 0.5mm at a various mass fraction (0.0, 0.3, 0.6, and 0.9 wt%) to acrylic resin (PMMA) reinforced with 0.3% of walnut shell nanoparticles (WSP) for building up the properties of PMMA to be utilized in attachment prosthetics. Some mechanical and physical properties were studied. The results indicated that all properties were improved when the hemp fibers reached the most extreme value at 0.9% mass fraction of HF to polymer nanocomposite (PMMA: 0.3% walnut shell nanoparticle (WSP)) test. Therefore, this hybrid composite might be used for accomplishing the required properties for the prosthetic application.

Keywords. PMMA, WSP, HF, Natural nanoparticles.

1. Introduction
In the most recent years, the industry is endeavouring to decrease the reliance on petroleum-based fills and items because of the increased ecological cognizance. This prompts the need to explore environmentally friendly, maintainable materials to supplant existing ones [1]. Natural fibers have become reasonable in contrast to traditional synthetic or artificial fibers and can be utilized in less expensive, increasingly feasible, and more environmentally friendly composite materials [2]. Natural fiber-reinforced polymer composites are seen as successfully used for polymer composites in different applications due to their attractive features of lightweight, high specific modulus, renewability, and biodegradability and conceivably minimal cost over conventional glass fibers [3]. Recently, there have been numerous inquiries that evolved in the field of natural fiber-reinforced polymers. Most of them depend on the investigation of the mechanical properties of composites strengthened with short fibers. Ochi S. (2014) investigated the mechanical properties of the polymer composite materials based on utilizing long bamboo fiber and bamboo powder. The mechanical properties of composites materials were expanded with expanding the fiber and powder proportion [4]. Khalaf H. A. (2016) prepared a composite sample of the PMMA matrix reinforced by the silanized mix of Siwak and polypropylene strands. That indicated expanding the silanized Siwak and polypropylene fibers into the PMMA improves the tried physical and mechanical properties [5]. Bharathiraja G. et al. (2016) considered the mechanical properties of coir fiber strengthened polyester composites by impregnating rice husk powder and bubbled eggshell particles in the polyester. The results demonstrated improved mechanical properties when the expansion of rice husk particulate in coir fiber strengthened polyester composites [6]. Salih S. I. et al. (2017) investigated the mechanical properties of PMMA matrix strengthened by Siwak fibers of various lengths and distinctive concentrations by weight. This investigation showed an
improvement in the mechanical properties of the strengthened examples as the weight division, and fiber length increased [7]. Oleiwi K. J. et al. (2017) explored the upgrade in the tensile properties of PMMA resin strengthened with Siwak fiber and bamboo fibers, which have various lengths and proportion of weight; the results showed that the tensile strength and modulus of elasticity would, in general, be improved with expanding the fiber length and weight fraction [8]. Okeke K. N. et al. (2018) studied the flexural and impact strength of PMMA resin strengthened by hibiscus sabdariffa fiber with various weight fractions. This study indicated that the hibiscus sabdariffa improved the flexural and impact strength by increasing the weight portion of the fiber [9]. Salih S. I. et al. (2018) investigated the adequacy of including the common nanopowder of pomegranate peels (PPP) and seed powder of dates Ajwa (SPDA) in singular structure, at different weight fraction. The outcomes demonstrated an extensive improvement in the mechanical and some of the physical properties of dental replacement base resin for both groups [10]. In this research, natural nanoparticles and hemp fibers are used to reinforce a polymeric material to study the mechanical properties.

2. The materials & methods

2.1. Materials used

For hybrid composite samples, acrylic resin (PMMA) reinforced by natural nanoparticles walnut shells powder (WSP) has a particle size of 40.8118 nm. Other reinforcements hemp fiber (HF) were supplied from Iraq; hemp chopped fiber was used in this work with a length of 0.5 mm. The Atomic force microscope AFM was used to determine the size of walnut shell nanoparticle, and its distribution is shown in Figure 1. Figures 2 and 3 show the EDX test for the WSP and HF, respectively.

![Figure 1. AFM test of walnut shell nanoparticles (average diameter of 40.8118 nm).](image1)

![Figure 2. The EDX test of the walnut shell nanoparticles.](image2)
2.2. Methods
In this work, mechanical mixing was utilized to prepare hybrid polymer composites by utilizing lamination (80:20) resin as a matrix material reinforced with steady proportions of nanoparticles, composed of 0.3% of walnut shells powder (WSP) and various rate proportion of chopped fiber (hemp) (0.3, 0.6 and 0.9%). Lamination (80:20) resin mixture is set up by walnut shell powder, and hemp fiber was added to laminations (80:20) resin and afterward combined till reach to the homogenous mixture, at that point adding the hardener to laminations (80:20) resin at room temperature relative to a percentage (100/2). At last, the hybrid nanocomposite materials poured into the silicon mold and left them inside the form at room temperature around 24 hrs. as per the instructions of the provider organization. After the polymerization relieving finished, the sample as a plate was then expelled from the silicon form, with an extremely smooth upper and lower surface. Afterward, they were exposed to complete the procedure to be prepared for the resulting tests.

