



Study of Physical Properties of Biocomposite Based on the Polymer Blends Used for Denture Base Applications

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HIGHLIGHTS

- Using natural particles to produce safe and healthy working environments is essential
- It was necessary to improve the properties of PMMA resin by reinforcing it with natural powders
- Composite denture base properties varied with components' types and weight fractions

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ABSTRACT

In this study, two different types of polymers—Polyamide (PA) type (6) and Polyvinylpyrrolidone (PVP) type (K30), each added separately with a different weight fraction (0%, 2%, 4%, 6%) to Polymethylmethacrylate (PMMA) heat-cured resin as blend matrix—have been blended with heat-cured PMMA resin to develop the PMMA resin properties used for prosthesis complete denture. Sisal and coconut powder, two natural powders, were added separately to the polymer blend matrices with varying weight fractions (2%, 4%, 6%) to create composite specimens. Testing for density, water absorption, thermal conductivity, FTIR, and DSC were included in this study. The results show that adding reinforcing powders and polymer blends increases density, water absorption, and thermal conductivity, except PA powder, which lowers density values. The ultimate thermal conductivity and the most negligible density value were (0.289 W/m.k and 1.182 gm/cm³), respectively, for (PMMA-6% PA). The highest water absorption value was (1.007%) for (PMMA-2% PA-6% coconut). According to FTIR and DSC tests, the miscibility between blend constituents is good, and no additional materials are formed in specimens. These findings lead to the conclusion that one of the promising composite materials that can be used for improving some physical properties of a denture base, and they are, is composed of a blended matrix and natural materials reinforcement. The materials which are used in this search are an introduction to future research in the applications of dental and other applications.

1. Introduction

A manufacturing device called a denture is used to replace missing teeth [1]. Since they are widely utilized in medicine, biotechnology, biotechnology, and dentistry, biomaterials should be nontoxic and not cause inflammatory or hypersensitive reactions [2]. The biomaterial has only recently come into being [3,4]. Numerous biomaterials are available in the medical and dental professions [5]. Polymeric-based material is often used to manufacture dentures [6,7]. Due to their unique properties, polymeric materials are an important component of dentistry since they may be used for various medical purposes that are impossible with other materials [8,9]. Acrylic resin is the most frequently employed polymer in biomedical and dental applications, especially as denture base materials [10,11]. When reinforced with several particles or fibers, the properties of polymethylmethacrylate are altered; scientists use this method to study how reinforced materials affect the mechanical and physical characteristics of composite materials [12,13].

Numerous studies have been conducted on bone, denture bases, and tooth substitutes made of composite materials [14,15]. For instance, natural and synthetic materials can be added to polymer composites as additives [16]. Natural materials can offer an excellent combination of beneficial features compared to human materials [17,18]. Natural particles have drawn considerable attention to boost polymer composites' mechanical and tribological uses [19]. Additionally, using natural particles creates secure and healthy working environments [20].

The literature survey includes several studies that have been conducted in this area, involving: aimed to determine how adding ramie and banana stem fibers would affect the acrylic denture base's ability to absorb water. 1.6% of the sample weights were added as fiber concentration. The addition of banana stem fiber had a major influence on the mean value of water absorption, followed by ramie fiber, and the free fiber/control had the slightest influence. Prawesthi et al. [21]. Examined thermal characteristics of two different polymethylmethacrylate groups reinforced with licorice and pomegranate peel powders. The

outcomes demonstrated that poly methyl methacrylate resin's thermal characteristics were enhanced by including licorice and pomegranate particles. Mohammed and Attallah [22].

Investigated the water sorption/solubility of nanoscale zirconium oxide (nano-ZrO₂) powder incorporated into heat-cured poly (Methyl Methacrylate) (PMMA) after thermocycling. Nano-ZrO₂ was added in ratios of 0%, 5%, 10%, and 20% to heat-cured PMMA. The specimens' water sorption/solubility values rose with the nano-ZrO₂ adding rate. Ergun et al. [23]. Employed heat-cured PMMA powder as the matrix, with walnut and peanut shells powder as reinforcement. These natural powders were incorporated in different weight fractions (4%, 8%, 12%) with comparable mean particle sizes (53 m) to study the density and water absorption capabilities. The findings showed that the weight fractions of both strengthening natural particles increase the density values while decreasing the water absorption values in PMMA resin by raising the weight fraction of both strengthening powders made of peanut and walnut shell powder. Abdul Monem et al. [24].

Examined the outcome of adding natural Pistachio Shell particles to PMMA. To evaluate the density property, the powder was introduced in various weight fractions (3%, 6%, 9%, 12%) with varying average particle sizes (53 m, 106 m, 150 m, 212 m%). The findings showed that when the filler particles' weight fraction rose, the composite specimens' density value increased as well. Oleiwi et al. [25]. Contrasted a few properties between traditional heat-cured acrylic resin and flexible polyamide (nylon) as the basic material for dentures. A certain dimension was followed to prepare 80 specimens, then divided into two groups. Group (A): 40 typical acrylic resin specimens. Forty samples of the base material for dentures made of polyamide, group (B). For both groups, water sorption tests were conducted. The information was gathered and statistically examined. Insignificantly increased water sorption was seen in the polyamide group compared to the traditional group. Thus, polyamide denture bases may be an alternative to heat-cured acrylic resin. Badr et al. [26].

Examined the effects of varying the volume of Al₂O₃ and SiC powders added to PMMA on thermal conductivity. Before testing, the samples were submerged in water for 30 days, and the transient hot bridge (THB) method was used to evaluate the thermal conductivity values. The addition of (15% SiC, 15% Al₂O₃) considerably improved the thermal conductivity of PMMA. Higher heat conductivity values were obtained by mixing 15% SiC powder with PMMA. Yesildal et al. [27].

There are many problems associated with PMMA denture base. To enhance the physical and mechanical characteristics of PMMA resin, natural materials reinforcements have many better properties than nonreinforced; for example, these natural reinforcements have higher thermal conductivity than PMMA resin.

This search focused on enhancing PMMA resin by using the polymer blending technique and additional natural reinforcement. Attempts were conducted to improve PMMA properties employed for denture bases and how adding PA and PVP polymers individually to the PMMA resin matrix affects the thermal conductivity, water absorption, and density properties of the polymer blend material used for dentures. Additionally, this search is conducted on how these composite material properties are affected by adding sisal and coconut powder separately to the polymer blend matrix. Using these materials introduces future research in dental and other applications.

2. Materials and Methods

2.1 Materials Used

The composite prosthetic dentures' specimen is composed of polymeric materials, which are heat-cured polymethylmethacrylate (PMMA) resin, polyamide (PA), and polyvinylpyrrolidone (PVP), and reinforced materials that are natural powders in micrometer size. The blend materials include PMMA resin mixed with (0, 2, 4, 6%) weight fractions for each PA and PVP particle individually. The matrix of composite materials included polymeric blends (PMMA + 2% for each PA, PVP) as a reference sample. PMMA material was used as powder type (Spofa Dental Company, the Czech Republic), its structural formula is [-CH₂-C(CH₃)(COOCH₃)-]_n and its average molecular weight is 350000.

The blending materials were polyamide having linear formula [-NH(CH₂)₅CO-]_n and polyvinylpyrrolidone having linear formula (C₆H₉NO)_n, both in white color and micrometer size. The reinforced materials were natural powder, including sisal powder and coconut powder, both in micrometer size, where the former has the average diameter value (0.936 μm) and the latter has an average diameter value (1.3195 μm). Figure 1 (a and b) shows particle size analysis of sisal and coconut powders. Sisal powder is light yellow, while coconut powder is brown. Where Figure 2 (a-d) illustrates sisal fiber, sisal powder, coconut fiber, and coconut powder. Each of these reinforcement powders was used in a weight fraction of (0, 2, 4, 6%) after being treated via a salinization treatment, where the saline agent used was 3-(Trimethoxysilyl) propyl methacrylate.

