Analysing Some Mechanical Properties of Cinnamon Powder Reinforced with Polymeric Materials Used in Dental Application

Abstract - In the dentures industry, materials must be chosen to have good mechanical properties in order to resist the conditions that may occur in the mouth. A study was conducted to assess tensile strength, elasticity coefficient, elongation, flexural strength, flexural modulus with impact properties of poly methyl methacrylate resin as matrix strengthened with cinnamon powder and also analysing these mechanical properties by using (OriginLab) software program. The samples of Poly Methyl methacrylate bio composites which containing 2%, 4%, 6%, and 8% weight fractions of cinnamon powder and an unfilled as control sample were fabricated using “hand lay up” method. The results indicate that the addition of 8% weight fraction cinnamon powder into Poly Methyl methacrylate resin improved of ultimate tensile strength, modulus elasticity, flexural strength, flexural modulus (62 MPa, 3.7 GPa, 96 MPa, 6.4 GPa) respectively, compared with the values of pure Poly Methyl methacrylate (51 MPa, 1.5 GPa, 78MPa, 2.0 GPa) respectively. Also can be noted that the elongation at break values decreases with an increase in weight fractions of filler, where the sample (Poly Methyl methacrylate +2% cinnamon) has the best value for elongation compared with samples reinforced (4%, 6% and 8% wt). The impact strength results observe the maximum value was present in the sample (Poly Methyl methacrylate+6% cinnamon). From the results, descriptive, One Way ANOVA statistical analysis and means comparison by used (Scheffe test and Tukey test) for all mechanical properties indicated, turns out if Sig equals 1 shows that the variance in mean is significant at the level of 0.05, whereas Sig is 0 designates that the mean variance is not significant at the level 0.05.

Keywords - Poly methyl methacrylate, Cinnamon powder, tensile properties, Flexural strength, Flexural modulus, Impact strength, Origin Lab.

1. Introduction
Composites are substances that do not resolve in any other and produce new material of unique advantages. Reinforcement materials in the form (particles or fiber or both together) usually are added to the based material to improve the mechanical properties, reduced shrinkage characteristic and improve bonding nature between the base material and the reinforcing material [1-2]. Composite materials which usually consist of a one or two materials' natural, non-toxic such as (jute fiber, eggshell, banana fiber, cinnamon, Clove, Pomegranate, Walnut,... etc.) are called bio-composite materials. Bio-composites materials are used in many applications, for example (teeth, prostheses, orthodontics, hip joints etc....). The bio-polymer resin composite materials are mostly used for immediate renovation, both posterior and anterior teeth, due to good mechanical and physical characteristic of these materials [3]. Poly Methyl methacrylate, a polymer used in the manufacture of a denture, an alternative to lose teeth and peripheral tissues, this material should be has good mechanical properties (impact strength, flexural strength and wear resistance.... etc.) and is compatible with the mouth environment, non-toxic and low water absorption [4-5]. Although Poly Methyl methacrylate materials it is widely used, but there are many drawbacks must be taken into consideration, so many researchers studied the effect of additives to improve mechanical and physical characteristic of Poly Methyl methacrylate material. Balos et al. [6] have studied effect of various additions Nano silica into Poly Methyl methacrylate resin matrix on modulus of elasticity and flexural strength. The samples are composed from Poly Methyl methacrylate resin reinforced with (0.05%, 0.1%, 0.2%, 0.5%, 1%, 2%) weight fraction Nano silica. Results observed
the weight fraction (0.05% into Poly Methyl methacrylate) give the highest values of modulus of elasticity and flexural strength. Jha et al. [7] has studied the tensile strength, flexural strength with impact strength of Poly Methyl methacrylate resin strengthened by ridge gourd fiber. These samples consist from Poly Methyl methacrylate with (5%, 10%, 15% wt) ridge gourd fiber. The results indicate that the sample (Poly Methyl methacrylate +10% ridge gourd fiber) has maximum values of tensile strength and flexural strength, while the sample (Poly Methyl methacrylate +15% ridge gourd fiber) has a maximum value of impact strength. Haitham et al. [8] have have investigation the tensile test, flexural test, impact test and hardness shore D for polymeric bio-composites made from (1% , 3% , 5% and 7%) weight fraction ZrO$_2$ into Poly Methyl methacrylate resin matrix. From results turns out the (7% ZrO$_2$ wt.) with Poly Methyl methacrylate resin have higher values of hardness shore D , ultimate strength and fracture toughness, while the (1% ZrO$_2$ wt.) with Poly Methyl methacrylate resin has a maximum value elongation. In the impact strength test (3% ZrO$_2$ wt.) has better values when comparing with other weight fractions. The objective of the current work is attempting to obtain the new bio-composites prepared from cinnamon powder into poly methyl methacrylate resin which is used in the denture application. Also study the effect of various additives cinnamon powder on tensile, flexural and impact test of the poly methyl methacrylate composite.

