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PHYSICAL AND MECHANICAL PROPERTIES OF COMPOSITE MATERIALS TO ENHANCE CULTIVATING POT MIX PROPORTIONS VIA TOPSIS-TAGUCHI APPROACH

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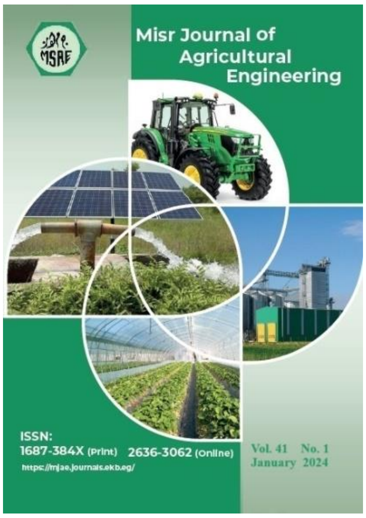

Keywords:
Physical properties;
Mechanical properties;
Composite; TOPSIS-Taguchi

ABSTRACT

The main aim of this work is to determine the physical and mechanical properties of composite materials based on different filler types made from different raw materials (sugarcane bagasse, compost, peat moss, vermiculite and activated carbon) by using the TOPSIS-Taguchi model to optimize combination of filler mixture proportion constituents towards enhancing composite properties. Water absorption, density and void were the measured physical properties; tensile strength and elongation were the analyzed mechanical properties. The results indicate that the highest value of the water absorption was 30%, while the lowest was 15%. The density ranged from 0.616 to 0.711 g cm^{-3} for all treatments under study. The highest value of the void (2.8%) was found with experiment run number 6, while the lowest value of the void (1.0 %) was found with experiment run number 2. The tensile strength ranged from 12.72 to 13.92 MPa for all treatments under study. The elongation ranged from 10.73 to 12.50 % for all treatments under study. The seventh experimental set was judged as the best composite from the analyzed properties perspective for TOPSIS composites ranking based on the Taguchi design of the experiment.

INTRODUCTION

With the rising demand for plastics in the world and their consequent disastrous outcomes for the environment, an appropriate environmental-friendly substitute like green materials or biodegradable composites is necessary. A plethora of numerous kinds of materials are thrown away as waste in all industries around the world, which can be employed as fillers in the green materials industry **(Shafqat *et al.*, 2021)**.

A composite is defined as any combination of two or more components held together in a matrix **(Mitra, 2014)**. Composite materials comprising organic and inorganic components since natural fibers tend to have strong mechanical qualities, they are increasingly being used as reinforcement in composite materials. They are well renowned for being completely biodegradable, renewable, environmentally benign, affordable, widely accessible, and low-density **(Bhat *et al.*, 2021)**. Bagasse belongs to the residual fibrous material that remains after the extraction of juice from sugarcane. Due to its many beneficial characteristics, bagasse fiber is an excellent candidate for composites. For instance, bagasse, a byproduct of sugarcane processing that is produced in vast amounts globally, is a cheap and simple source of fiber. This biomass has been utilized by researchers for several purposes, including sustainable energy and environmental practices. Bagasse fiber is a good option for lightweight composite reinforcement owing to its low density. Bagasse fiber is an excellent choice for usage as a reinforcement component in composite materials because of its good mechanical characteristics, which include substantial tensile strength, stiffness, and endurance. Bagasse fiber is eco-friendly and biodegradable, making it an effective substitute for synthetic fibers in composite applications. Bagasse-fiber-reinforced composites have been extensively tested in a variety of various industries **(Yashas *et al.*, 2023)**.

The physical and mechanical properties of these fillers play a pivotal role in providing an optimal environment for plant growth, ensuring effective water retention, nutrient delivery, and structural stability. The selection of appropriate filler materials within composite mixes is crucial in determining their overall performance. The physical and mechanical attributes of composite materials using various filler types, including sugarcane bagasse, compost, peat moss, vermiculite, and activated carbon were investigated. Compost is currently considered the core of sustainable agriculture systems. Compost is employed to condition the soil. Compost offers greater organic matter content than synthetic chemical fertilizers, making it clearly superior and more environmentally benign when it comes to boosting soil carrying capacity. The amount of organic material in the soil, which is frequently employed for directly assessing the soil fertility index, has a significant impact on soil fertility. The compost can benefit the soil and plants in several ways, including feeding the plants with nutrients, enhancing soil structure, increasing the population and activity of soil organisms, enhancing the ability of soil aggregates to hold water, increasing infiltration, avoiding erosion, and more **(Achmad and Sapsal 2018)**. Adopting biodegradable pots eliminates the need to transplant and then waste a container. Planting pots made from paper, peat moss, or other waste products from the industrial and agricultural sectors can be placed in the soil with the plant, where they will gradually degrade. Similar to this, pots made of biodegradable polymers will similarly decompose when buried **(Tomadoni *et al.*, 2020)**.

The physical characteristics of various fillers significantly influence their water management capabilities, density, and structural integrity. Parameters such as water absorption, density, and void space play integral roles in determining the overall efficiency of water retention and root aeration. The incorporation of sugarcane bagasse, compost, peat moss, and vermiculite as fillers facilitates oxygen access **(Balaguer *et al.*, 2016)** and activated carbon, which attains more absorption capability due to its high surface area **(Ayyaswamy *et al.*, 2019)**, provides a diverse range of attributes that impact the physical characteristics of the composite materials. Water absorption reflects the potential for moisture retention, while density influences the compactness of the mix. Void space, on the other hand, causes root penetration and aeration. In addition to physical attributes, the mechanical properties of those mixes significantly contribute to the stability and support of plant growth. Tensile strength and elongation are key mechanical attributes that determine the ability of the mix to withstand mechanical stresses and maintain structural integrity. The incorporation of various fillers contributes to the composite material's mechanical attributes, with each filler type offering distinct reinforcement mechanisms that can impact tensile strength and elongation properties. High stiffness and tensile strength values have been demonstrated for natural fibers. The reinforcing employed in composites is a major determinant of tensile strength. Natural fibers and matrices can create the necessary mechanical qualities for a particular application **(Bhat *et al.*, 2021)**.