2.2 Preparation of Test Specimens

An appropriate quantity of PMMA acrylic resin is required for the preparation of the samples in metallic mold estimated following the manufacturing instructions, where the standard ratio 2.25:1 (powder: liquid) is used to combine the acrylic powder (PMMA) and liquid monomer (MMA), where 2.25 is the PMMA powder's weight ratio, and 1 is the liquid monomer's weight ratio. The stages were in the mixing process of PMMA and MMA (hard, rubbery, dough, sticky, sandy). It's advised to pour the powder upon the liquid in place of pouring the liquid upon the powder, the chief cause for this being to monitor the speed of the solubility of PMMA into MMA until the mix attains reaches the stage of dough stage and temperature rise. The needed pure matrix material (PMMA, MMA) weight and the weight fraction ratio selected of the blend matrix material and reinforcing materials, which are needed for filling the cavities of mold as well as in the mixture rule base, being weighed via utilizing an electronic balance having a (0.001) digits precision. The (PMMA) powder is continuously mixed at room temperature with one type of blend powder (Polyamide and Polyvinyl pyrrolidone). Then the blend matrix is mixed with reinforcing natural powder (Sisal and Coconut) to ensure that the mixture is homogenous before adding this mixture to the liquid monomer (MMA) to produce composite material samples as denture-base material. The mixture was mixed in a glass beaker which must be cleaned and dried before use; this was accompanied by gradually adding dry powder (PMMA + PA or PVP) and reinforcing natural powder, either Sisal or Coconut powders, to the liquid (MMA) by constantly shaking the beaker for ensuring the solubility of the powder into liquid as well as avoiding the accumulation (use sonication apparatus to sure no agglomerate). The beaker is concealed and kept for (10 min). Beyond such time, the mix passed through the stage of sandy and sticky and attained the stage

of dough for around 20 min (following the guide of manufacture), that's where the samples are shaped by squeezing the appropriate quantity of dough in every cavity of the mold via utilizing the fingers of a hand. Where the technique (hand lay-up) was used as previously described, and then the mold was concealed via a metallic plate having a similar area as well as the metal of the mold also it was secured via ten screws for obtaining the required pressure recommended in the industrial guide of the Spofa dental company.

The force needed to form the samples was about 2.5 bars to achieve the composite samples' smooth upper surface. Beyond the final stage, the fitted mold was positioned in a path of water where the temperature of water gradually raised till it reached (70°C) for (30 min) and remained at such temperature for around (30 min). This temperature was gradually raised till it went (100°C) for (30 min) and such temperature was installed for another (30 min). Also, such conduct aims to accomplish the procedure of the polymerization of the samples of composite as well as to improve their physical characteristics at this temperature for about (30 min). After these steps, the mold was removed from the path of water and left at the open air track for some hours, where it was cooled gradually to complete the cycle of the procedure of polymerization and reaching the lowermost level of residual monomer in the composite samples. After curing, the samples with too-smooth lower and upper surfaces were removed from the metallic mold. Then they were exposed to the finishing procedure to prepare for the following test.

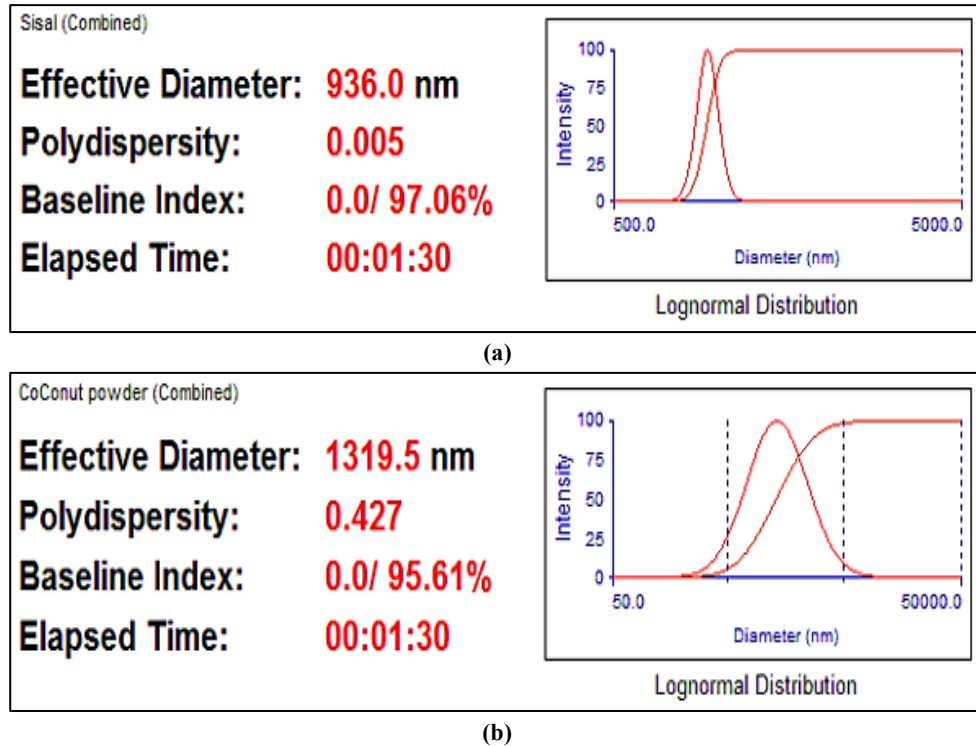


Figure 1: Particle size analysis of (a) Sisal powder and (b) Coconut powder

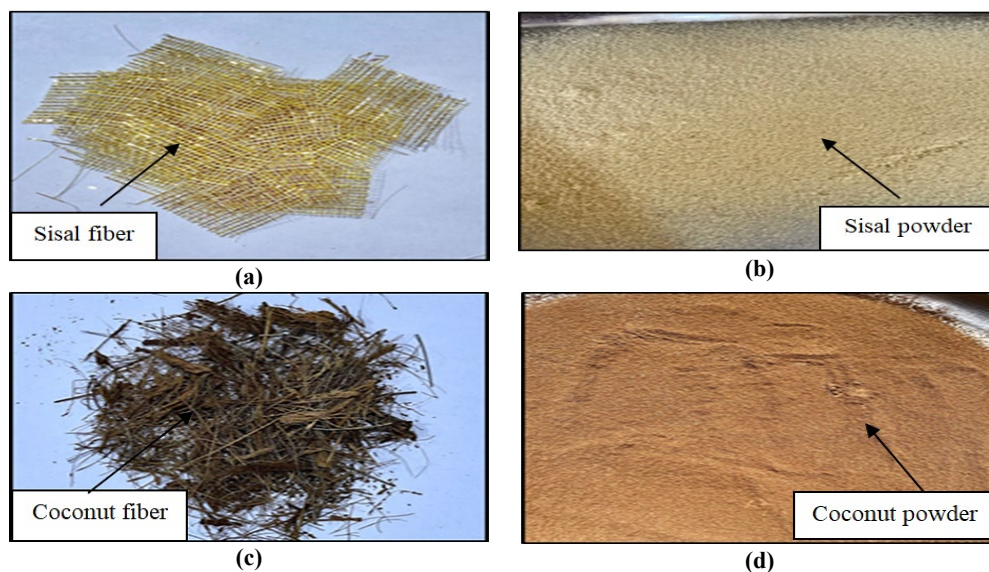


Figure 2: (a) Sisal fiber, (b) Sisal powder, (c) Coconut fiber, and (d) Coconut powder

3. Experimental Tests

3.1 Fourier Transform Infrared (FTIR) Spectrometry

This analysis was achieved following standard (ASTM E1252) via employing an FT-IR spectrometer produced via Bruker Optics Company (kind TENSOR-27). Also, such a test was done in the air after putting the specimen in the apparatus. Fourier transform analysis was conducted upon the neat PMMA's spectrum, blend, and composites strengthened via coconut or sisal powder. The infrared spectrums were determined in the absorption and were established for operating in the (400-4000 cm^{-1}) range at a specimen thickness within (0.5-1 mm) in the form of strips. All FTIR outcomes denote that the arranged specimens in the present investigation were without any remaining monomer as well as every 2nd influence, like allergenicity, responses of cytotoxicity, and bacteria [28].