1. Materials

I. Poly Methyl methacrylate

Poly Methyl methacrylate cold curing used a resin matrix kind from (Castavaria) equipped with a company “Vertex–Dental” to production the bio-composite samples used in denture base. Some mechanical and physical characteristic of Poly methyl methacrylate is indicated on the Table 1.

| Table 1: Some mechanical and physical characteristic of Poly methyl methacrylate according to the Company Processed (Vertex – Dental Company) |
|--------------------------|----------------|-----------------|-----------------|-----------------|
| Flexural strength        | Young modulus | Impact strength | Density | Water absorption |
| 79 MPa                   | 1.63 GPa      | 8.3 KJ/m$^2$   | 1.19 gm/cm$^3$ | 2.5% |

II. Cinnamon Natural Material

Cinnamon is a tree belonging to the Laureaceae family and crosses one of the most significant spices used in everyday life cinnamon originally contains vital oils and other derivative, example cinnamaldehyde, cinnamic acid, and cinnamate. The cinnamon can be used as an antioxidant, antimicrobial and antiinflammatory [9]. Cinnamon has a beneficial effect on oral health and is utilized to treat oral infection, treat toothache with removing bad breath [10]. In this research was used cinnamon sticks after grinding for 3 hours by (Mill) to obtain cinnamon powder that used as a strengthened material at a different weight fraction (2%, 4%, 6%, 8%) with Poly methyl methacrylate resin. The Figure 1 shows steps to prepare cinnamon powder. The particle size distribution was examined using (MASTERSIZER 2000) for cinnamon powder after grinding as illustrated in Figure 2, where the average particle size for cinnamon powder was (24µm). The chemical composition of the cinnamon powder was examined using X-ray Fluorescence spectrometer Technique, Table 2 shows the ratio oxides of the elements existent cinnamon powder, while Figure 3 (A-B) shows the ratio of elements existent cinnamon powder under the influence reagent compton secondary molybdenum , reagent Barkla scattering HOPG respectively.

Figure 1 : Steps to preparing cinnamon powder.
3. Preparation Samples of Bio-Composites Materials

The dimensions of mould used in this research to prepare samples were (150 mm x 150 mm x 5 mm). The mold was made of glass and covered with a layer glass to achieve samples with fine surface and non-roughness. Poly methyl methacrylate denture base materials consist from monomer liquid and polymer powder. The mixing ratio of poly methyl methacrylate (cold cure) is usually about 17 gm powder and 9.5 gm liquid polymer. At the beginning, the specific ratio of polymer liquid is placed in a dry and clean glass flask and then adds the specified ratio of the dry powder gradually to the polymer liquid. The mixtures are mixed continuously and homogenously at room temperature and then pour the mixture into the middle of the mold. Leave the mixture inside the mold for 9-15 minutes at room temperature from beginning the mixing process to increase the viscosity of the mixture. Removing samples from the mold and put them in the oven at a temperature of 55 for 30 minutes [11] and cutting the samples according to ASTM of each test as shown Figure 4. Table 3 shows the composition details of bio-composite samples.

### Table 2: Percentage oxides of elements existent cinnamon powder

| Oxides Elements | Ratio % |
|-----------------|---------|
| Na₂O            | 0.45    |
| MgO             | 0.86    |
| Al₂O₃           | 0.20    |
| SiO₂            | 0.13    |
| P₂O₅            | 0.08    |
| K₂O             | 0.55    |
| CaO             | 4.66    |
| TiO₂            | 0.17    |
| MnO             | 0.25    |
| Fe₂O₃           | 0.13    |
| CoO             | 0.03    |
| NiO             | 0.16    |
| CuO             | 0.09    |
| ZnO             | 0.07    |
| Rb₂O            | 0.015   |
| SrO             | 0.01    |
| SnO₂            | 0.02    |
Engineering and Technology Journal

Vol. 37, Part A. No. 3, 2019

Figure 4: Composite samples after cutting according to ASTM (Tensile, Flexural and Impact test).