3. Characterization and test methods
1. The tensile test of the samples was performed based on ASTM D638. This test is finished by utilizing a universal tensile instrument with a cross-head speed of 5 mm/min [10].
2. The compression test of the samples was completed based on the standard ASTM D-695. This test is finished by utilizing a universal tensile instrument with a cross-head speed of 5 mm/min; the compression load was applied and gradually increased until the sample get broken [11].
3. The impact test is performed based on ISO-180 international standard utilizing a universal Izod impact instrument. For the Izod test, the sample was braced toward one side and held vertically as a cantilevered shaft, and it has broken by a pendulum impact of 5.5 J energy and 3.5 m/s impact velocity [12]. Impact test samples may be with or without an indent.

4. Test results

4.1. Mechanical test results

4.1.1. Tensile test. Figures 4, 5 and 6 show the tensile strength, modulus of elasticity, and elongation at break of the hybrid nanocomposites ((PMMA: 0.3%WSP): X% HF) before and after the addition of hemp fibers in terms of tensile strength. It can be seen that when adding hemp fibers in polymer nanocomposites, the tensile strength and modulus of elasticity are increased, but the elongation at

Figure 3. The EDX test of the hemp fibers.
break is decreased. This could be credited to how hemp fiber is portrayed by their high tensile strength and resistance to crack propagation contrasted with the base polymer nanocomposites. In this way, the hybrid composite samples can be completed higher load, particularly the fibers that did the enormous piece of the external stress applied on nanocomposite material sample and bearing reach for these fibers relatively with its volume division [13, 14].

The hybrid nanocomposites ((PMMA:0.3%WSP):0.9% HF) have the highest values of the tensile strength, and the modulus of elasticity was equal to 65 MPa and 2.7 GPa, respectively. The elongation at breaking was decreased with increasing the content of hemp fibers in composite, where it reached 1% at 0.9% percent ratio of chopped hemp fiber.

![Figure 4](image1.png)

**Figure 4.** The tensile strength of pure PMMA, nanocomposite sample, and hybrid composite [(PMMA):0.3% WSP): X% hemp fiber] in the specimen.

![Figure 5](image2.png)

**Figure 5.** Modulus of elasticity of pure PMMA, nanocomposite sample, and hybrid composite [(PMMA):0.3% WSP): X% hemp fiber].
Figure 6. Elongation of pure PMMA, nanocomposite sample and hybrid composite 
[((PMMA):0.3% WSP) : X% hemp fiber].

4.1.2. Compression test. The compression test resulted in the nanocomposite specimen 
((PMMA):0.3%WSP) reinforced with hemp fibers are shown in Figure 7; it is increased with 
increasing the mass fraction for chopped fibers. The increase in compression strength is due to the 
ability of fibers to strengthen the polymer and improve mechanical bonding between fibers and matrix 
(PMMA) [15]. This could be attributed to fibers absorb, transfer, and distribute the load uniformly 
throughout the cross-segment of sample hybrid composite polymer. Therefore, this leads to improving 
the compressive strength of the hybrid composite specimens [16]. The maximum values of 
compressive strength are increased from 54 MPa for nanocomposite (PMMA:0.3%WSP) to 89 MPa at 
0.9% hemp fiber.

Figure 7. Compression strength of pure PMMA, nanocomposite sample and hybrid 
composite [((PMMA):0.3% WSP) : X% hemp fiber].

4.1.3. Impact test. When hybrid composite samples reinforced with hemp fibers, the impact strength 
and fracture toughness increased with increasing the fiber content in the composite, as shown in 
Figures 8 and 9, where they reached the optimum values at 9 kJ/m² and 6 MPa√m, respectively, at 
0.9% ratio of chopped fiber, which might be upgrading the interfacial surface holding of fibers and 
matrix parts and that lead to moving the load from the matrix to fibers; this identified with the great 
wettability and great bond between the interfaces of these fibers and all constituents of the readied 
composites [17].
4.2. Physical test results

4.2.1. Density test. Figure 10 shows the relationship between the density of hybrid composite samples and the reinforcement fiber content of hemp fiber added to a sample of polymer nanocomposite (PMMA:0.3%WSP) in the form of chopped fiber at different weight fraction. It was observed that the density of nanocomposites samples slowly increased to 1.12 g/cm³ when reinforced with chopped hemp fiber at 0.9% percent.
4.2.2. Water absorption test. The relationship between the water absorption of hybrid composites and fiber content hemp in composite added to the pure polymer nanocomposite (PMMA: 0.3% WSP) is illustrated in Figure 11. It can be observed that the water absorption increases with increasing the percentage of hemp fibers content in the composites. This is because of the proclivity of the fibers towards the moisture. Furthermore, it might be because of the high moisture ingestion level of natural fibers in the polymer matrix that results from polar hydroxide bunches in the fibers [18-22].

5. Conclusions
The hybrid composites samples were prepared by adding hemp fiber (HF) to the sample nanocomposite (PMMA:0.3%WSP). The following points are concluded:-

1. A hybrid composites samples, which reinforced by 0.9% of chopped hemp fiber having the highest value of the tensile strength and modulus of elasticity, which reached 65 MPa, and 2.7 GPa) respectively, and lower value of the elongation percentage, which reached to (1%) as compared with a sample of base composite materials.

2. The compression and impact results were improved when hemp fiber (HF) was added, and precisely when it reaches the most extreme value at 0.9% mass fraction of HF.

The density of hybrid composites samples was increased and reached to the highest values at 0.9% ratio of hemp fiber, as well as the water absorption increased with the addition of hemp fiber to the nanocomposite material.
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