3.2 Differential Scanning Calorimetry (DSC) Analysis

This analysis was done by standard (ASTM D3418) via employing a thermal analysis apparatus (differential scanning calorimeter), produced via by (Perkin-Elmer Corporation), kind (Shimadzu-DSC-60), for measuring the typical physical variations occurring in the specimen of a test, especially the temperature of glass transition. The whole analyses were achieved upon a sample having a mass of (10 mg), at a programmed DSC within (20-300°C) at a (10°C/min) rate of specimen heating for the temperature rise with a scanning till (300°C) and held at such temperature between (5 min) and (10 min) pursued via the lab temperature cooling. And, the sample is located in an Al crucible (cell) with a cover, but the reference crucible (cell) is unfilled. Also, the sample's glass transition temperature is determined from differential scanning calorimeter (DSC) spectra's tangents in temperature [29].

3.3 Density Test

The test of density was carried out under the standard (ASTM D792) by utilizing the technique of displacement depending on the theory of Archimedes. In the present test, every suitable specimen's dimension can be employed. Still, the volume must not be $< 1 \text{ cm}^3$, and the specimens' surfaces and edges must be smooth and without grease, oil, or an external substance [26].

3.4 Water Absorption Test

This test was carried out under standard (ASTM D570). In such a test, a specimen has been submerged in distilled water beneath a particular period and temperature. Via complete specimens were submerged into a distilled water vessel at the lab temperature ($23 \pm 2^\circ\text{C}$) and kept for (24 hr) upon an edge. These specimens have been taken from the water. After that, the whole surface was wiped from the water with a desiccated cloth and weighed via a digital balance [30].

3.5 Thermal Conductivity

Circular samples were prepared to perform the thermal conductivity test utilizing the disk of the Lee method with a (40 mm) diameter, and a (5 mm) thickness, under the international standard specifications. A disk device was manufactured via the Company of (Griffin and George) for the aim of achieving such a test; the Sample (S) of a test is located between the 2 discs (A and B), and the Heater (H) is located between the 2 discs (C and B), where the heat is transmitted to the following disc till it reaches the last disc. Thermometers placed inside determine the temperature of the three disks (T_a , T_b , T_c) until a state of thermal stability is reached. Applying the thermal conductivity relationship calculates the magnitude of the sample's thermal conductivity coefficient. It is significant to guarantee that the disks' surfaces, which are made of lead, are clean and that these disks are in good contact to obtain the best transition. Figure 3 shows the thermal conductivity testing machine.

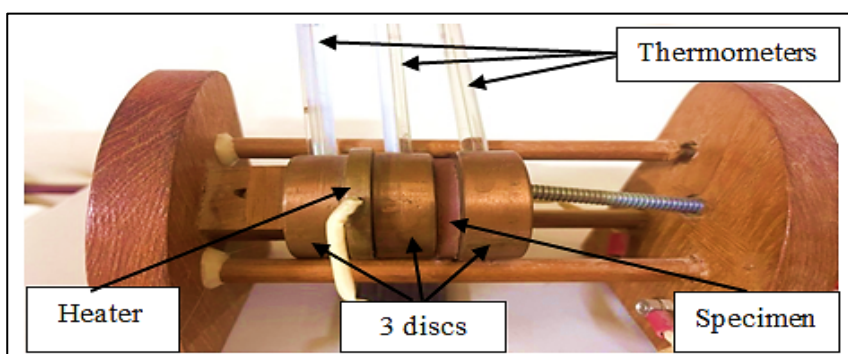


Figure 3: Thermal conductivity testing machine

4. Results and Discussion

4.1 Fourier Transform-Infrared (FT-IR) Spectrometry Analysis

The infrared spectrum of PMMA, polyamide (PA), and PMMA blended with (2%, 4%, and 6%) PA are shown in Figure 4. PMMA structural formula is $[-\text{CH}_2-\text{C}(\text{CH}_3)(\text{COOCH}_3)-]_n$. The main chain's (C-C) and (C-H) distinct groups, the ester group's (C-C, C=O, C-O) parts, and the methyl substituent's (C-C, C=O, C-O) parts all contribute to PMMA's infrared emission spectrum [31].

At 1722.55 cm^{-1} (C = O) and 1434.60 cm^{-1} (C - O), respectively, are where PMMA's primary distinctive vibration bands (ν) can be found. The bands at (1386.20-1434.60) cm^{-1} refer to (C-H) symmetric and symmetrical stretching modes, respectively, and the bands at (2853.22-2950.32 cm^{-1}) belong to the stretching of the methyl group (CH_3). The ester group (C-O) vibration correlates to the band's peak at 1186.78 cm^{-1} , whereas the methylene group (CH_2) is assigned to the (1138.52-1057.61) cm^{-1} band. The methylene group is given the 1241.79 cm^{-1} band. Using stretching bands, measure (C-C) distance (804.28–988.22) cm^{-1} and (C-H) distance (626.87–749.57) cm^{-1} [32].

As a result, the most significant features in the spectra of the reacted specimens observed in the vibration frequency range were associated with the amine group of PA particles. Figure 4 displays the infrared spectrum of PA particles. This figure shows three leading bands attributed to the amine group: (1637.34 cm^{-1} assigned to (N-H) bending and the two bands at (1167.95 and 1123.04 cm^{-1} assigned to (C-N) stretching.

As the PMMA-PA blend materials, the infrared spectrum of PMMA was combined with various weight fractions of PA particles. The (FTIR) spectra of the specimens from the PMMA-PA blend have all the characteristic vibration bands of the PMMA blend shown in Figure 4. As seen in this figure, the infrared spectrum of PMMA was blended with (2%, 4%, and 6%) PA. (1607.13, 1621.24, and 1599.16) cm^{-1} for (2%, 4%, and 6%) PA, respectively, are the locations of the (N-H) bending peaks. (1059.12, 1063.05, and 1063.32) cm^{-1} for (2%, 4%, and 6%) PA, respectively, are the locations of the (C-N) stretching peaks. As shown in Figure 4, no additional new peaks or peak shifts were seen in the (PMMA-PA) specimens because of the physical bond discovered and cross-linking absence. Peak intensity for the (C-N) peak rises with rising weight fractions of PA and reaches a maximum of 6% PA, but after that point, it begins to fall. Peak intensity for the (C-N) peak rises with a rising weight fraction of PA until it reaches 6% PA, which increases again. The reason for this behavior relates to the finding of physical bonds between the components of the blend, which is a positive sign for an improvement in the miscibility between the components and an absence of any residual monomer or contaminant that might be hazardous, allergic, or inflammatory to the human body.

Figure 5 displays the PVP particles' infrared spectrum as a point of comparison. The two bands at (1166.25) cm^{-1} ascribed to (C-N) stretching and the two bands at (1658.34) cm^{-1} allocated to (C=N) stretching are the two primary bands attributed to the amine group in this figure. As a result, the amine group of PVP particles was linked to the most significant features in the spectra of the reacting specimens seen in the vibration frequency range. The (PMMA - PVP) blend materials, which were made using various weight percentages of PVP particles, are depicted in Figure 5. In this figure, the (FTIR) spectrum of blend specimens shows all of the PMMA blend's unique vibration bands. As seen in Figure 5, the infrared spectrum of PMMA was combined with (2%, 4%, 6%) PVP. While this peak does not occur in 6% PVP (N-H), bending peaks can be found at (1597.78 and 1667.08) cm^{-1} for (2%, 4%) PVP, respectively. (1024.93-1099.79, 1020.36-1063.75, 1063.19) cm^{-1} for (2%, 4%, 6%) PVP, respectively, are the (C-N) stretching peaks. Due to the physical bond found and the lack of cross-linking in the (PMMA-PVP) specimens, no additional new peaks or peak shifts were noticed. Peak intensity for the (N-H) peak increases with increasing PVP weight fraction and reaches a maximum of 4% PVP. In contrast, peak intensity for the (C-N) peak decreases with increasing PVP weight fraction. This action is defined as physical bonds between these constituents, an encouraging sign of an improvement in the miscibility states between blend ingredients and the absence of any leftover monomer or contaminant that may be noxious, allergic, or inflammatory to the human body. Additionally, when both kinds of polymer blends were added to PMMA in various fractions, no additional peak appeared, and the peak intensities were comparable to those of PMMA. This demonstrates that the state of miscibility for all blend constituents is improving and that no byproducts or leftover monomers are toxic to humans or can trigger an allergic reaction or inflammation [33].

