

Comparing the Flexural Properties of Peanut Oil Cake Powder/Rice Straw Based Natural Polyester Composites and Peanut Oil Cake Powder Composite

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Abstract

Aim: The major aim of this research work is to improve the flexural properties of polyester hybrid composites made from Peanut oil cake powder and Rice straw fibre mate. **Materials and Methods:** In this research work peanut oil cake powder acts as a control group and Rice straw fibre mate acts as an Experimental group. Each group is constructed with 20 samples and a total of 40 samples. This study used an independent sample by using G power of 80 %. The fibres were treated in 5% NaOH solutions for varying periods of time. Particle size of peanut oil cake powder (μm), number of layers of Rice straw fibre mate (no), and NaOH treatment (hours) were all chosen at three different levels for composite fabrication. The specimen was cut into the size required by ASTM for flexural strength estimation. The L₉ orthogonal array was used for composite fabrication. The composite materials were fabricated using hand-lay-up technique. **Results:** As per the results obtained, The flexural strength of peanut oil cake powder composite and hybrid composites are 28.31 MPa and 30.43 MPa the significant values 0.007 ($P < 0.05$). **Conclusion:** The proposed peanut oil cake powder based composite and hybrid composite's flexural strength has been tested. It was concluded that the hybrid composite has a 8.61% higher flexural strength than peanut oil cake powder.

Keywords: Natural fibre, Flexural strength, Novel hybrid composite, Peanut oil cake powder, Rice straw fibre mate, NaOH.

INTRODUCTION

Natural fibres are formed from geological processes or plant and animal tissues. Fibres have been recommended as a suitable reinforcement material for polymer-based composites because of their environmentally friendly nature (Sekar, Suresh Kumar, and Vigneshwaran 2020). They are low-density materials that produce a composite that is relatively lightweight and has good specific characteristics (Velmurugan, Pasha, and Arasu 2018a). Natural fibres can be used for a wide range of applications and it has developed over the last few years from a concern for the environment. Current environmental regulations have put pressure on the engineering industry, such as the vehicle, packaging, and manufacturing industries, to develop new goods that can effectively be recycled. As a replacement for typical composite materials (Velmurugan et al. 2020). Non-biodegradability, skin allergies, combustibility, and other downsides of working with man-made fibres exist. Plant fibres are becoming increasingly popular as environmental concerns develop, thanks to their abundance and availability as a renewable resource, as well as their biodegradability and inexpensive cost (Velmurugan et al. 2020). Composites are made up of two or more fillers encapsulated in the same matrix. Hybridization improves the mechanical properties of natural fibre reinforced plastic composites by addressing the common shortcomings of individual composites. The mechanical characteristics of glass/palm fibre waste sandwich composites are said to benefit from hybridization (Ganesan and Kaliyamoorthy 2020a).

Several research publications have been published in recent years and the articles were published in the past five years, 171 research papers were published in Google Scholar and 157 research papers were published in Science Direct. The best fibres, such as Rice straw, kenaf, hemp, and flax, have low density and high specific strength, and are of almost interest in applications striving for lightweight and high strength. Peanut oil cake powder is one of the most abundant lignocellulosic fibres having similar properties to jute fibre. Peanut oil cake powder is an affordable, readily available natural fibre that has a better strength and modulus of stiffness than plastic. Peanut oil cake is a waste product that results from the extraction of oil from groundnut. Extracted peanut oil cake in natural fibre composites, cellulose micro filler (CMF) is utilised to improve mechanical and thermal