The Taguchi technique has been applied to the selection of materials under ideal circumstances. The Taguchi method offers the additional advantage of keeping experimental costs to a minimum. When the performance value is brought to the target value, it also reduces the variability around the target. The ideal conditions discovered during the experimental work can also be duplicated in the actual production setting, but the Taguchi technique requires only one response into consideration. However, the TOPSIS-based Taguchi expects mixtures of constituent materials **(Noryani *et al.*, 2018 and Warda *et al.*, 2022)**.

The main aim of this work is to determine the physical and mechanical properties of composite materials based on different filler types. To accomplish this, a multi-criteria decision-making (MCDM) approach, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), integrated with the Taguchi experimental design, will be employed to get the optimal mixture constituent of each filler type in the bio-composites for seedling pots.

MATERIALS AND METHODS

The experiments were carried out at the Agricultural and Bio-Systems Engineering Department, Faculty of Agriculture, Moshtohor, Benha University, during the months of October and November, 2022 season.

Sugarcane bagasse was collected from local farms dried and milled to get the powders. Different fillers, including compost, peatmoss, vermiculite, and activated carbon were purchased from local suppliers. Palm wax was obtained from the local market. Sorbitol was added as a plasticizer and brought from a local provider.

Cultivating pots fabrication

Eight sets of filler mixes were configured for fabricating cultivating pots. The cultivating pot composites were fabricated by melt-blending and compression molding. Palm wax was heated and mixed well with each combined design of filler in a ratio of 80:60 by weight, then poured in a pre-prepared steel mold for hot pressing and forming at 160 bars and 60 ^{O}C. Afterwards, it was left at room temperature for curing. Sorbitol was added to fillers at a 0.5: 2 by weight in percentage before mixing with palm wax. Specimens were cut from fabricated composite pots for further measurements.

Experimental design

Five factors are sugarcane straw (S), compost (C), peat moss (P), Vermiculite (V) and Activated carbon (AC) and each of which had two levels (20 and 30%). The Taguchi orthogonal array and the experimental results are shown in Table (1). Quality characteristics for the optimization phase of the TOPSIS method are presented in Table (2). Fig. (1) shows the flow chart illustrating the determination of the optimal mix proportions using the fuzzy TOPSIS-Taguchi.

Table (1): Taguchi orthogonal array (L8 = 2^5) designation of mixture constituent composites of cultivating pots

Experimental run	S	C	P	V	AC
1	20	20	20	20	20
2	20	20	20	30	30
3	20	30	30	20	20
4	20	30	30	30	30
5	30	20	30	20	30
6	30	20	30	30	20
7	30	30	20	20	30
8	30	30	20	30	20

Table (2): The objective of each criterion for the TOPSIS-Taguchi method

Criterion	Objective
Water absorption (%)	Smaller is better
Void (%)	Smaller is better
Density (kg m^{-3})	Larger is better
Tensile strength (MPa)	Larger is better
Elongation (%)	Larger is better