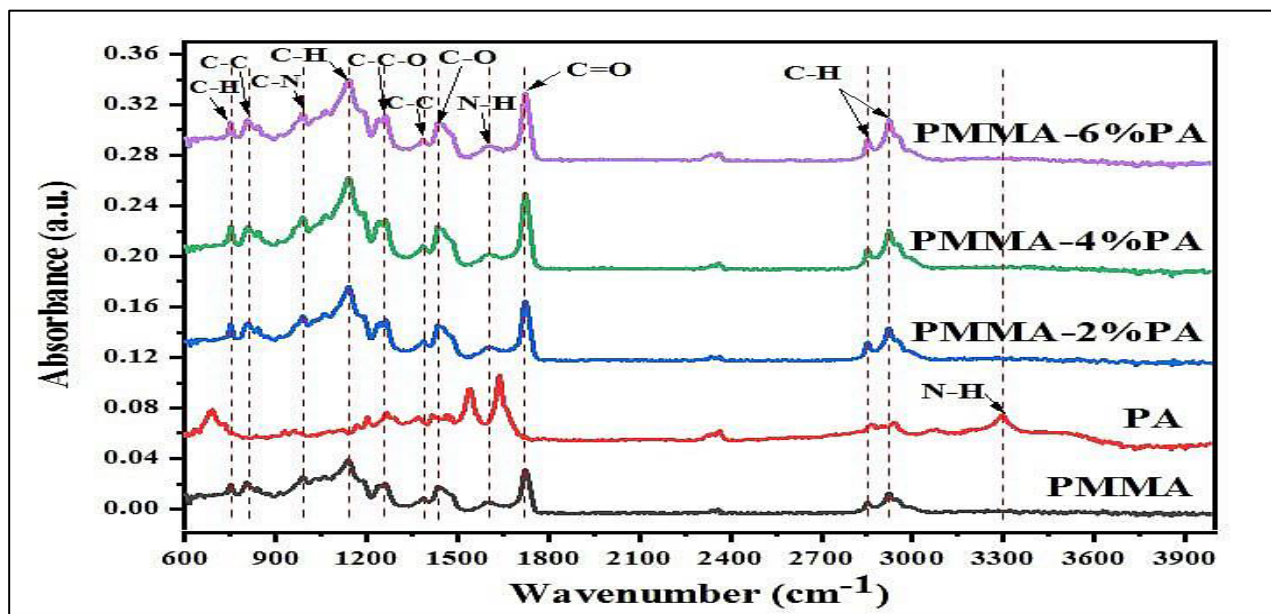


Figure 4: The Infrared Spectrum for each of PMMA, Polyamide (PA), and PMMA polymer blends as a function of PA

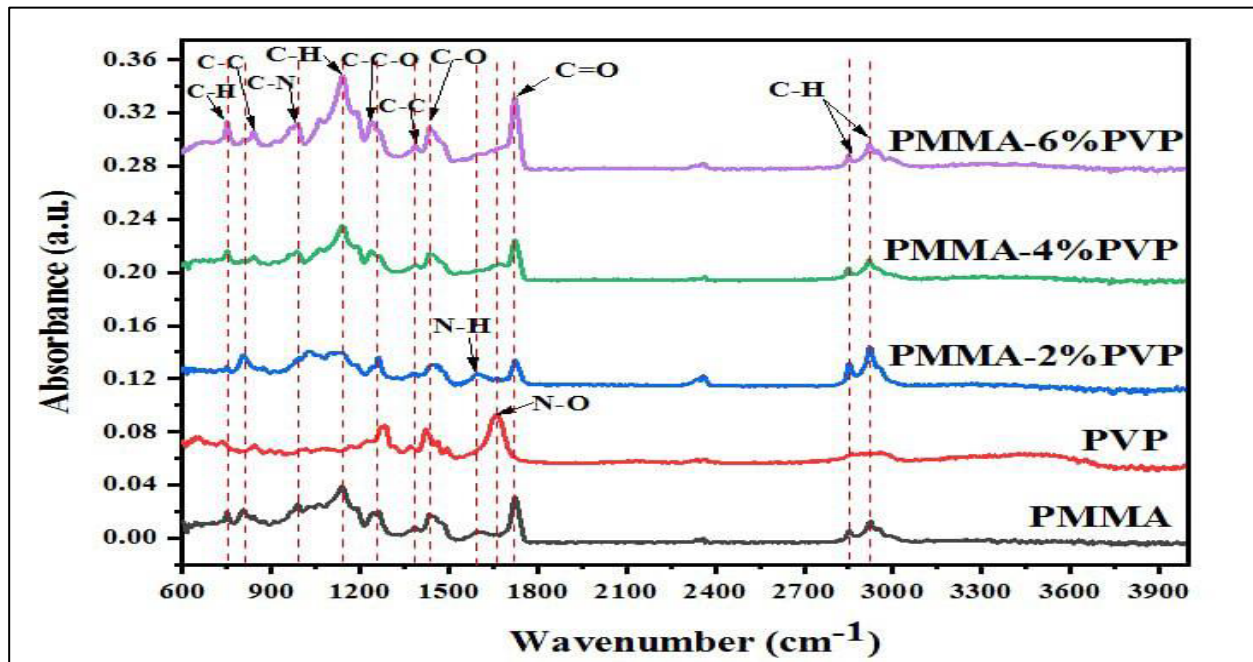


Figure 5: The Infrared Spectrum for each of PMMA, Polyvinylpyrrolidone (PVP), and PMMA polymer blends as a function of PVP

4.2 Differential Scanning Calorimetry (DSC) Analysis

This experiment assessed the thermal behavior and physical changes that occurred when the PMMA and polymer blend samples were heated. The tacticity, crosslinking, polarity, cohesive energy density, molecular weight, and flexibility of the main chain, as well as the existence of bulky or stiff side chains, are all factors that affect the T_g in polymers [34]. Figure 6 displays the differential scanning calorimetry traces for PMMA and polymer blends that occurred in the temperature range of 20°C to 250°C. As shown in Figure 6 (a), it is apparent that the glass transition temperature for PMMA is 110°C. Adding 2% PA particles to PMMA causes the glass transition temperature to drop from 110°C to 75°C, as shown in Figure 6 (b), this may be due to the nature of PA particles. As shown in Figure 6 (c), adding 2% PVP particles to PMMA causes the glass transition temperature to drop from 110°C to 73°C.

Table 1 contains the T_g values for PMMA, (PMMA-2%PA), and (PMMA-2%PVP). However, the polymer blends' DSC scans showed no appreciable additional endothermic appearances for the scan range. Additionally, when PA and PVP particles were added to PMMA, just one T_g value appeared, promoting an optimal interfacial reaction and demonstrating effective compatibility between the polymer blend's constituents. No additional material was formed in this test, supported by the FTIR information [1]