Table 3: Details composition of the samples

| Samples | Composition (wt.)       |
|---------|-------------------------|
| A0      | Pure PMMA               |
| A2      | PMMA+2% Cinnamon powder |
| A3      | PMMA+4% Cinnamon powder |
| A4      | PMMA+6% Cinnamon powder |
| A5      | PMMA+8% Cinnamon powder |

4. Mechanical Test

I. Tensile Test

Figure 5 shown dimensions samples of the tensile test L=150mm, W=20mm and T=5mm according to ASTM D 638-03[12]. The tensile properties values can be calculated through equations (1) and (2) [13-14].

\[ \sigma = \frac{P}{A} \quad (1) \]

Where:
\[ \sigma: \] Tensile strength of sample MPa
\[ P: \] applied load N
\[ A: \] original crosses sectional area before testing m²

\[ \epsilon = \frac{\Delta L}{L_0} \quad (2) \]

Where:
\[ \epsilon: \] strain
\[ \Delta L = L - L_0 \]

II. Flexural Test

Figure 6 shown dimensions samples of the flexural test L=100 mm, W=10mm and T=4.8=mm according to ASTM D-790 [15]. Flexural strength and flexural modulus can be calculated from equations (3) and (4) [16-17].

\[ F.S = \frac{3PL}{2bd^2} \quad (3) \]

Where:
\[ F.S: \] flexural strength MPa
\[ P: \] force N
\[ L: \] length sample mm
\[ b: \] thickness sample mm
\[ d: \] width sample mm

\[ E_B = \frac{PL_3}{4b \delta} = \frac{mL_3}{4bd \delta} \quad (4) \]

Where:
\[ E_B: \] Flexural modulus MPa
\[ \delta: \] deflection of samples mm
\[ P: \] load applied N
\[ L: \] support span mm
\[ b: \] width of sample mm
\[ d: \] thickness of sample mm
\[ m: \] Slope of the tangent in the load- deflection curve N/mm

III. Impact Test

Figure 7 shown dimension samples of the impact test L=80mm, W=10mm and T=4mm according to standard (ISO-180) [18]. Impact strength can be calculated from equation (5) [19].

\[ \sigma = \frac{P}{A} \quad (1) \]

Where:
\[ \sigma: \] Tensile strength of sample MPa
\[ P: \] applied load N
\[ A: \] original crosses sectional area before testing m²

\[ \epsilon = \frac{\Delta L}{L_0} \quad (2) \]

Where:
\[ \epsilon: \] strain
\[ \Delta L = L - L_0 \]

II. Flexural Test

Figure 6 shown dimensions samples of the flexural test L=100 mm, W=10mm and T=4.8=mm according to ASTM D-790 [15]. Flexural strength and flexural modulus can be calculated from equations (3) and (4) [16-17].

\[ F.S = \frac{3PL}{2bd^2} \quad (3) \]

Where:
\[ F.S: \] flexural strength MPa
\[ P: \] force N
\[ L: \] length sample mm
\[ b: \] thickness sample mm
\[ d: \] width sample mm

\[ E_B = \frac{PL_3}{4b \delta} = \frac{mL_3}{4bd \delta} \quad (4) \]

Where:
\[ E_B: \] Flexural modulus MPa
\[ \delta: \] deflection of samples mm
\[ P: \] load applied N
\[ L: \] support span mm
\[ b: \] width of sample mm
\[ d: \] thickness of sample mm
\[ m: \] Slope of the tangent in the load- deflection curve N/mm

III. Impact Test

Figure 7 shown dimension samples of the impact test L=80mm, W=10mm and T=4mm according to standard (ISO-180) [18]. Impact strength can be calculated from equation (5) [19].

\[ \sigma = \frac{P}{A} \quad (1) \]

Where:
\[ \sigma: \] Tensile strength of sample MPa
\[ P: \] applied load N
\[ A: \] original crosses sectional area before testing m²

\[ \epsilon = \frac{\Delta L}{L_0} \quad (2) \]

Where:
\[ \epsilon: \] strain
\[ \Delta L = L - L_0 \]
5. Statistical Analysis

All statistical analysis was performed with (Origin Lab) program software using ((One-Way analysis)) of variance (ANOVA) with (Scheffe test and Tukey test) was utilized to analyze groups. The variations were always considered significant at (P-values) less than 0.05.