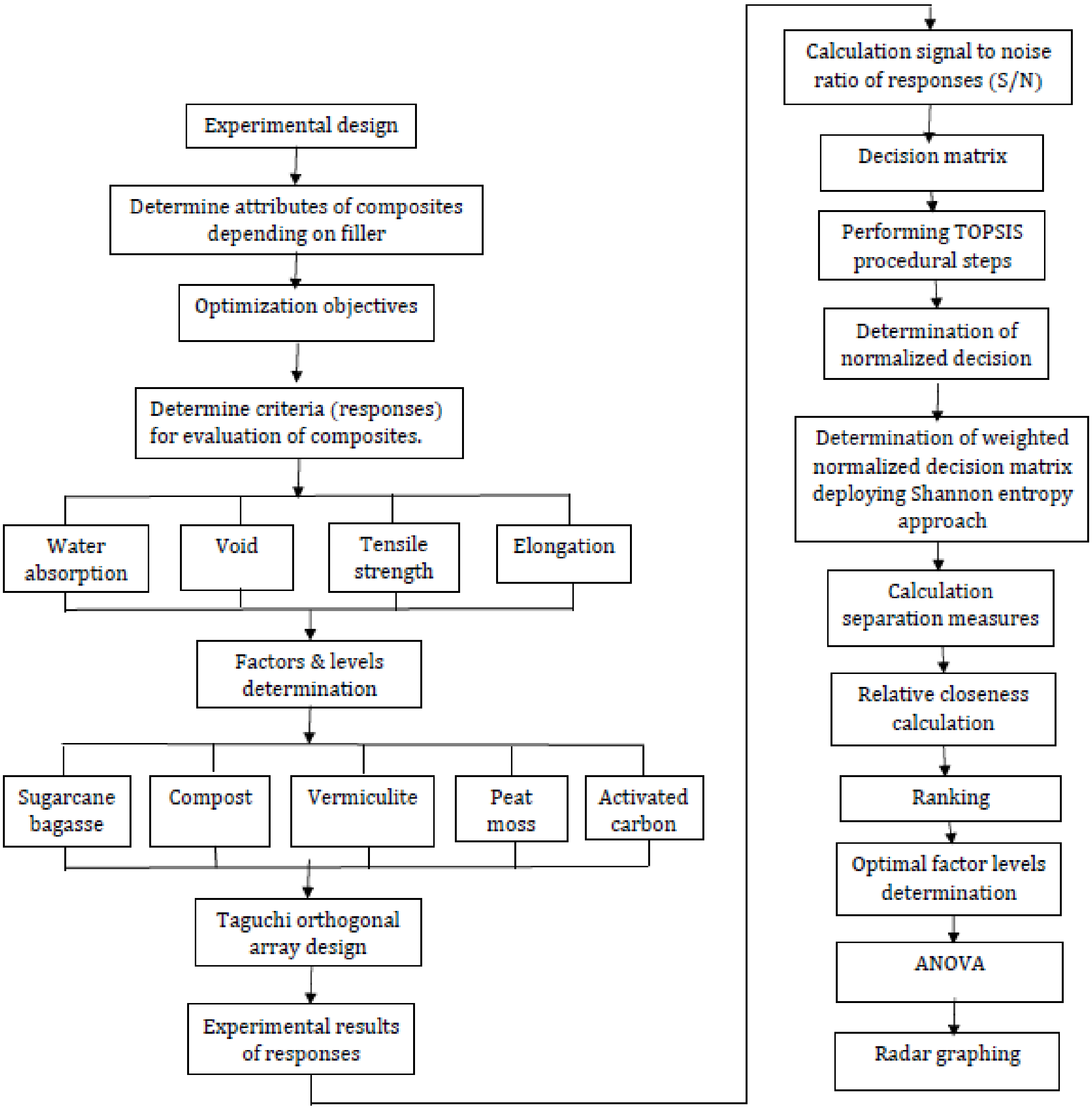

Fig. (1): Flow chart of the TOPSIS-Taguchi's experimental execution

Regardless of the performance objective function category, the S/N ratio corresponds to higher performance characteristics **(Balasubramaniyan and Selvaraj, 2017)**.Therefore, the Signal (S) to Noise (N) Ratio (S/N ratio) can be classified into three categories depending on the optimization objective function, as in the following equations **(Mustapha *et al.*, 2021)**:

$$Smaller\text{ is better}: \quad S/N = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \tag{1}$$

$$Larger\text{ is better}: \quad S/N = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^{\frac{1}{2}}\right) \tag{2}$$

The combination of TOPSIS and Taguchi facilitates the decision of multiple criteria or responses with less data by reducing the number of experimental runs needed via an orthogonal array robust design.

Measurements

Physical Properties

Water absorption (WA)

The water sorption (WA) by the composite specimens was measured taking the initial weight (W_0) before immersing them in a beaker filled with water for approximately 24 h, then removing out, surface drying using tissue paper to remove the excess water up to reach equilibrium state and recording their weight (W) frequently using a digital balance with a 0.1 mg accuracy. Average value was calculated considering three reps of square specimens (20 × 20 mm). The water absorption was calculated according to **Fuentes *et al.* (2021)**:

$$WA(\%) = \frac{W - W_o}{W_o} \times 100 \tag{3}$$

Density (ρ, g cm^{-3})

The Bulk density was calculated using Equation (2) according to **(Werber, 1980**:

$$\rho = \frac{mass\text{ of product}}{Bulk\text{ volume}} \tag{4}$$

Porosity or Voids (V)

As the bulk density (ρ) may not agree with the actual density (ρ, g cm^{-3}) due to voids existence in the composites, the actual density was determined experimentally by means of a simple gravimetrical water immersion technique and the voids were determined as the ratio of difference between densities to the theoretical one as follows:

$$V = \frac{\rho - \rho_a}{\rho} \tag{5}$$

Mechanical Properties

Tensile strength (TS, kN m^{-2})

Seedling pots face numerous forces emanating from the inside due to plant growth and handling in a greenhouse setting **(Juanga-Labayen and Yuan, 2021)**. Therefore, tensile strength is an important indicator of internal bonding and pot stability. Uniaxial tensile strength was conducted on the specimens with dimensions 500 × 250 mm cut from the fabricated pot's wall using a universal testing machine (UTM) instrument equipped with a 5 kN load cell at a crosshead extension speed of 2 to ~5 mm/min at room temperature.

$$TS = \frac{P}{bh} \tag{6}$$

Where:
P is the load, kN
b is the width of a sample at the gauge region, m
h is the height of the sample at the gauge region, m

Elongation at break (E)
Elongation of the composites was detected at the break point at the ultimate tensile strength.

Statistical Analysis
TOPSIS-Taguchi optimization was performed simultaneously on the physical and mechanical attributes using Minitab 19 software. ANOVA was used to evaluate the effect of an individual factor in the orthogonal experiment on the response criteria.

RESULTS AND DISCUSSION

Physical properties of composites
Water absorption (WA)
Fig. (2) shows the water absorption for twenty-four hours of experiment run number. It could be seen that the water absorption was 20, 16, 22, 30, 21, 25, 15 and 17 % for 1, 2, 3, 4, 5, 6, 7 and 8 experiment run number. The results indicate that the highest value of the water absorption (30%) was found with experiment run number 4, while the lowest value of the water absorption (15%) was found with experiment run number 7. Table 3 displays the orders of control factors based on delta values. The delta value is calculated as the highest average minus the lowest average level for each factor. Minitab software assigns rank power of affecting factors depending on delta values in descending order; the highest ranked 1st and the lowest ranked 5th. Generally, ranks prove the relative effectiveness of each factor in the response.

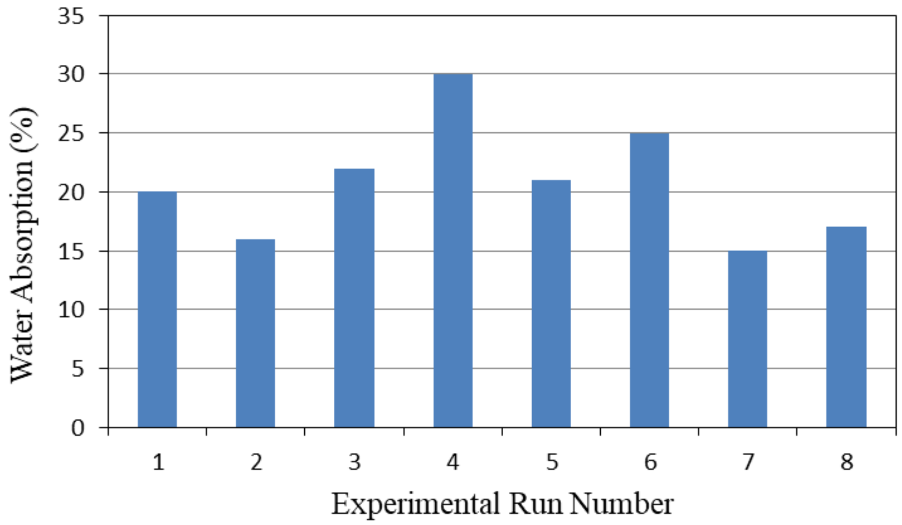

Fig. (2): The water absorption of experiment run number

Fig. (3) shows the optimal mixture of constituents for the minimum water absorption that was found in sugarcane straw (S), compost (C), peat moss (P), Vermiculite (V) and Activated carbon (AC).