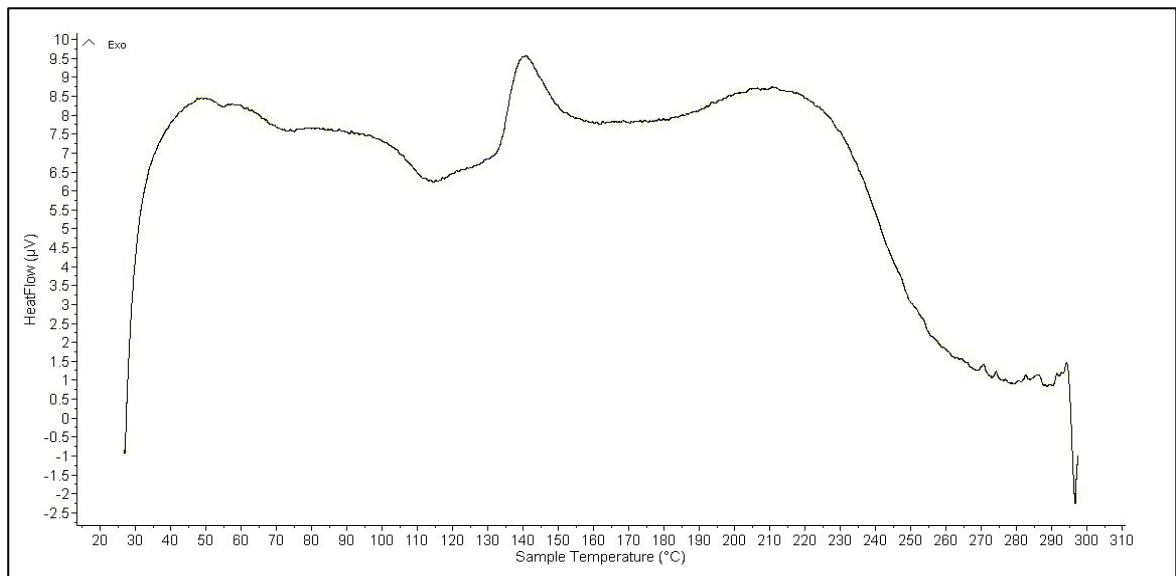
Table 1: (T_g) Values for polymer blend samples

Samples	T_g (°C)
Pure PMMA	110
PMMA + 2% PA	75
PMMA + 2% PVP	73

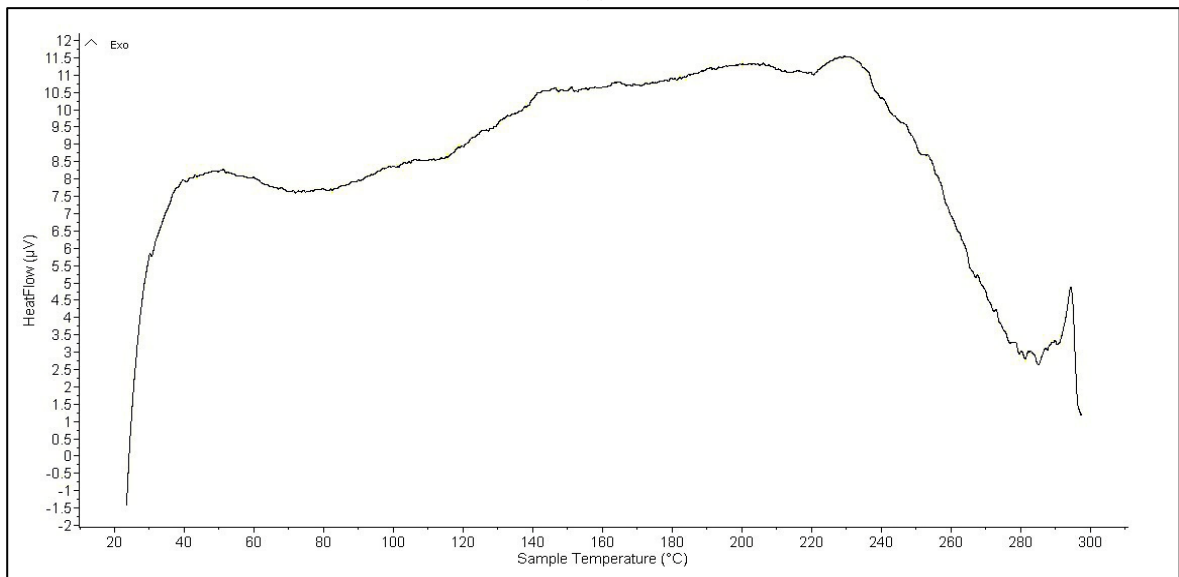
4.3 Density Test Results

Figure 7 shows the relation between the weight fractions of (PA and PVP) in PMMA resin and the density of the specimens. The density value rose as the weight fraction of PVP in PMMA resin increased while decreasing with increasing the weight fraction of PA in PMMA resin. This is because PA particles have a density value lower than PMMA resin, whereas PVP particles have a density value higher than PMMA resin. Further, it is clear from this figure that PVP additions have a more noticeable influence on the density of composite specimens than PA additions.

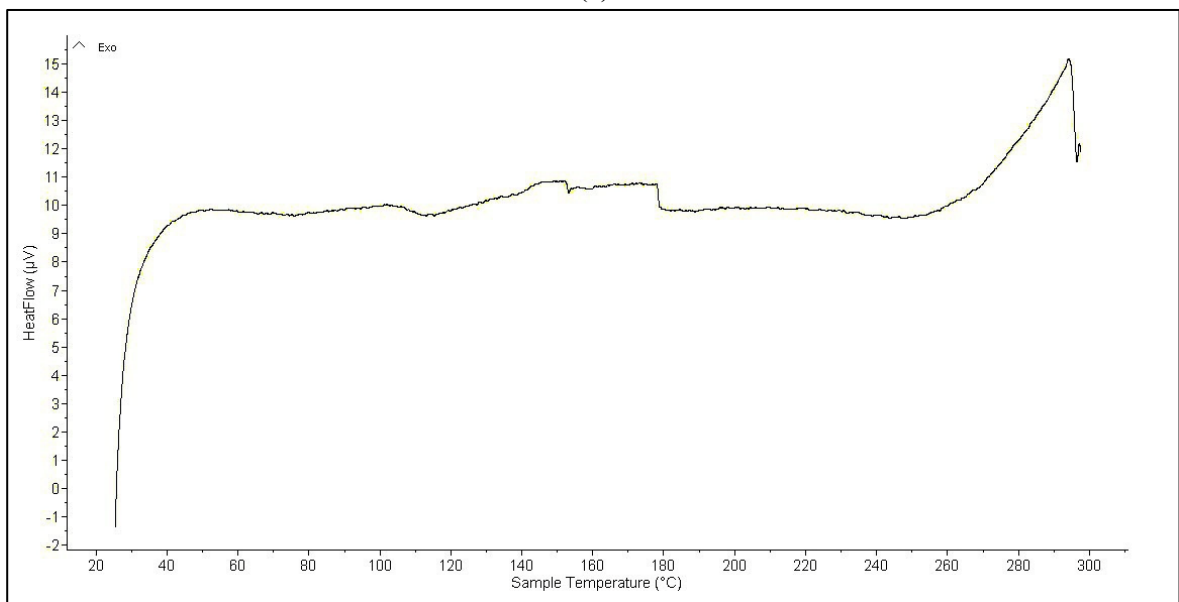
Therefore, the density values for (PVP-PMMA) composite specimens are higher than those for (PA-PMMA). This is because of the higher density of PVP particles compared to PA particles. Unlike PA particles, PVP particles can reduce or occupy voids and spaces throughout the matrix [25]. Thus, the density values decreased from (1.186 gm/cm³) for PMMA (as referenced) to (1.182 gm/cm³) for (the PMMA-6% PA) composite.



