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Effects of Addition Waste Food as Filler on the Tensile Strength, Modulus of Elasticity and Compression Strength of PMMA Composite Based on Taguchi Method

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Abstract

In recent years, concerns about the environment linked forneeds of financial, in addition to that the adoption policies of smart, for example bio-economy and circular economy, are widely debated. Natural resource management is also resulting in the development of new types of materials. In this context, interestin polymer composites containing natural-organic fillers is increasing. Thus, selection of a material that succeed when using it in denture base, should be acceptable to be employed by the dental surgeon, the dental who is a technician and most important than that, to the patient. To fulfill all of the aforementioned needs, the material must have (stable, physical, aesthetic, mechanical, biological) properties. So that, in this study, mechanical effect of adding three types of waste food as a filler particles (eggshells powder , Musselshell powder, walnut shells powder)to PMMA composite was investigated. By using hand lay-up technique, all samples were prepared, the optimum process parameters with its significant factor was determined by using ANOVA analysis and experimental design L9 by Taguchi (MINITAB 18) under four factors: Eggshells weight fraction, weight fraction of Musselshell powder, weight fraction of walnut shells powder and grain size) with three levels for each factor to create L9 (3^4) orthogonal array. The mechanical experiments were carried out, and the result indicate the optimal parameter combinations and values for higher (Tensile strength, Modulus of Elasticity and Compression Strength). Musselshell has a greatest impact on mechanical qualities, ranging for 16.42 to 68.01%, following by eggshellfiller.

Keywords: *composite material, PMMA, mechanical properties, waste food.*

1.0 Introduction

The process of technological progress has increased the need for materials with properties not available in natural raw materials. In addition, urban expansion and increased industrialization with increased waste generation and resulting dangerous environmental problems are all reasons that led to the use of materials that help reduce pollution. For this reason, biodegradable materials or recyclable food waste are preferred upcoming materials instead of traditional materials due to their abundant availability, low cost and considered environmentally friendly materials. For sustainable and responsible actions, composites producers are altering their manufacturing to develop and replace conventional products with another one which new that have a high concentration of bio-based components that are recyclable or biodegradable. Composites are made up of two or more materials having differing mechanical and physical properties that are combined to create a hybrid new material with characteristics missing from the original components[1].

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Composites have unique qualities that allow them to be employed in a variety of structural components or/and structures while preserving durability and structural integrity. Using a natural materials in the composites, on the other hand, makes the construction more eco-friendly and cost-effective[2,3]. There is a dearth of appropriate biomaterials for dental applications despite extensive study and understanding of biomaterials[4]. Although PMMA has many positive characteristics (such as strength, ease of manipulation, and cost-effectiveness) and has grown in popularity for a variety of dental applications, it has a lot of weaknesses that make it less than idea. To denture bases or other applications of dental. For example, PMMA's weak bonding strength, poor fatigue strength, low impact strength and low thermal conductivity are all characteristics that need to be improved (PMMA)[5]. Investigated enhancement tensile properties for acrylic resin reinforced with fibers (bamboo and siwak) which cut in lengths of (2, 6, 12) mm with weight at different ratios (3, 6 and 9 wt%). According to the results, the young modulus with the tensile strength enhanced by raising the length of the fiber and the weight fraction[6]. investigated mechanical, analytical and physical properties of addition nanoparticles as natural fillers (seed powder of dates ajwa and pomegranate peels powder) to bio PMMA material. The strength to fracture of dental kits' bases improved as a result of the study[7]. Examining the effect of the fill ratio and particle size of (seashells particles on the compressive strength and thermal characteristics of PMMA-based bio composites. The result showed enhanced compressive strength and found the Nano size have a big effect in enhancing the compressive strength and the bio composite's thermal stability andobserved suitability of using this material for dentures and implants[8]. Study to determine impact strengths and flexural of PMMA acrylic resins strengthen with the fiber of Hibiscuss abdariffa at (2.5, 5, 7.5.10) weight percentages, the results howed improvement in properties of PMMA denture base resins when adding 7.5 wt% Hibiscus sabdariffafiber.