Table (3): Response for Signal to Noise Ratios (SN ratio) “Smaller is better” for water absorption

Level	S	C	P	V	AC
1	-26.62	-26.13	-24.56	-25.71	-26.36
2	-25.63	-26.13	-27.70	-26.55	-25.90
Delta	0.99	0.00	3.14	0.84	0.46
Rank	2	5	1	3	4

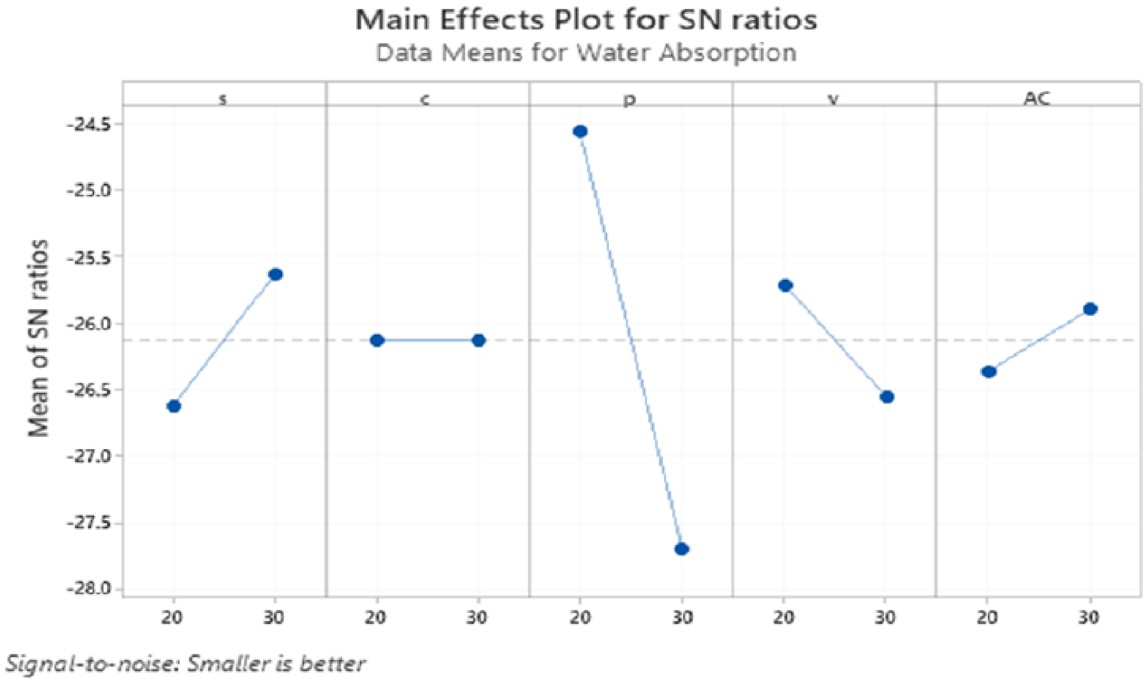

Fig. (3): Main effects plot of SN ratios for water absorption using the Taguchi method

Density

Fig. (4) shows the density of experiment run number. It could be seen the density of different pots was 0.650, 0.616, 0.664, 0.632, 0.703, 0.617, 0.711 and 0.623 g cm^{-3} for 1, 2, 3, 4, 5, 6, 7 and 8 experiment run number. The results indicate that the highest value of the density (0.711 g cm^{-3}) was found with experiment run number 7, while the lowest value of the density (0.616 g cm^{-3}) was found with experiment run number 2. The S/N ratio response graph for density is shown in Fig. (5).The activated carbon element has a remarkable effect on the density due to its water absorbance property. The analysis of variance for density of the composite mix was shown the most significant prime factor that affected these results was the vermiculite component of the mix followed by activated carbon, sugarcane bagasse, compost, and peat moss in descending order. The obtained results were identical to the results from Taguchi’s single response, as illustrated the percentage contributions of the mixtures on the radar graphs for density. However, the result of density from the Taguchi was 0.70 g cm^{-3}, which is less than the ranked TOPSIS one of 0.71g cm^{-3}.