(a)



(b)



(c)

Figure 6: The glass transition temperatures for (a) Pure PMMA, (b) PMMA + 2% PA,(c) PMMA + 2% PVP

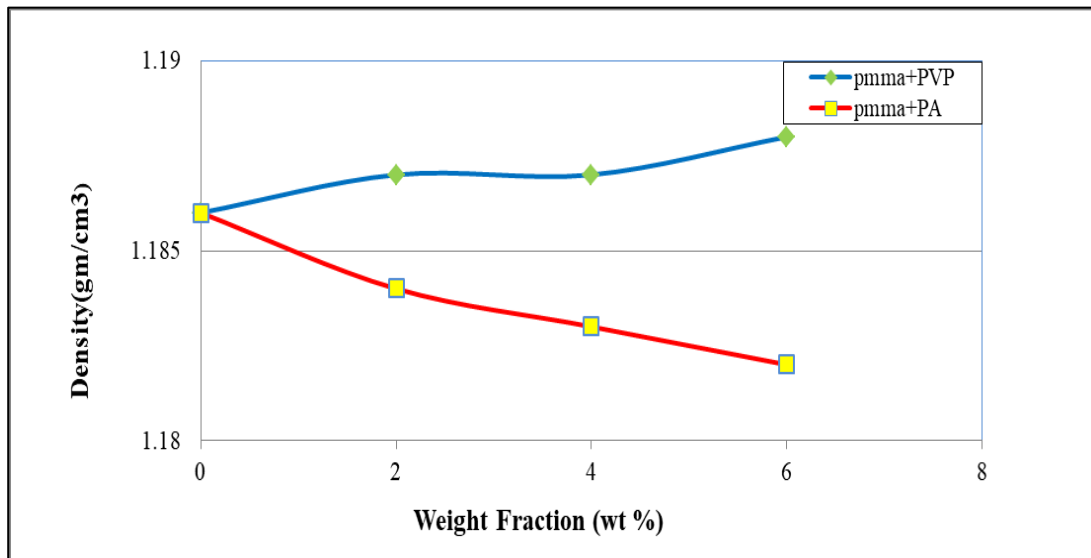


Figure 7: Density of polymer blend materials as a function of PA and PVP

Figures 8 and 9 show the relation between the weight fraction of (sisal and coconut) powder for each of the (2% PA-PMMA) and (2% PVP-PMMA) blend matrices and the density of the composite specimens, respectively. It is evident that by adding sisal or coconut to composite materials, the density increases. This could be explained by the fact that sisal and coconut have higher densities than the blend matrix, which increased the composite specimens' densities. Additionally, it is evident in these figures that the magnitudes of density rise with the weight fraction of sisal and coconut powders for whole composite materials.

This is a result of the particles' rise, which has reduced the weight fraction of the blend matrix, which has less density than (sisal and coconut) powders. In addition, due to the high-density value of these powders compared with blend materials such as (PA and PVP) and PMMA material, which have low-density values. Consequently, as the weight fraction of (sisal and coconut) powders rises, the density value of the composite specimens also increases. Furthermore, these particles can reduce or fill the matrix's voids and spaces. The reinforcing particles are finally denser than the matrix with identical volume [25]. Furthermore, it is evident in Figures 8 and 9 that the density value for the composite specimens blended by PVP is higher than the density value for the composite specimens blended by PA with every increase in the weight fractions of (sisal and coconut) powders. This is due to the characteristic that PVP has a higher density than PA. Moreover, these figures show that the density magnitude increased when adding coconut powder to the specimens more than the density values when adding sisal powder to the specimens. This is due to the density of coconut powder being greater than the density of sisal powder. Thus, the higher values of density reach (1.196 gm/cm³) for composite (PMMA-2% PVP-6% coconut).

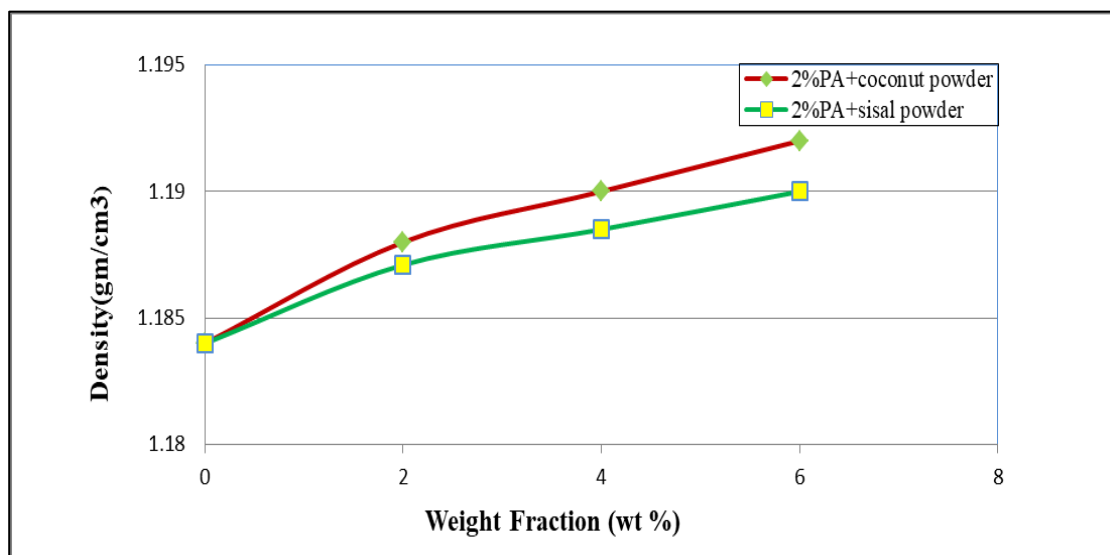


Figure 8: Density of 2% PA-PMMA composite as a function of sisal and coconut

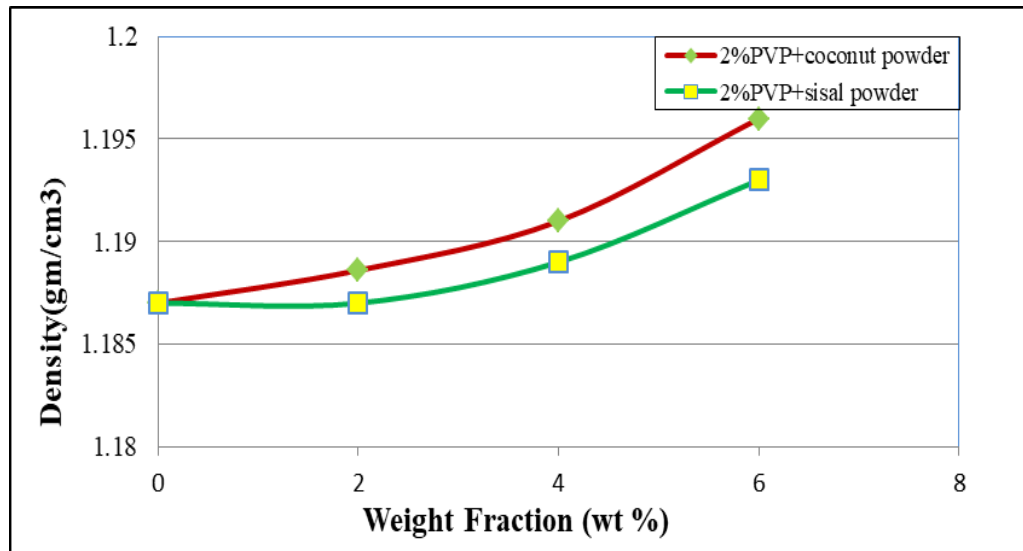


Figure 9: Density of 2% PVP-PMMA composite as a function of sisal and coconut

4.4 Water Absorption Test

The relation between the weight percentage of (PA and PVP) in PMMA resin and the specimens' percentage of water absorption is shown in Figure 10. It is evident that when the weight fractions of both blends rise, the value of the water absorption % also increases. This is so that all pores and voids inside the PMMA resin can be filled when fine particles like PA or PVP are added. The rise in water absorption magnitudes is caused by natural powders' affinity towards moisture. It may also result from the high moisture absorption levels of these powders' polar hydroxide groups [30]. As a result, the created composite specimens' water absorption percentage will ultimately increase. Furthermore, it is clear from this figure that the values and rates of the water absorption percentage for the composite specimens made of (PVP-PMMA) are larger than those made of (PA-PMMA). The water absorption values increased from (0.488 %) for PMMA to (0.716 %) for (PMMA-6% PVP) composite.

Figures 11 and 12 show the relation between the weight fraction of (sisal and coconut) powder for each of the (2% PA-PMMA) and (2% PVP-PMMA) blend matrices and water absorption of the composite specimens, respectively. It is apparent that when adding sisal or coconut in composite, the water absorption rises. It is evident in Figures 11 and 12 that the value of water absorption increased with increasing the weight fraction of (sisal and coconut) powders for all composite materials. This occurs due to the insertion of small particles like sisal or coconut, which fill all the pores and spaces inside the matrices. The increase in water sorption amounts can be attributed to the natural powders' affinity towards moisture and the natural powders' high moisture absorption levels in the polymer blend matrix, which are brought on by the polar hydroxide groups in these powders [30]. In addition, these figures demonstrate that the values and rate of water absorption percentage decreased when adding coconut powder to the specimens are more than the values of water absorption percentage when adding sisal powder to the specimens for the third and fifth groups. Thus, the water absorption percentage increased to a higher value (1.007%) for the composite (PMMA-2% PA-6% coconut).