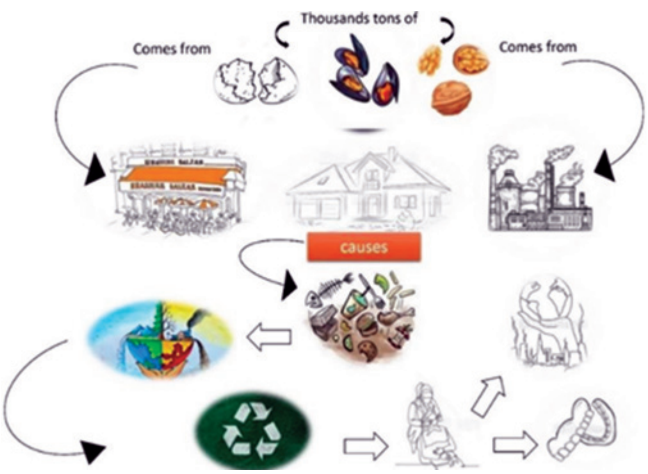


Figure 1: scheme of the study

2.0 Expermontal Work

2.1 Materials

In general, in order to prepare any composite material, we need to use a reinforcing and matrix material. In this study, to prepare test specimen swe was used natural strengthening materials consisted from (Mussel shell, chicken eggshell, walnut shell) as powder, while the matrix made up of poly methacrylate as a powder and methyl methacrylate as a liquid monomer manufactured by (Spofa Dental) company.

2.2 Specimen Preparation

To prepare the test specimens of the PMMA composite prosthetic dentures the cold cured was used, it consist of polymer powder (methyl methacrylate) and monomer liquid (MMA), mixed with 2:1 of a volumetric ratio (2 parts of powder and 1 part of liquid)[9]. Depending on how much PMMA, which needed to fill the glass mold cavity, and by using electronic sensitive balance with accuracy (0.0001) digits, each sample was prepared using the hand layup method. The mold used in this research is glass with dimensions (250 mm × 250 mm × 4 mm). composite samples were prepared depending on the required selection ratio of the weight parts of the reinforcing materials which was calculated depending on the total weight of the composite materials required to fill the mold cavity using the mixture rule shown in the equation (1 and 2) below[10-11]. The samples prepared by mixing the PMMA and adding the filler to it and Stir it until becomes a dough, then pouring it in the mold cavities and left to dry for 30 minutes in the mold. Then removed and cut according to (ASTM D638-87b and ASTM D695) for tensile and compression tests respectively.

$$W_p = \frac{w_P}{w_C} \, . \, 100\ \% \quad \text{... 1}$$

$$W_m = \frac{w_m}{w_c} \, . 100\% \quad \text{... 2}$$

where: wp, wc, wm : weight of the (particles, composite and matrix).

Wp, Wm : weight fraction of (the particles and matrix).

2.3 Design of Experiment

By using experimental design L9 by Taguchi (MINITAB 18) with four factors and three levels, the experimental design was done. Evidently, using a Taguchi orthogonal array would result in fewer tests. The orthogonal array had (4 columns and 9 rows) depending on suggestion of Taguchi as shown in Tables 1 and 2.