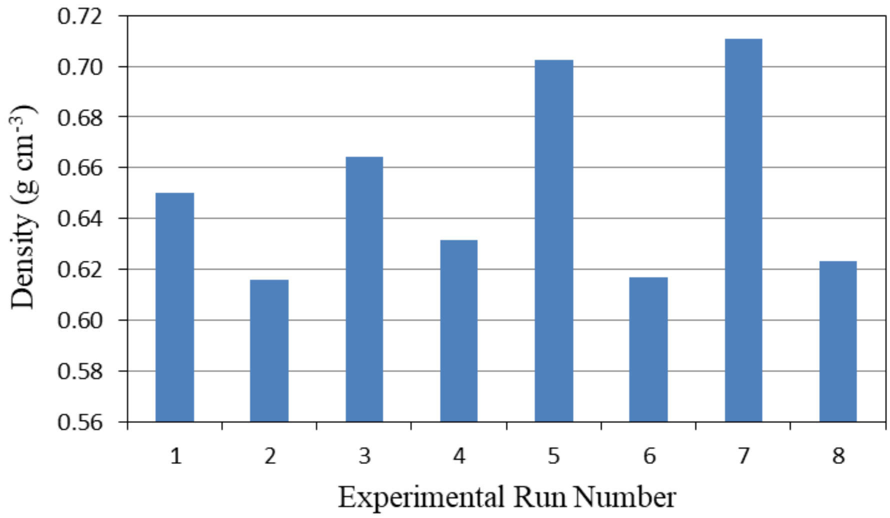

Fig. (4): The density of experiment run number

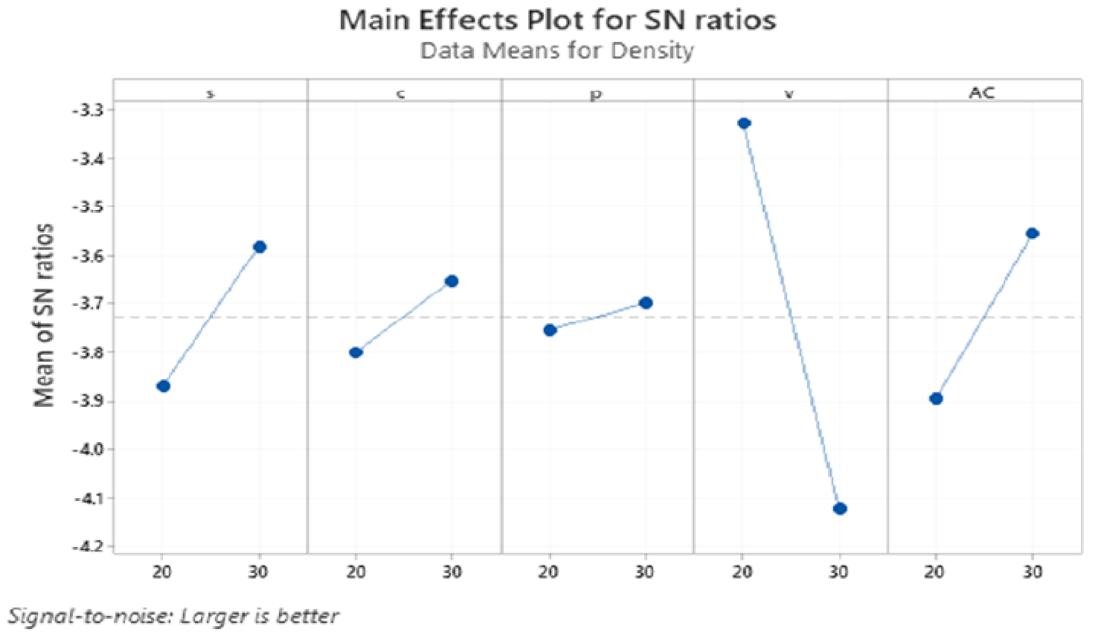

Fig. (5): Main effects plot of SN ratios for density using the Taguchi method

Porosity or void of composites

Fig. (6) shows the void of experiment run number. The void of different pots was 2.0, 1.0, 2.5, 3.0, 2.2, 2.8, 1.5 and 1.8 % for 1, 2, 3, 4, 5, 6, 7 and 8 experiment run number, respectively. The results indicate that the highest value of the void (2.8%) was found with experiment run number 6, while the lowest value of the void (1.0 %) was found with experiment run number 2. The S/N ratio response graph for void is shown in Fig. (7). Obviously, the most significant prime factor that affected these results was the vermiculite component of the mix, followed by activated carbon, sugarcane bagasse, compost, and peat moss in descending order. The obtained results were identical to the results from Taguchi's single response illustrated the percentage contributions of the mixtures on the radar graphs for void. Overall, the results show that vermiculite is the main determinant, with a value of about 72.54% contribution, followed by activated carbon at 14.19%, sugarcane bagasse at 10.45%, compost at 2.49%, and finally a peat moss contribution of 0.31%, which agrees with the results of the Taguchi.

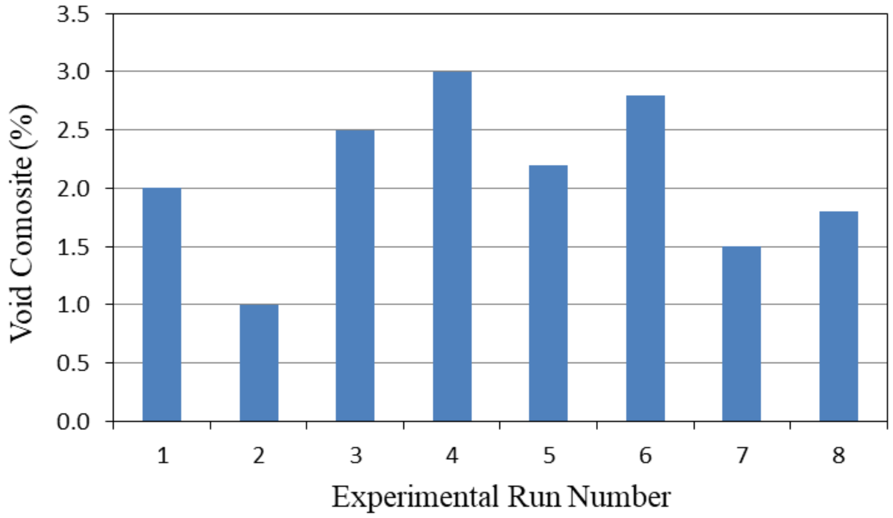

Fig. (6): The void of experiment run number

Fig. (7): Main effects plot of SN ratios for void using the Taguchi method

Mechanical properties of composites

Tensile strength

Fig. (8) shows the tensile strength for composites of experiment run number. It could be seen that the tensile strength was 12.72, 13.23, 13.33, 12.86, 13.69, 13.79, 13.92 and 13.32 MPa for 1, 2, 3, 4, 5, 6, 7 and 8 experiment run number. The results indicate that the highest value of the tensile strength (13.92 MPa) was found with experiment run number 7, while the lowest value of the tensile strength (12.72 MPa) was found with experiment run number 1. Table (4) displays the orders of control factors based on delta values. The delta value is calculated as the highest average minus the lowest average level for each factor. Minitab software assigns ranks power of affecting factors depending on delta values in descending order; the highest one ranked 1st and the lowest ranked 5th. Generally, ranks prove the relative effectiveness of each factor in the response. Fig. (9) shows the optimal mixture of constituents for the minimum tensile strength that was found sugarcane straw (S), compost (C), peat moss (P), Vermiculite (V) and Activated carbon (AC).