6. Discussion of Results

I. Ultimate Tensile Strength

Figure 8 shown the results of ultimate tensile strength performed on cinnamon powder based poly methyl methacrylate bio-composites. From the graph, there is clearly with the increased weight fraction of cinnamon powder leads to an increase tensile strength, where the sample (poly methyl methacrylate+ 8% cinnamon) has a high tensile value and improves the tensile strength property by 22% compared with pure sample. The reasons for increasing the tensile strength value; the first reason is that the elements and oxides found in cinnamon powder have increased the possibility of transfer the stress from poly methyl methacrylate polymer [20]. The second reason is that the average particle size of the cinnamon powder (6-200m) increases the covalent bond between the base poly methyl methacrylate resin polymer and the cinnamon powder material. Table 4 indicates the descriptive, One Way ANOVA statistical analysis and means comparison by used (Scheffe test and Tukey test) of the results ultimate tensile strength for the poly methyl methacrylate reinforced with various cinnamon powder (2%,4%,6% and 8%). From results analysis One Way ANOVA can be noted the mean values of all levels are equal, where (at the 0.05) level population means is significantly varying. Also, from (Tukey test and Scheffe test) notes if (Sig equals 1) indicates the difference of the means is significant at the 0.05 level. These meaning the weight fractions of cinnamon powder reinforced with poly methyl methacrylate were positively on the ultimate tensile strength value.

II. Modulus of Elasticity

Figure 9 refers to the relation between modulus of elasticity and weight fraction of cinnamon powder into poly methyl methacrylate composite. It can be seen that the properties of the elasticity modulus improve with increase weight fraction of cinnamon powder into poly methyl methacrylate bio-composite. This advance in the properties modulus of elasticity depends on to the nature of cinnamon powder in terms of high strength. Thus modulus of elasticity values increased from (1.5GPa) for poly methyl methacrylate to (3.7GPa) for (Poly methyl methacrylate + 8% cinnamon). The elasticity modulus values improvement about (146%) compared with the pure sample this is due to the mean particle size, distributed regular of cinnamon powder inside the poly methyl methacrylate resin and easiness the penetration of polymer matrix material this leads to create good interfaces between the matrix material and reinforcing material [21]. Table 5 shown the descriptive, One Way ANOVA statistical analysis and means comparison by used (Scheffe test and
Tukey test) of the results elasticity modulus for the poly methyl methacrylate reinforced with various cinnamon powder (2%, 4%, 6% and 8%). From One Way ANOVA analysis turns out the means of all levels are equal, where (at 0.05 levels) population means are significantly various. Also, from Scheffe test and Tukey test notes if (Sig equals 1) indicates the difference of the means is significant at (0.05 level). This meaning the weight fractions of cinnamon powder reinforced with poly methyl methacrylate has more significance on values modulus of elasticity.

III. Elongation Percentage

Figure 10 illustrates the value elongation percentage of the samples poly methyl methacrylate reinforced with various weight fraction cinnamon powders. It can be observed that elongation percentage values decreased with increasing weight cinnamon powder, where an elongation value of pure sample poly methyl methacrylate (3.9%) decreased to (2.7%) with addition 8% cinnamon powder. The reason is that increase weight fraction of the reinforcement material will be the concentration of stress in polymeric composite materials and thus lead to a decrease in the value of elongation at break. In addition, the elongation properties depend on the natural behavior of the polymeric composite material (brittle or ductile) and the natural bond between the polymer matrix material and strengthening materials [22-23]. Table 6 illustrates the descriptive, One Way ANOVA statistical analysis and means comparison by used (Scheffe test and Tukey test) of the results elongation percentage for the poly methyl methacrylate reinforced with various cinnamon powder (2%, 4%, 6% and 8%). From this Table can be noted One Way ANOVA analysis, the mean of all levels are equal, where at (0.05 level) population means are not significantly various. Also, from (Scheffe test and Tukey test) notes if (Sig equals 0) indicates the difference of the means is not significant at (0.05) level. This meaning that the weight fractions of cinnamon powder reinforced with poly methyl methacrylate was negative on the elongation percentage at break properties. From tensile properties, can be observed the pure poly methyl methacrylate has the lowest tensile strength and elasticity coefficient (51 MPa and 1.5 GPa), respectively. Ultimate tensile strength and elasticity coefficient raise with increase weight fraction cinnamon powder into poly methyl methacrylate resin reach to (62 MPa and 3.7 GPa) respectively, while the elongation percentage at break decrease (3.9% to 2.7%) with an increasing weight fraction of cinnamon powder.
IV. Flexural Strength