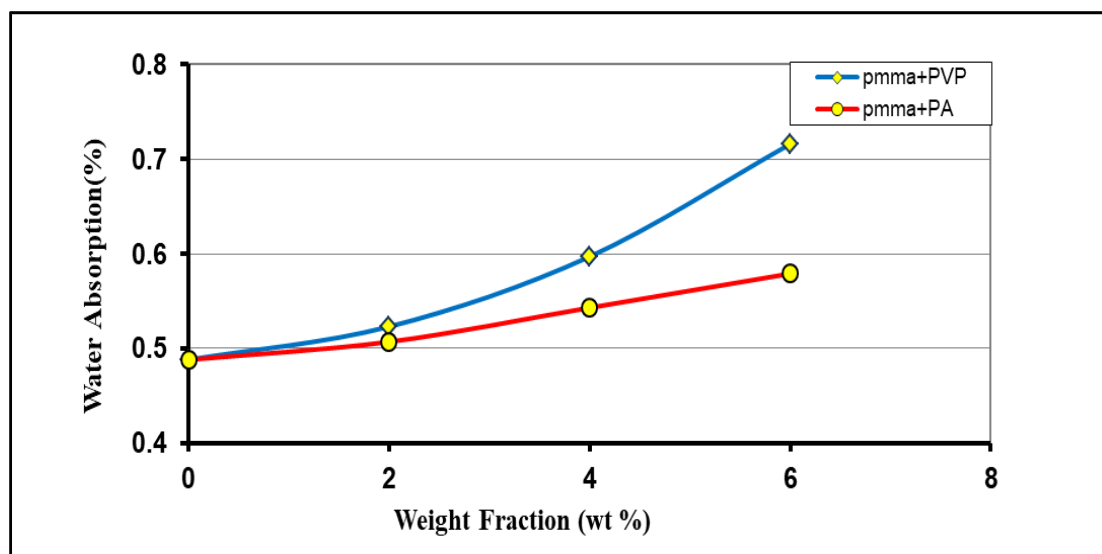


Figure 10: Water absorption (%) of polymer blends as a function of PA and PVP

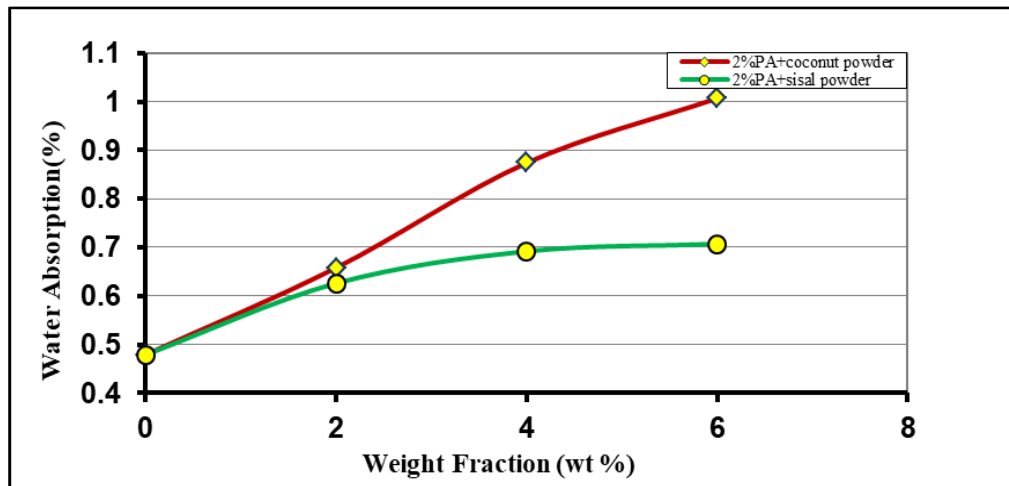


Figure 11: Water absorption (%) of 2% PA-PMMA composite as a function of sisal and coconut

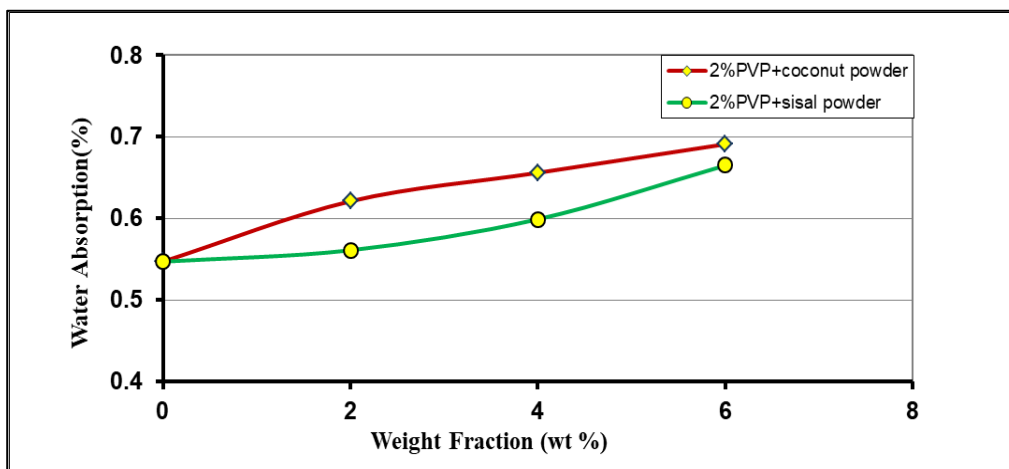


Figure 12: Water absorption (%) of 2% PVP-PMMA composite as a function of sisal and coconut

4.5 Thermal Conductivity

Figure 13 depicts the relation between the thermal conductivity of the specimens and the weight percentage of (PA and PVP) in PMMA resin. It is evident that when the weight percentage of both types of mixes grew, the thermal conductivity values also increased. This is because, compared to PMMA resin, these particles have higher heat conductivity values. Additionally, the presence of these particles fills in the gaps and spaces in the PMMA resin. The result is that the heat transfer process via composite specimens is made easier [35].

Additionally, it is clear from this figure that the addition of PA has a more significant influence than the addition of PVP on the thermal conductivity of composite specimens. As a result, the thermal conductivity found for (PA-PMMA) composite test specimens is greater than that for (PVP-PMMA) composite specimens. This is brought on by PA particles' greater thermal conductivity when compared to PVP particles. As a result, the PMMA-6% PA blend's thermal conductivity magnitudes increased from (0.2117 W/m.k) for PMMA (as referenced) to (0.289 W/m.k).

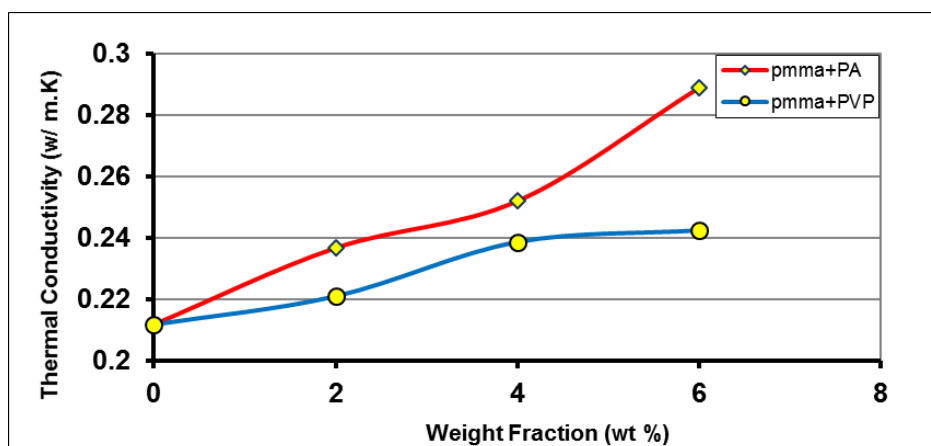


Figure 13: Thermal conductivity of polymer blends as a function of PA and PVP

Figures 14 and 15 show the relation between the weight fraction of (sisal and coconut) powder for each of the (2% PA-PMMA) and (2% PVP-PMMA) blend matrices and the thermal conductivity of the composite specimens, respectively. It can be seen that when adding sisal or coconut to the composite, the thermal conductivity slightly increases for the composite. This might be because these powders fill in the pores and voids in the matrix, which causes heat to pass through the composite specimens. Furthermore, it is evident in these figures that for all composite materials, the values of thermal conductivity elevated as the weight percentage of (sisal and coconut) powders grew. This is because these powders have higher thermal conductivity values than matrix materials. Additionally, the matrix's spaces and empty regions are filled by the existence of these particles. At last, the outcome helps to facilitate the heat transfer process through composite test specimens [36]. This is because these powders have naturally high heat conductivity, contrasting the matrices [37].