properties. The extracted material is called peanut oil cake. The addition of peanut oil cake to the mix appears to improve the outcome. When peanut oil cake powder was applied to the fabric, it lowered the clothes (Sumesh, Kanthavel, and Kavimani 2020) and other mechanical properties. The mechanical properties of glass/palm fibre waste sandwich composites are said to be improved by hybridization (Prabhuram, Somurajan, and Prabhakaran 2010). Hybridisation produces efficient effects in composites, as evidenced by different polymer composites research studies. Epoxy composites based on hybrid carbon and glass fibres were produced. Hybridisation increased the failure strain of Polymers composites by 15%, according to this study (Alagumalai et al. 2021). Natural fibres derived from agricultural wastes are gaining popularity in the polymer sector due to numerous benefits such as light weight, low cost, and environmental friendliness. Rice straw fibre is the best substitute for wood among the various natural fibres since it is inexpensive, readily available, and has higher strength and modulus of stiffness than plastic. Rice is the most common food consumed on a daily basis, and it has grown in popularity in recent years. According to the demand of billions of people, the world's second most important cereal crop sector Rice production in 2019 was estimated to be over 756 million metric tonnes worldwide. Asia was responsible for 90% of overall output. Because of more availability. Rice straw is a low-cost residue of rice milling that is removed from the rice crop (Reza et al. 2015). Using rice straw as a fibre in composite material helps to increase the tensile strength and compressive strength in comparison to synthetic fibre, mechanical properties of a Rice straw fibre based natural composites were high. It has good flexural strength and tensile strength. Chemical treatment is a common procedure for natural fibres and NaOH removes the usual wax and gloss from the cellulose fibre exterior, activating the hydroxyl groups in the process. The NaOH treatment causes two types of reactions in the fibres: In the creation of a -OH functional group of sodium hydroxide in the fibres, and copolymerization in the matrix, which increases the covalent connections between fibres and improves mechanical characteristics (Ganesan and Kaliyamoorthy 2020a).

Our team has extensive knowledge and research experience that has translate into high quality publications (Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021). Among all these papers the best cited article in the current research work is (Velmurugan et al. 2020) (Velmurugan et al. 2020) because it is mainly focused on the chemical treatment used to improve characteristics of composite. Based on the above mentioned literature no one fabricated the natural composites with the combinations of Peanut oil cake powder and Rice straw fibre mate. The main objective of this research work is to measure the flexural strength of the novel hybrid composite and to compare the effectiveness of NaOH treatment for the above mentioned novel combinations. The peanut oil cake powder and Rice straw fibre mate fibre based hybrid composite were fabricated by hand lay-up method. Table 1 shows the physical and mechanical properties of reinforcement and its matrix.

MATERIALS AND METHODS

The fabrication was carried out at Saveetha School of Engineering, Saveetha Institute of Medical and Technical Science, Chennai. The size for each gathering was determined by utilising past concentrate on outcome online sample calculator by keeping G power as 80%, edge 0.05 and certainty span as 95% (Mohamed Adil, Fathima, and Others 2020). Number of groups involved was 2, in which each sample had a size of 20 and total number of samples involved were 40. In this research, peanut oil cake powder and Rice straw fibre mate based composite are the two groups involved. Peanut oil cake powder was collected from GVR enterprises in Chennai, Tamil Nadu, India. Rice straw fibre mates were collected from a Jute service industry, Chennai, Tamilnadu. Both peanut oil cake powder and Rice straw fibre mate were sun-dried for 2 days to remove moisture. Both were treated in 5% of NaOH solutions with different time lengths. The extraction of peanut oil cake powder from peanut oil cake and rice straw fibre mate from rice husk is shown in Fig. 1 and 2. Unsaturated polyester (resin), methyl ethyl ketone peroxide (catalyst) and cobalt naphthenate (accelerator) were procured from were supplied from GVR enterprises, Chennai, Tamil Nadu, India.

Fabrication of composite

In Groups I, Individually, peanut oil cake powder was washed with 1 to 2 percent detergent solvents at 60°C to 70°C for 1 hour to eliminate any impurities, then rinsed with distilled water before being dried in a vacuum oven at 70°C for 1 hour and 30 minutes. Untreated fibres were defined as dried fibre. Fillers were made out of dry peanut oil cake powder and Rice straw fibre mate was used (Ganesan and Kaliyamoorthy 2020a).

In Groups II, Rice straw fibre mate was cleaned as per the above mentioned procedure, After that, both fibres were chemically treated. The de-waxed yarns were then immersed in a 5 % NaOH solution in a beaker. According to the parameter levels of the experiment, the alkali treatment time varied from 2 to 6 hours. They were then properly rinsed in distilled water and dried in 24 hours of atmospheric air (Velmurugan and Babu 2020).

The mould was made of stainless steel with dimensions of 150 mm x 150 mm x 3 mm. Unsaturated polyester resin was mixed thoroughly with 1 % by weight of cobalt naphthenate and 1 % by weight of methyl-ethyl ketone peroxide. The treated peanut oil cake powder along with the rice straw fibre mate were used for composite fabrication by hand lay-up technique. Thorough stirring was used to distribute the Peanut oil cake powder in the produced polyester resin. Using a hand roller, the prepared resin mixture was put into the mould and spread out. Rice straw fibre mate was laid over the resin mixture and another layer of polyester resin was again poured and spread out using a hand-roller. Composites were prepared with up to three layers of rice straw fibre mate fibre sandwiched between the polyester resin matrices as per the experimental design requirements. The mould was then bolted in place, and a consistent pressure of 50 kg/cm² was applied to the mould, which was then allowed to cure for 24 hours at room temperature. To avoid moisture absorption, the manufactured hybrid composite samples were placed in desiccators. The fabrication of the hybrid composite shown in Fig. 3. The parameters along with their levels and L₉ orthogonal array (OA) respectively are listed in the Table 2 and 3.