Table 1: Design summary

Taguchi Array	L9(3^4)
Factors	4
Runs	9

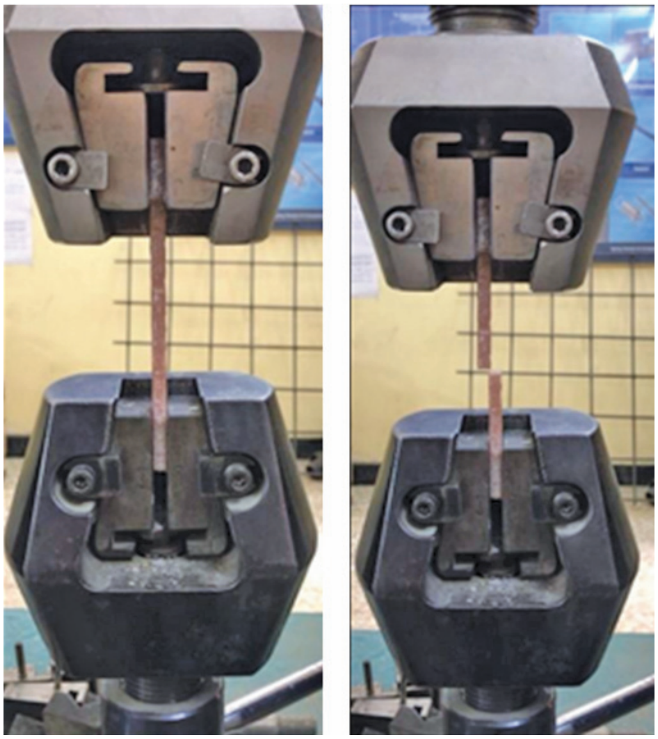
Table 2: Factor Information

Factor	Type	Levels	Values
Grain size	Fixed	3	75;100;125
Eggs hells %	Fixed	3	1.0;1.6; 2.0
Mussel shells %	Fixed	3	1; 3; 4
walnut shells %	Fixed	3	1.0;1.2; 2.0

Table 3 shows the mixing ratio of the composite specimens, which was Taguchi suggested it after entering the factor and levels in (Minitab 18) programme.

2.4 Experimental Test

By using the universal tensile machine, the tensile and compression test were done according to the international standards (ASTMD 638-87b), (ASTMD695) respectively. Figure (2) explains the experimental tensile tests samples in the machine before and after thetest.



(a) Before (b) after the test.
Figure 2: tensile tests samples in machine

3.0 Result and Discussion

After done the experimental tests, we get on the tensile strength, compression strength and modulus of elasticity with estimated their S/N ratios, where the larger is better as explain in the Table 4. While the pure polymethel methylate acrylic has (35.5 MPa) tensile strength (1.16 GPa) modulus of elasticity, (48MPa) compression strength.

3.1 Signal to noise ratio results and discussion

After obtaining the results of the mechanical tests of the samples, the value of S/N ratio was determined and placed in a Table 4. It was notices that the experiment[9] have the largest tensile strength that present (125µm grain size, 1.6% eggshell filler, 3% Musselshell filler and 2% walnut shell filler). Experiment number 2 show the largest compression strength value that present (75µm grain size, 2% eggshell filler, 3% Musselshell filler and 1% walnut shell filler). Whereas experiment number 6 shows the largest compression strength that present (100µm grain size, 1.6% eggshell filler, 1% Musselshell filler and 1% walnut shell filler).

According to the results of combinations got from Taguchi array. The optimum levels were predicted by chosen the control factors for different three levels, which listed in Table 5. Figures (3, 4, and 5) shows the main effects plot for S/N for tensile strength, modulus of elasticity and compression strength respectively. The optimal parameters combination with their levels for higher tensile strength are (125µm grain size, 2% eggshell filler, 3% Musselshell filler and 2% walnut shell filler) with 93% from (PMMA). for higher modulus of elasticity (75µm grain size, 1.6% eggshell filler, 3% Mussel shell filler and 1% walnut shell) filler with 94.4% from (PMMA). While the optimal parameters combination with their levels for compression strength (100µm grain size, 2% eggshell filler, 1% Musselshell filler and 1% walnut shell filler) with 96% from (PMMA).

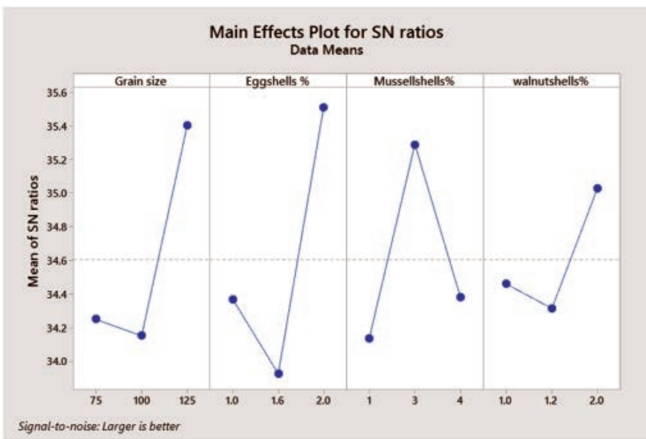


Figure 3: Main Effects Plot for S/N ratios for tensile strength

Table 3: Mixing ratio of the composite specimens

Sample No.	Grain size	PMMA %	Eggshell %	Mussellshell %	Walnutshell %
1	75	96	1	1	2
2	75	94	2	3	1
3	75	93.2	1.6	4	1.2
4	100	94.8	1	3	1.2
5	100	92	2	4	2
6	100	96.4	1.6	1	1
7	125	94	1	4	1
8	125	95.8	2	1	1.2
9	125	93.4	1.6	3	2