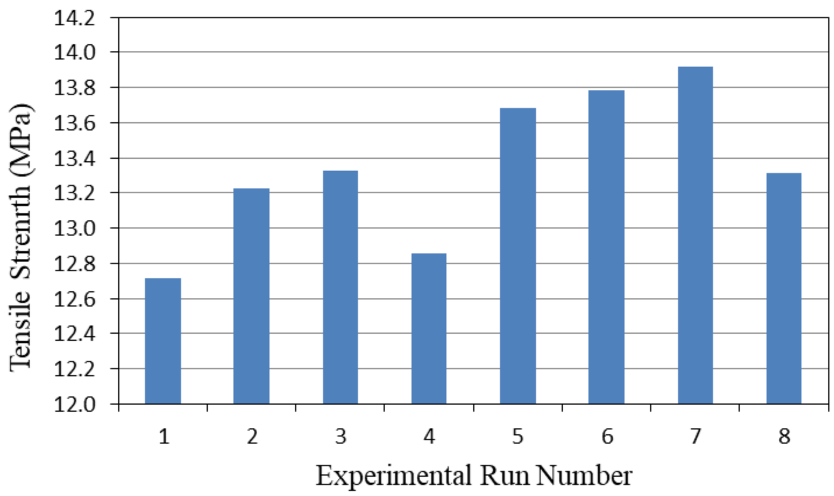

Fig. (8): The tensile strength of experiment run number

Table (4): Response for Signal to Noise Ratios "Larger is better" for tensile strength

Level	S	C	P	V	AC
1	22.30	22.51	22.47	22.54	22.46
2	22.72	22.51	22.55	22.47	22.55
Delta	0.42	0.00	0.08	0.07	0.09
Rank	1	5	3	4	2

Fig. (9): Main effects plot of SN ratios for tensile strength using the Taguchi method

Elongation

Fig. (10) shows the elongation of experiment run number. It could be seen that the elongation of different pots was 11.05, 10.84, 10.73, 10.95, 12.27, 12.37, 12.50 and 12.20 % for 1, 2, 3, 4, 5, 6, 7 and 8 experiment run number. The results indicate that the highest value of the elongation (12.50 %) was found with experiment run number 7, while the lowest value of the elongation (10.73 %) was found with experiment run number 3. Furthermore, the results of the Taguchi method are (S), (C), (P), (V) and (AC) for the elongation as a single response, as shown in Fig. (11). The results also indicate that the sugarcane bagasse is the highest constituent factor affecting tensile strength and elongation. From the ANOVA, all constituents had no significant effect on the responses except elongation, which was significantly influenced by sugarcane bagasse content. This result is reasonable, as peat moss and vermiculite might not inherently possess elongation values, as they are not typically measured for their ability-stretch. In addition, sorbitol plasticizer reduces tensile strength with a rise in elongation at break **(Mitra, 2014)**.

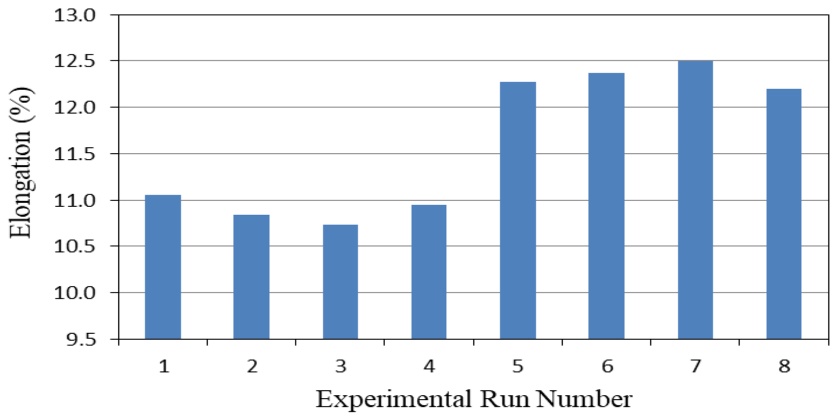

Fig. (10): The elongation of experiment run number

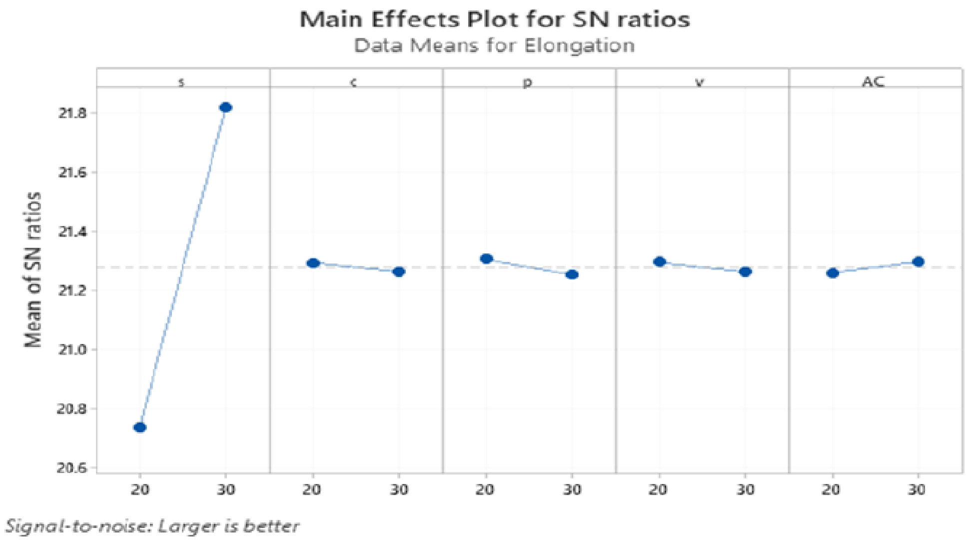

Fig. (11): Main effects plot of SN ratios for elongation using the Taguchi method

Optimization of composites using the TOPSIS-Taguchi approach

The natural fiber composite material selection options are flexible. Hence, the technique of order preference similarity to the ideal solution (TOPSIS) is an influential technique to select the best alternative option **(Noryani *et al.*, 2018)**. Herein, the optimization approach of natural fiber composite selection was carried out depending on the TOPSIS after setting the Taguchi orthogonal array of experimental runs. The TOPSIS method selects the best experimental set among the different alternatives depending on how far it is from the positive ideal solution and farther from the negative one. Tables (5, 6, 7, 8 and 9) show the decision matrix of responses, signal-to-noise ratio, normalization matrix, weight normalized decision matrix, separation measure, relative closeness, and TOPSIS ranking, sequentially as described in **(Balasubramaniyan and Selvaraj 2017 and Prasad *et al.*, 2020)**.