TESTING

The specimen was cut to the size recommended by ASTM D-256 to determine the flexural properties of the composites (width 10 mm, length 125 mm, and thickness 3 mm). A Universal Test Machine (UTM) was used to examine the samples. Equation (1) is used to determine flexural strength values of the composites (Velmurugan, Pasha, and Arasu 2018b).

$$\text{Flexural Strength} = \frac{3PL}{2bd^2} \quad (1)$$

Statistical analysis

The statistical analysis was conducted using IBM SPSS version 26 software that was used for the execution of statistical analysis, through which an independent sample t-Test was carried out. The particle size, number of layers and NaOH treatment hours are the independent variables in this analysis. Flexural strength is a dependent variable since it depends upon the input (Ganesan and Kaliyamoorthy 2020b).

Results

The flexural test determines how much force is necessary to break a beam under three-point loading. In engineering applications, fibre reinforced composites are typically assumed to be flexible under greater stress situations. The flexural strength of the peanut oil cake powder based composite and Peanut oil cake powder and Rice straw fibre mate based Novel hybrid composite is investigated. The flexural strength of novel hybrid composite for the proposed combinations of the parameters are given in Table 4 and 5. The flexural strength values obtained for peanut oil cake powder based composite and hybrid composite are 28.31 MPa and 30.43 MPa respectively. Table 6 and 7 Shows the Group statistics of sample mean, standard division and standard error mean. The mean value is 21.2 and the standard deviation 2.08 obtained for peanut oil cake powder. The mean value is 23.5 and the standard deviation 3.48 obtained for hybrids. Results reveal that the significant value between the two groups is observed to be P = 0.007. Bar graph represents the flexural strength of peanut oil cake powder based composite and hybrid composite. The bar graphs are comparing the mean +/-1SD as shown in Fig. 4. The flexural strength of natural fibre Novel hybrid composites was increased and using a novel combination of Peanut oil cake powder and Rice straw fibre.

Discussion

In this analysis, the independent sample test is done with the significance of P = 0.007 for a peanut oil cake powder in comparison with novel hybrid composite. From the result it has been observed that the proposed Novel hybrid composite has a flexural strength of 28.31 MPa. which is better than the peanut oil cake powder based composite. Fibre reinforced composites are commonly thought to be flexible under higher stress conditions in engineering applications (Sekar et al. 2020). The flexural test calculates the amount of force required to break a beam under three-point loading. Table 4 shows the results of three point bending tests on recommended hybrid bio composites. It indicates that increasing the particle size of peanut oil cake powder increases composite strength. This is because the presence of mate-based fibre materials mitigates the effects of voids, which is consistent with the findings of author Velmurugan G (Velmurugan et al. 2020).

The composites improved when the number of layers of Rice straw was increased throughout the complete specified level, owing to an increase in the contact area between the fibre and matrix as fibre content rose. As a result, breaking the bond between the interlaced fibre bundles requires more energy (Ganesan and Kaliyamoorthy 2020a)(“Website,” n.d.; Ganesan et al. 2021)(Sekar et al. 2020). Natural and other impurities were eliminated from the fibre when it was treated with NaOH solution, resulting in rough surface texture. According to the experimental results, level 2 (4 hour) had the maximum flexural strength among the parameter (NaOH

treatment hours) levels 1 and 3. It aids in improving natural fibre compatibility and adherence to the polymer matrix (Velmurugan et al. 2020). As a result of the reduction in porosity content, the degree of crystallinity and polymerization was raised. The concentration of NaOH in the fibre increased when it was treated for more than 4 hours, lowering the crystalline index of the fibre. As a result, the efficiency of stress transferring the fibre surface is reduced, resulting in a loss of mechanical characteristics (Ganesan and Kaliyamoorthy 2020a) & (Velmurugan et al. 2020).