The flexural strength of poly methyl methacrylate strengthening with various weights fraction cinnamon powders is shown in Figure 11. Results showed that the weight fraction (2%, 4%, 6%, 8%) has influences were significantly in flexural strength of Poly Methyl methacrylate resin, where the sample (PMMA+8% Cinnamon powder) has higher values of flexural strength (96 MPa). Lastly, the percentage improvement of the flexural strength was (23.8%). These resultly may be attributed to dispersal of the reinforced material in a matrix resin material, which negatively affects the grade of conversion that leads to a raise non-reactant monomer that acts as plasticizer [24-25].

Table 7 explains the descriptive, One Way ANOVA statistical analysis and means comparison by used (Scheffe test and Tukey test) for the results flexural strength of all samples. From One Way ANOVA analysis indicates the mean of all levels are equal, where at (0.05 level) population means are significantly various. Also, from (Scheffe test and Tukey test) a note if (Sig equals 1) show the difference of the means is significant at (0.05 level). Nature interconnection between cinnamon powder reinforced and poly methyl methacrylate was good is the reason for the increase in values flexural strength.
V. Flexural Modulus

Figure 12 shown flexural modulus values results acquired of flexural test of the bio-composite 12. Can be observed from this figure, it the values of flexural modulus increases with increased weight fraction cinnamon powder in poly methyl methacrylate resin bio-composite. This is because the regular, randomly distribution and ease penetration poly methyl methacrylate resin outof the filler (cinnamon powder) to forming strong adherence at interfaces between matrix resin with strengthening material, all of these reasons result in increased flexural modulus with each increase in the weight fraction of the particles [26]. The presence of 8% cinnamon powder increases the value of the flexural modulus to (6.4 GPa) compared with the value of the flexural modulus (2.0 GPa) of the pure sample. Table 8 shows the descriptive, One Way ANOVA statistical analysis and means comparison by used (Scheffe test and Tukey test) for the results flexural modulus of all samples. From One Way ANOVA analyses refer the mean of all levels are equal, where at (0.05 level) population means are significantly various. Also, from (Scheffe test and Tukey test) notes if Sig equals 1 indicate the various of the means are significant at (0.05 level). That means, nature bonded between cinnamon powder reinforced and poly methyl methacrylate was good this is the reason for the increase in values flexural modulus.

VI. Impact Strength

This difference in impact strength of the bio-composites with 2%, 4%, 6%, 8% of cinnamon powder are shown in Figure 13. This Figure clearly indicates that the impact strength improves with the added weight fraction by 2%, 4% and 6% cinnamon powder, while decreases with addition weight fraction by 8% cinnamon powder. The sample (poly methyl methacrylate+6% Cinnamon) showed approximately 47.9% increment in impact strength from pure poly methyl methacrylate. The reason increasing the impact resistance is that the strong bond between reinforcement material and resin material causes formation of molecular bonds that prevent crack propagation through polymer composite materials [8]. The value of impact strength decreases when cinnamon powder is added by 8% weight fraction because the increase in surface area of reinforced materials and the increase in the stress, leading to the possibility of crack growth. Also, at high concentrations of the weight fraction reinforcing material effect on the interface area, thus reducing the energy dissipation during the test [27&28]. Table 9 shows the descriptive, One Way ANOVA statistical analysis and means comparison by used (Scheffe test and Tukey test) for the results flexural modulus of all samples. From this Table One Way ANOVA analysis, the mean of all levels is equal,

![Figure 12: Flexural modulus values as a function of cinnamon powder in PMMA.](image-url)
where at (0.05 level) population means are significantly various. Also, from (Scheffe test and Tukey test) a note if Sig equals 1 indicates the various of the means is significant at (0.05 level). That means nature bonded between cinnamon powder reinforced and poly methyl methacrylate was good to absorb energy during the test.

![Impact Strength vs Weight Fraction Graph](image)

**Figure 13:** Impact strength values as a function of cinnamon powder in PMMA.

**Table 9:** Results descriptive, One Way ANOVA and means comparison by (Scheffe, Tukey test) of the impact strength between all sample.