Table 4: The experimental results and it's response for signal to noise ratio

No. of experimental	Tensile strength Mpa	S/N ratio	Modulus of elasticity gpa	S/N ratio	Compression strength MPa	S/N ratio
1	50	33.979	1.06	0.506	45	33.064
2	61	35.707	1.6	4.082	42	32.465
3	45	33.064	1.3	2.279	44	32.869
4	52	34.320	1.1	0.828	33	30.370
5	58	35.269	1.26	2.007	55	34.807
6	44	32.869	1.34	2.542	57	35.117
7	55	34.807	1.12	0.984	49	33.804
8	60	35.563	1	0.000	55	34.807
9	62	35.848	1.2	1.584	38	31.596

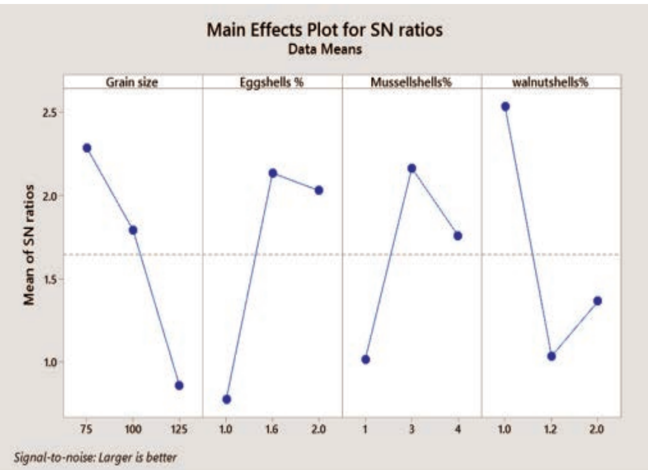


Figure 4: Main Effects Plot for S/N ratios for modulus ofelasticity

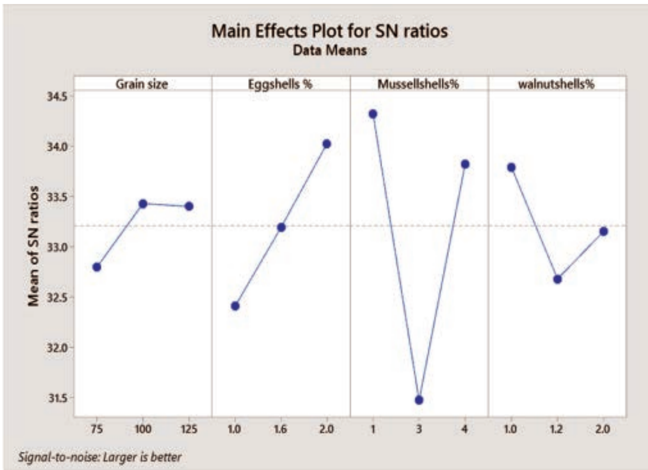


Figure 5: Main Effects Plot for S/N ratios for compression strength

Table 5: Average signal to noise ratio of different parameter levels

Tensile strength		Modulus of elasticity		Compression strength	
Term	Fitted Mean	Term	Fitted Mean	Term	Fitted Mean
Grain size		Grain size		Grain size	
75	34.25	75	2.289	75	32.80
100	34.15	100	1.792	100	33.43
125	35.41	125	0.8560	125	33.40
Eggshells %		Eggshells %		Eggshells %	
1.0	34.37	1.0	0.7728	1.0	32.41
1.6	33.93	1.6	2.135	1.6	33.19
2.0	35.51	2.0	2.030	2.0	34.03
Musselshell%		Musselshell's%		Musselshell's%	
1	34.14	1	1.016	1	34.33
3	35.29	3	2.165	3	31.48
4	34.38	4	1.757	4	33.83
walnut shells%		walnut shells%		walnut shells%	
1.0	34.46	1.0	2.536	1.0	33.80
1.2	34.32	1.2	1.036	1.2	32.68
2.0	35.03	2.0	1.366	2.0	33.16