For the weight-normalized matrix, the sum of the factor's weightage must be equal to one. The following factor weightages for different attributes were calculated based on Entropy method as described in **(Rao and Venkatasubbaiah 2016)**. The obtained weights for: Water absorption (%) = 0.032, Void (%) = 0.061, Density (g/cm^3) = 0.903, Tensile strength (MPa) = 0.0005, and Elongation (%) = 0.0025.

Table (5): Decision matrix

Run	Responses (Criteria of Decision Matrix)				
	water absorption %	Void %	Density (g cm^{-3})	Tensile strength (MPa)	Elongation %
1	20	2.0	0.650	12.717	11.045
2	16	1.0	0.616	13.227	10.835
3	22	2.5	0.664	13.327	10.725
4	30	3.0	0.632	12.857	10.945
5	21	2.2	0.703	13.687	12.265
6	25	2.8	0.617	13.787	12.365
7	15	1.5	0.711	13.917	12.495
8	17	1.8	0.623	13.317	12.195

Table (6): Signal to noise (S/N)

Run	S/N Ratio				
	water absorption %	Void %	Density (g cm^{-3})	Tensile strength (MPa)	Elongation %
1	-26.021	-6.021	-3.739	22.087	20.863
2	-24.082	0.000	-4.209	22.429	20.697
3	-26.848	-7.959	-3.550	22.494	20.608
4	-29.542	-9.542	-3.989	22.182	20.784
5	-26.444	-6.848	-3.066	22.726	21.773
6	-27.959	-8.943	-4.194	22.789	21.844
7	-23.522	-3.522	-2.967	22.871	21.935
8	-24.609	-5.105	-4.107	22.488	21.724

Table (7): Normalization matrix

No.	Normalized Decision Matrix				
	water absorption %	Void %	Density (gcm^{-3})	Tensile strength (MPa)	Elongation %
1	-0.351	-0.319	-0.352	0.347	0.347
2	-0.325	0.000	-0.396	0.352	0.344
3	-0.362	-0.422	-0.334	0.353	0.342
4	-0.399	-0.506	-0.375	0.348	0.345
5	-0.357	-0.363	-0.289	0.357	0.362
6	-0.377	-0.474	-0.395	0.358	0.363
7	-0.317	-0.187	-0.279	0.359	0.364
8	-0.332	-0.271	-0.387	0.353	0.361

Table (8): Weight normalized matrix

Run	Weighted Normalized Decision Matrix				
Wj	0.032	0.061	0.903	0.001	0.003
	water absorption %	Void %	Density (g cm^{-3})	Tensile strength (MPa)	Elongation %
1	-0.011	-0.020	-0.318	0.000	0.001
2	-0.010	0.000	-0.358	0.000	0.001
3	-0.012	-0.026	-0.302	0.000	0.001
4	-0.013	-0.031	-0.339	0.000	0.001
5	-0.011	-0.022	-0.261	0.000	0.001
6	-0.012	-0.029	-0.357	0.000	0.001
7	-0.010	-0.011	-0.252	0.000	0.001
8	-0.011	-0.017	-0.349	0.000	0.001

Wj is the weights of responses (criteria) by Entropy

Table (9): Separation measure (S_m), relative closeness (Ci), and TOPSIS ranking

Run	S_m+	S_m-	Ci
1	0.068555	0.041535	0.37728
2	0.105584	0.031131	0.227707
3	0.055977	0.056223	0.501098
4	0.092299	0.0187	0.168468
5	0.023857	0.097544	0.803483
6	0.108352	0.002405	0.021712
7	0.011456	0.107416	0.903627
8	0.098359	0.016956	0.147041

The studied composites of ranking based on the physical and mechanical attributes shown in Fig. (12). The eighth experimental set was judged as the best composite from the analyzed properties perspective. From statistical analysis, vermiculite and activated carbon significantly affect the relative closeness coefficient (Ci), with contribution percentages of 71.15 and 19.43% as plotted in Fig. (13) and this was identical with the Taguchi of Ci as a single response, as shown in Table 18. The ranking of Ci was typical of the Taguchi of Ci, as seen in Fig. (14).

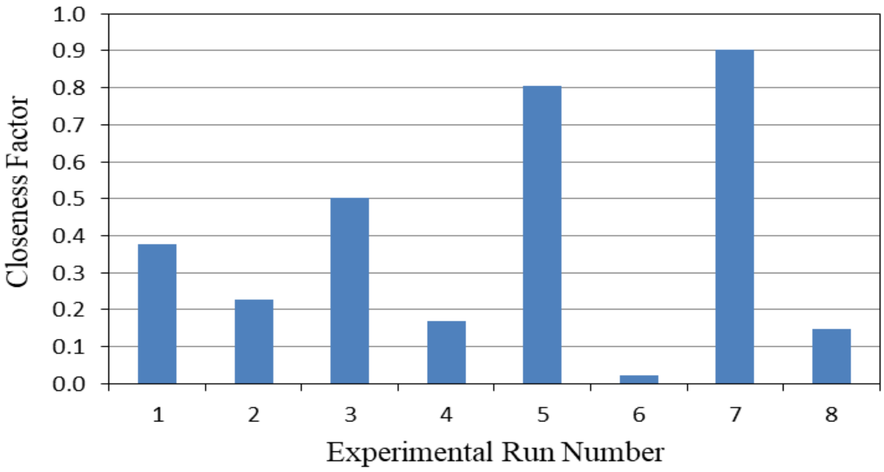

Fig. (12): TOPSIS composites ranking based on the Taguchi design of the experiment