---

**7. Conclusions**

From this study, we conclude that integration the cinnamon powder into the acrylic resin improved the ultimate tensile strength, young modulus, flexural strength, flexural modulus and impact strength. Maximum values of tensile strength, young modulus, flexural strength and flexural modulus are (62MPa), (3.7GPa), (96 MPa) and (6.4 GPa) respectively of specimens reinforced with (8%) weight fraction cinnamon powder. The sample reinforced with 2% cinnamon powder into poly methyl methacrylate has a maximum value of elongation percentage at break (3.6) when compared with the other weight fraction (4%, 6% and 8%), while the sample reinforced with 6% cinnamon powder into poly methyl methacrylate give maximum value of impact strength (10.9 KJ/m²). From results, descriptive, One Way ANOVA statistical analysis and means comparison by used (Scheffe test and Tukey test) of all mechanical properties indicated, turns out if (Sig equals 1) indicates the difference of the means is significant at (0.05 level), while if (Sig equals 0) indicates the difference of the means is not significant at (0.05) level. Therefore, there is for filler content a significant on tensile strength, young modulus, flexural strength, flexural modulus and impacts strength.

**References**

[1] T. Kanie, K. Fujii, H. Arikawa, K., Inoue, “Flexural properties and impact strength of denture base polymer reinforced with woven glass fibers. Dental Materials,” Vol.16, PP.150–158, 2000.

[2] A.B. Abdul-Hussein, E.S.Al-Hassani , Reem Alaa Mohammed, “Erosion Wear Behavior of Industrial Material Reinforced Epoxy Resin Composites and its Coating with Natural Based Material,” Eng. & Tech. Journal, Vol.33, No.4, Part (A) , PP.902-918, 2015.

[3] C. EvangeliaVouvoudi, D. IriniSideridou, “Dynamic mechanical properties of dental nanofilled light cured resin composites: Effect of food-simulating liquids,” Journal of mechanical behaviour of Biomedical materials, Vol.10, PP. 87–96, 2012.

[4] F. Bahrami., A. Safari., M.Vojdani., “Comparison of hardness and surface roughness of two denture bases polymerized by different methods,” World Journal of Dentistry Vol.3, No. 2, PP.171-175, 2012.

[5] S.I. Salih, J.K. Oleiwi and Alaa Mohammed T., “Flexural and Impact Properties of PMMA Nano Composites and PMMA Hybrids Nano Composite Used in Dental Applications,” The Iraqi Journal for Mechanical and Material Engineering, Vol.17, No.1, March, PP.21-40, 2017.

[6] S. Balos, T. Puskar, M. Potran, D. Markovic, B. Pilic, J. Pavlicevic and V. Kojic, “Modulus of Elasticity, Flexural Strength and Bicompatibility of Poly(methylmethacrylate) Resins With Low Addition of Nanosilica, Journal of Dental Sciences,” Vol. 4, Issue 1, PP.26-33, 2016.

[7] J. Kanishka, Y.K. Tyagi1 and Hari Om Maurya , “Study on the Mechanical Properties of PMMA Composite Using Ridge Gourd Fibre,” ARPN Journal
of Engineering and Applied Sciences, Vol. 11, No. 18, PP.11085-11088, 2016.

[8] R. Haitham, H. Anwer, S. Salih, “Mechanical Properties of Composites Materials Reinforced in Ceramic Particles,” International Conference, Berlin, Germany, 2017, ISBN: 978-93-86291-88-2.

[9] M. Vangalapati, N. Sree Satya, D. Surya Prakash, and S. Avanigadda, “A review on pharmacological activities and clinical effects of cinnamon species,” Research Journal of Pharmaceutical, Biological and Chemical Sciences, Vol. 3, No. 1, PP. 653–663, 2012.

[10] S. Shah, M. Tarig, R. Zaman, S. Imtiyaz, “The In vitro Anti-acne Activity of Two Unani Drugs” Anc. Sci. Life Vol. 33, Issue 1, PP.35–38, 2013.

[11] A.B. Abdul-Hussein, E. S. Al-Hassani, Reem Alaa Mohammed, “Effect of Natural Materials Powders on Mechanical and Physical Properties of Glass Fiber / Epoxy Composite,” Eng. & Tech. Journal, Vol.33, No.1, Part (A), PP.175-197, 2015.

[12] Annual Book of ASTM Standard, “Standard Test Method for Tensile Properties of Plastics,” D 638-03, PP. 1-12, 2003.