3.2 Analysis of Variance results and discussion

ANOVA-variance analysis's objectives are to identify discrepancies between the averages of various levels of the independent variable and how they affect the dependent variable[12,13]. It is possible to determine which independent variable prevails over the others and the percentage econtribution of that independent variable by using analysis of variance. Table 6 shows that the dominant factor is the eggshell filler, which indicates the eggshell filler is more significant among others for the tensile strength with contribution (40.11%) followed by grain size (29.12%) then Musselshell (22.18%) with small effect of walnut shell (8.58%). Table 7 shows that the dominant factor is the walnut shell filler, with contribution (30.12%) for modulus of elasticity followed by eggshell filler (27.82%) then grain size (25.65%)

Table 6: Analysis of variance results of tensile strength

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Grain size	2	2.9169	29.12%	2.9169	1.4585	*	*
Eggshells %	2	4.0180	40.11%	4.0180	2.0090	*	*
Mussellshells%	2	2.2223	22.18%	2.2223	1.1111	*	*
walnutshells%	2	0.8599	8.58%	0.8599	0.4300	*	*
Error	0	*	*	*	*		
Total	8	10.0171	100.00%				

Table 7: Analysis of variance results of modulus of elasticity

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Grain size	2	3.178	25.65%	3.178	1.589	*	*
Eggshells %	2	3.447	27.82%	3.447	1.723	*	*
Mussellshells%	2	2.034	16.42%	2.034	1.017	*	*
walnutshells%	2	3.731	30.12%	3.731	1.866	*	*
Error	0	*	*	*	*		
Total	8	12.390	100.00%				

Table 8: Analysis of variance results of compressionstrength

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Grain size	2	0.7640	3.73%	0.7640	0.3820	*	*
Eggshells %	2	3.9073	19.10%	3.9073	1.9536	*	*
Mussellshells%	2	13.9122	68.01%	13.9122	6.9561	*	*
walnutshells%	2	1.8729	9.16%	1.8729	0.9364	*	*
Error	0	*	*	*	*		
Total	8	20.4563	100.00%				

Table 9: Confirmation test results

Properties	Experimental value	Predicted value	Error %
Tensile strength (Mpa)	64.4	68.7	6.2
Modulus of elasticity (Gpa)	1.56	1.4667	5.9
Compression strength (Mpa)	62.9	58.44	7.09

and (16.42%) Musselshell contribution. While in Table 8 noticed the Musselshell has the largest effect on the compression strength with (68.01%) contribution followed by (19.10%) of eggshell filler and small effects of walnut shell filler and grain size at (9.16 %), (3.73) respectively.

4.0 Conclusion

In this study noticed improvement in the mechanical properties with addition a fillers to the PMMA. The tensile strength was enhancement (81.4%) when addition the fillers where the eggshell filler has the main parameter effect on it with a contribution (40.11%). While the modulus of elasticity improved (34.4%), and the main effect parameter was walnut shell with a contribution (30.12%). In addition to improvement the compression strength (31%) when addition the fillers and Musselshell filler, it was the main effect parameter with a contribution (68.01%). The optimal parameters combination for higher tensile strength, modulus of elasticity and compression strength are (125µm grain size, 2% eggshell filler, 3% Musselshell filler and 2% walnut shell filler) with 93% from (PMMA), (75µm grain size, 1.6% eggshell filler, 3% Musselshell filler and 1% walnut shell) filler with 94.4% , (100µm grain size, 2% eggshell filler, 1% Musselshell filler and 1% walnut shell filler) with 96% from (PMMA) respectively. Between all the parameters the Musselshell was the most significant factor with contributing for 16.42-68.01%, followed by eggshell filler. The predicted values obtained from the Taguchi method are very close to the values of experimental, with an error 7%. Thus, we can get on a composite material made from food waste that has good mechanical properties for denture applications.

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