Consequently, an increase in the percentage of weight of (sisal and coconut) powders results in a rise in the thermal conductivity values of the composite specimens. Furthermore, it can be noticed in these figures that the values of thermal conductivity for the composite specimens blended by PA are higher than values compared with the value of thermal conductivity of the composite test specimens blended by PVP with every increase in the weight fraction of (sisal and coconut) powders. Moreover, these figures show that the value of thermal conductivity increased when adding sisal powder to the test specimens is higher than when adding coconut powder to the specimens. This is because sisal powder's thermal conductivity is greater than coconut powder's thermal conductivity. Thus, the higher values of thermal conductivity reach (0.2482 W/m.k) for composite (PMMA-2% PA-6% sisal).

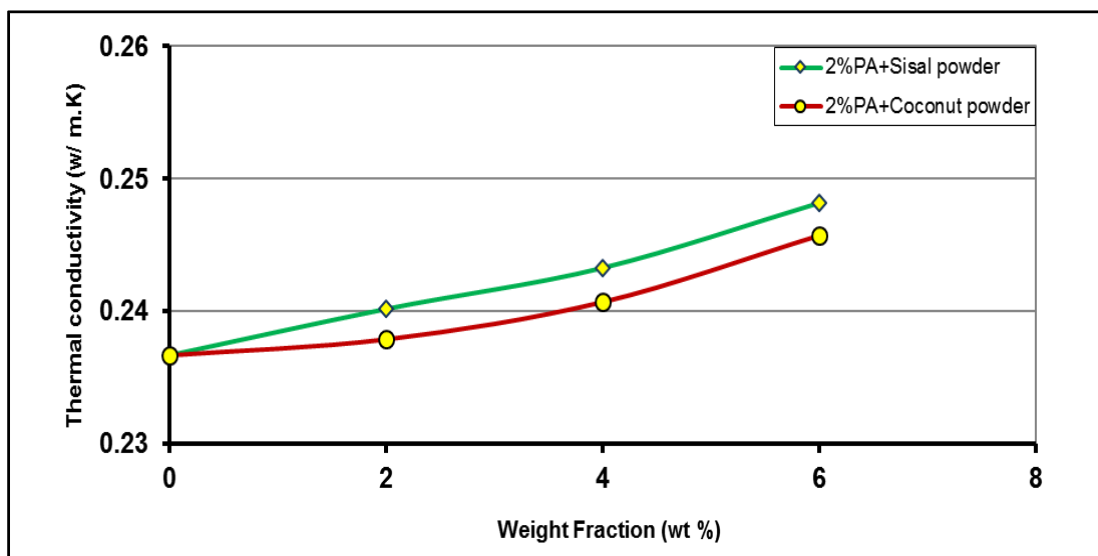


Figure 14: Thermal conductivity of 2% PA-PMMA composite as a function of sisal and coconut

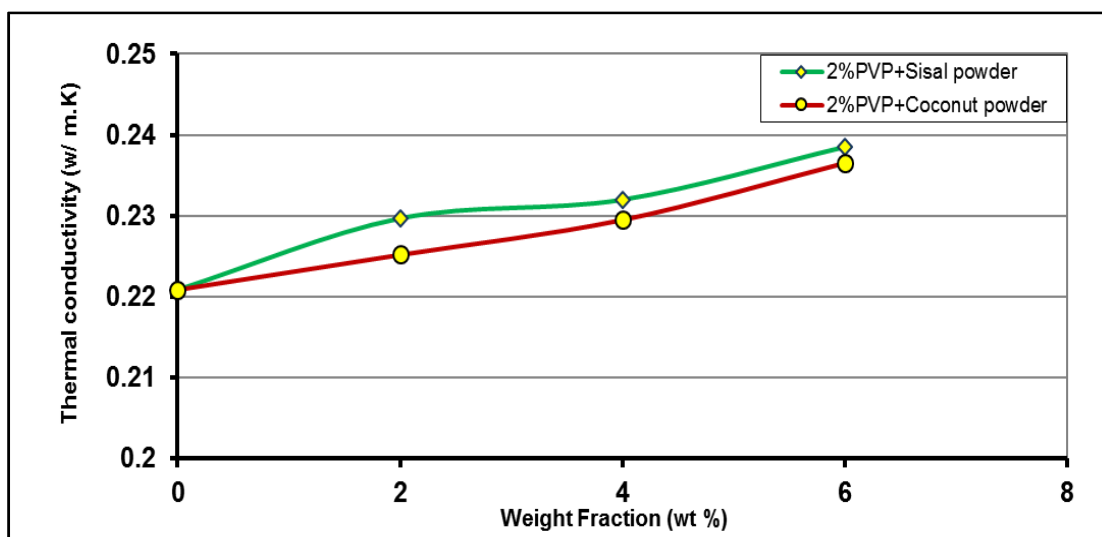


Figure 15: Thermal conductivity of 2% PVP-PMMA composite as a function of sisal and coconut

5. Conclusion

The study was performed on a denture base, which is used to compensate for missing teeth that may have been lost for several reasons. Nineteen samples were prepared using a polymer blend of PMMA with (PA and PVP) as a matrix, the reinforcement powders were (sisal and coconut), and the most important tests for the denture base were performed.

The PVP and coconut particle addition have a visible influence on the density and water absorption properties higher than the particles of PA and sisal. The PA and sisal particle addition have a visible influence on the thermal conductivity property higher than the particles of PVP and coconut. The ultimate values of density properties were obtained in the (PMMA- 2% PVP-6% coconut) composite because PVP and coconut particles have higher densities than PA and sisal particles. The ultimate values of water absorption properties were determined in (PMMA- 2% PA-6% coconut) composite; this can be attributed to the natural coconut powders' affinity towards moisture as well as to the natural powders' high moisture absorption levels in the polymer blend matrix, which are brought on by the polar hydroxide groups in these powders. The ultimate values of thermal conductivity properties were determined in (the PMMA-6% PA) blend because PA particles have greater thermal conductivity when compared to PVP particles. According to the FTIR test, no additional peak appeared, and the peak intensities were comparable to those of PMMA. The state of miscibility for all blend constituents is good, and no byproducts or leftover monomers are toxic to humans or can trigger an allergic reaction or inflammation. According to the DSC test, one Tg value appeared in specimens, promoting an optimal interfacial reaction and demonstrating effective compatibility between the polymer blend's constituents. No additional material was formed in this test.

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Author contributions

Conceptualization, J. Oleiwi. Q. Hamad. and W. Hussain; methodology, Q. Hamad; software, W. Hussain; validation, J. Oleiwi. Q. Hamad and W. Hussain; formal analysis, J. Oleiwi; investigation, Q. Hamad; resources, W. Hussain; data curation, Q. Hamad; writing—original draft preparation, W. Hussain; writing—review and editing, Q. Hamad; visualization, J. Oleiwi; supervision, J. Oleiwi; project administration, Q. Hamad. All authors have read and agreed to the published version of the manuscript.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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