[13] J.K. Oleiwi, Sihama I. Salih, and Hwazen S Fadhil, “Effect of Siwak and Bamboo Fibers on Tensile Properties of Self-Cure Acrylic Resin Used for Denture Applications,” J Material Sci Eng 6: 370, 2017, doi: 10.4172/2169-0022.1000370.

[14] S.I. Younis, J.K. Oleiwi, Reem Alaa Mohammed, “Some Mechanical Properties of Polymer Matrix Composites Reinforced by Nano Silica Particles and Glass Fiber,” Engineering and Technology Journal, Vol.36, No.12, Part (A), PP.1283-1289, 2018.

[15] Annual Book of ASTM Standard, “Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics D 790-86,” Vol. 10.01 1986.

[16] A.B. Abdul-Hussein, E.S. Al-Hassani, Reem Alaa Mohamed, “Effect of industrial powder on mechanical properties of glass fiber reinforced epoxy composite “, Iraqi Journal of Physics, Vol.12, No.25, PP.8-24, 2014.

[17] S.I. Salih, Jawad Kadhim Oleiwi, Sajid Abd Alkhidhir, “Investigation of Flexural Strength and Impact Strength of Binary Polymer Blends Fabricated by Friction Stir Processing,” Journal of University of Babylon, Engineering Sciences, Vol.26, No.5, PP.339-346, 2018.

[18] Annual Book of ISO Standard, “Standard Test Method for Unnotched Izod Impact Testing of Plastics,” ISO-180, PP. 1-2, 2006.

[19] R. Alaa Mohammed, “Study of some Mechanical Properties and Erosive Behavior by Taguchi Method for Hybrid Nano Composites,” Eng. & Tech. Journal, Vol.36, No.4, Part (A), PP.471-479, 2018, DOI:http://dx.doi.org/10.30684/etj.36.4A.15.

[20] S. Issa Salih, J.K. Oleiwi, Hwazen S. Fadhil, “Preparation and Investigation of some Properties of Acrylic Resin Reinforced with Siwak Fiber Used for Denture Base Applications “Kurdistan Journal of Applied Research, Vol. 2, Issue 3, PP.1-6, 2017.

[21] S. Issa Salih, Wafaa Mahdi Salih, Masara A. Abdul Hameed,” Preparation and Characterization of Polymers Blends Hybrid Nano composites for Structural Applications,” Advances in Natural and Applied Sciences, Vol.10, No.15, pp 90-103, 2016.

[22] M. Sreekanth S., V. Bambole A., Mhask S. T. and Mahnanwar P. A., “Effect of concentration of Mica on Properties of Polyester Thermoplastic Elastomer Composites,” Journal of Minerals and Materials Characterization and Engineering,” Vol. 8, No. 4, PP. 271-282, 2009.

[23] S.I. Salih, Jawad K. Oleiwi and Qahtan A. Hamad, “Studying the Tensile Properties and Morphology Test for the Self Cured PMMA Resin of Prosthetic Complete Denture,” The Iraqi Journal For Mechanical And Material Engineering, Special Vol., Part II, PP.508-522, 2015.

[24] T. Shibata, N. Hamada, K. Kimoto, T. Sawada, T. Sawada, H. Kumada, T. Umemoto, M. Toyoda, “Antifungal Effect of Acrylic Resin Containing Apatite-Coated TiO2 Photocatalyst”, Dental Materials Journal, Vol.26, PP. 437-444, 2007 http://dx.doi.org/10.4012/dmj.26.437.

[25] R. Haitham Abdel-Rahim, Reem Alaa Mohammed, “Experimental Investigation of Some Properties of Epoxy Reinforced by Egg Shell Particles,” International Journal of Mechanical Engineering and Technology, Vol. 10, Issue 1, PP.152-163, 2019.

[26] H. Kaiser, Vistasp M. Karbharb., “Quality and Monitoring of Structural Rehabilitation Measures,” UCSD, Version (1.2), 2001.

[27] H. Karim H., B.D.S., H. Abdul R and B.D.S., “The effect of addition nano particle ZrO2 on some properties of autoclave processed heat cure acrylic denture base material “,Department of Prosthodontics,College of Dentistry, University of Baghdad., Vol. 27, No. 1, PP.37, 2015.

[28] R. Alaa Mohammed, “Effect of Al2O3 Powder on Some Mechanical and Physical Properties for Unsaturated Polyester Resin Hybrid Composites Materials Reinforced by Carbon and Glass Fibers “, Eng. &Tech.Journal, Vol.34, No.12, Part (A), PP.2371-2379, 2016.