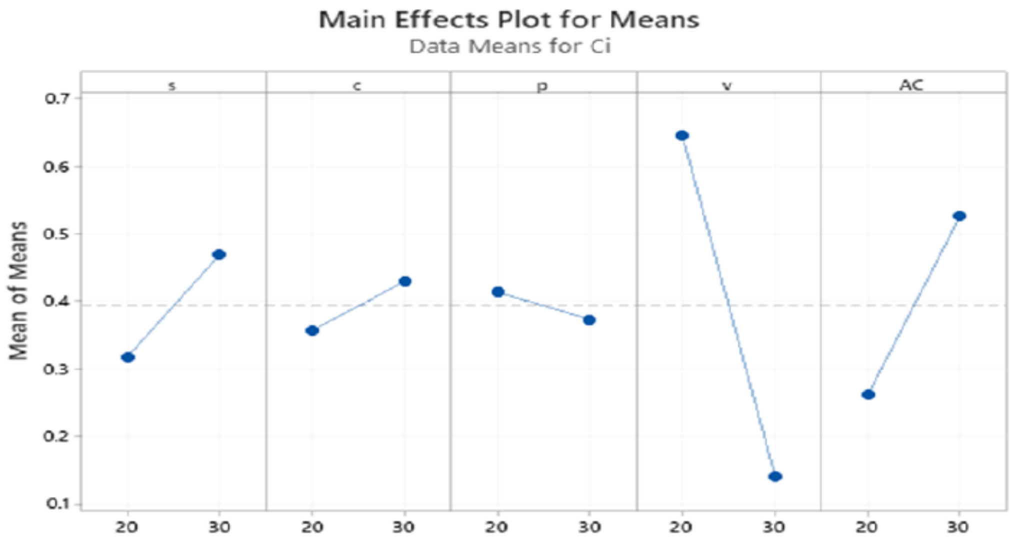

Fig. (13): Main effects plot of SN ratios for closeness using the Taguchi method

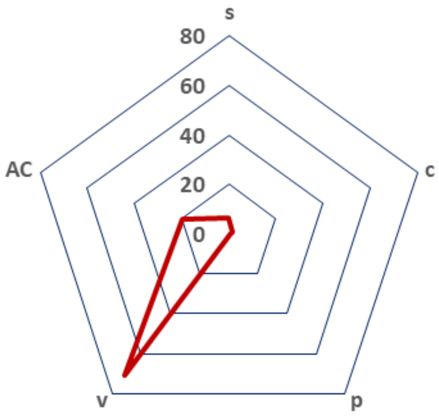

Fig. (14): Radar graphs representing the percentage contributions of the mixture ingredients to the closeness

CONCLUSION

The experimental study was carried out successively to optimize the physical and mechanical properties of composite materials based on different filler types made from different raw materials (sugarcane bagasse, compost, peat moss, vermiculite and activated carbon) by using TOPSIS-Taguchi model to optimizing combination of filler mixture proportion constituents towards enhancing composite properties. The obtained results can be summarized as follows:

- The highest value of the water absorption (30%) was found with experiment run number (4), while the lowest value of the water absorption (15%) was found with experiment run number (7).
- The density of different pots was 0.650, 0.616, 0.664, 0.632, 0.703, 0.617, 0.711 and 0.623 g cm^{-3} for 1, 2, 3, 4, 5, 6, 7 and 8 experiment run number.
- The highest value of the void (2.8%) was found with experiment run number 6, while the lowest value of the void (1.0 %) was found with experiment run number (2).
- The tensile strength ranged from 12.72 to 13.92 MPa for all treatments under study. The elongation ranged from 10.73 to 12.50 % for all treatments under study.
- The seventh experimental set was judged as the best composite from the analyzed properties perspective for TOPSIS composites ranking based on the Taguchi design of the experiment.

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الخصائص الطبيعية والميكانيكية للمواد المركبة لتحسين نسب خليط الأصص الزراعية عبر منهج TOPSIS-Taguchi

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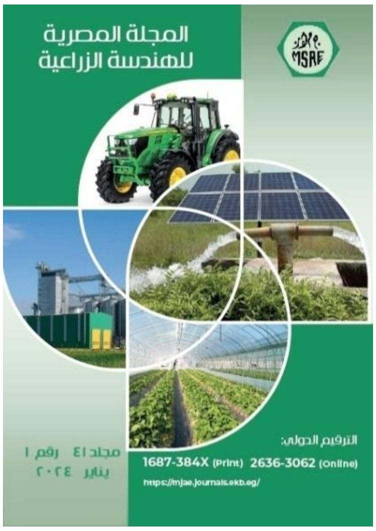

الكلمات المفتاحية:
الخصائص الطبيعية؛
الخصائص الميكانيكية؛
الخليط؛ امتصاص المياه؛ الكثافة.

الملخص العربي

إن الهدف الرئيسي من هذه الدراسة هو تحديد الخواص الفيزيائية والميكانيكية للمواد المركبة اعتمادا على أنواع من مواد خام مختلفة مثل تفل قصب السكر والسماد العضوى المكمور (الكمبوست) والبيتموس والفيرميكوليت والكربون المنشط باستخدام نموذج TOPSIS-Taguchi لتحسين التركيبة للوصول الى نسبة مكونات الخليط من المواد المختلفة لتحسين خصائص المركب الناتج. ولتحقيق ذلك تم دراسة الخصائص الطبيعية والميكانيكية من خلال تقدير امتصاص الماء والكثافة والفراغ بالنسبة للخصائص الفيزيائية. وتقدير قوة الشد والاستطالة بالنسبة للخصائص الميكانيكية. واظهرت النتائج أن أعلى قيمة لامتصاص الماء كانت ٣٠%، بينما كانت أقل قيمة لامتصاص الماء هى ١٥%. وتراوحت الكثافة للمواد المختلفة من ٠,٦١٦ إلى ٠,٧١١ جم سم$^{-٣}$ لجميع المعاملات تحت الدراسة. بيمنا كانت أعلى قيمة للمسامية هى ٢,٨% وجدت مع الخليط رقم ٦، بينما كان أقل قيمة للمسامية هى١,٠% وجدت مع الخليط رقم ٢. وتراوحت قوة الشد من ١٢,٧٢ إلى ١٣,٩٢ ميجا باسكال لجميع المعاملات تحت الدراسة. وتراوحت نسبة الاستطالة من ١٠,٧٣ إلى ١٢,٥٠% لجميع المعاملات تحت الدراسة. وأظهرت النتائج ان الحكم على مجموعة الخليط التجريبية السابعة كأفضل خليط من منظور الخصائص التي تم تحليلها لتصنيف مركبات TOPSIS بناءً على تصميم Taguchi للتجربة.