In the present study, the parameters 150 µm of peanut oil cake powder, 3 mm of Rice straw fibre mate length, and 2 hours of NaOH treatment have the lowest flexural strength. In the future there is a scope to improve the flexural strength and overcome the above -mentioned limitations by altering the levels of chemical concentration or chemicals.

Conclusion

Peanut oil cake powder and rice straw fibre mate reinforced Novel hybrid composites were fabricated via hand-lay-up method and its flexural behaviours were evaluated to understand the influence of peanut oil cake powder reinforcement on mechanical properties of Rice straw fibre mate. According to the results, the parameters of peanut oil cake powder and Rice straw fibre mate based hybrid composites should be maintained at a recommended level. Among the 2 hours and 6 hours, 4 hours of NaOH treatment showed an increase in the flexural strength. It was concluded that the hybrid composite has higher flexural strength than peanut oil cake powder.

DECLARATION

Conflict of Interest

No conflict of interests in this manuscript.

Author Contributions:

Author KK was involved in the sample collection, fabrication, data analysis, and manuscript writing. Author GV was involved in the conceptualization, guidance, and critical review of the manuscript.

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Tables and Figures

Table 1. Physical and Mechanical properties of Reinforcements and Matrix used in the hybrid composite

SI.no	Properties	Peanut oil cake powder	Rice straw fibre mate	Polyester resin
1	Cellulose (%)	28	35	-
2	Hemicellulose (%)	48	18	-

3	Lignin (%)	3.0	15	-
4	Density (g/cm ³)	0.228	600-700	1.16
5	Tensile strength (Mpa)	41.2-75.3	69.72	8-9
6	Young's modulus (Mpa)	-	24.27	0.58

Table 2. Parameters and their levels used for the novel hybrid composite experiment in μm , no and hours

Sl.no	Parameters	Symbol	Levels		
			L ₁	L ₂	L ₃
1	Particle Size (μm)	A	150	212	300
2	No. of rice straw Layer (no)	B	1	2	3
3	NaOH Treatment Hours (hours)	C	2	4	6

Table 3. L₉ Orthogonal array of novel hybrid composite in μm , no and hours

Run	Particle Size A (μm)	No. of Rice straw layer B (no)	NaOH Treatment Hours C (hours)
1	150	1	2
2	150	2	4
3	150	3	6
4	212	1	4
5	212	2	6
6	212	3	2
7	300	1	6
8	300	2	2
9	300	3	4

Table 4. L₉ Orthogonal array of hybrid composite along with flexural strength outcome in MPa

Run	Particle Size A (µm)	No. of (Rice straw fibre) Layer B (no)	NaOH Treatment Hours C (hours)	Flexural Strength (MPa)
1	150	1	2	25.18
2	150	2	4	27.45
3	150	3	6	25.99
4	212	1	4	29.08
5	212	2	6	28.25
6	212	3	2	27.56
7	300	1	6	24.12
8	300	2	2	26.32
9	300	3	4	30.43

Table 5. Comparison 20 samples outcomes of Peanut oil cake powder and Hybrid composite

SI.no	Flexural Strength of Peanut oil cake powder (Mpa)	Flexural strength of Hybrid Composite (Mpa)
1	28.31	30.43
2	24.08	25.12
3	20.01	20.03
4	21.26	29.02
5	20.01	21.03
6	21.24	29.01
7	20.11	20.11
8	21.22	25.14
9	19.01	21.01
10	21.11	24.12
11	20.01	20.12

12	20.21	22.12
13	20.11	21.03
14	23.34	23.11
15	20.67	22.01
16	20.01	29.01
17	20.20	20.01
18	22.12	23.12
19	20.12	26.01
20	22.01	20.43

Table 6. Independent sample t-test showing the number of samples, mean, standard deviation and standard error of peanut oil cake powder and Hybrid composites

Group Statistics					
	Groups	N	Mean	Std. Deviation	Std. Error Mean
Flexural Strength (MPa)	Peanut oil cake powder	20	21.2015	2.08242	0.46564
	Hybrid	20	23.5995	3.48230	0.77867

Table 7. Independent sample test showing that both the groups are statistically significant with P value (<0.05) for the flexural strength. The study was conducted with 95% confidence interval of the difference.

Independent Samples Test					
Levene's Test for Equality of Variances					
Properties		F	Sig.	t	df
Flexural Strength	Equal variances assumed	8.286	0.007	-2.643	38

(Mpa)	Equal variances not assumed	-	-2.643	29.329
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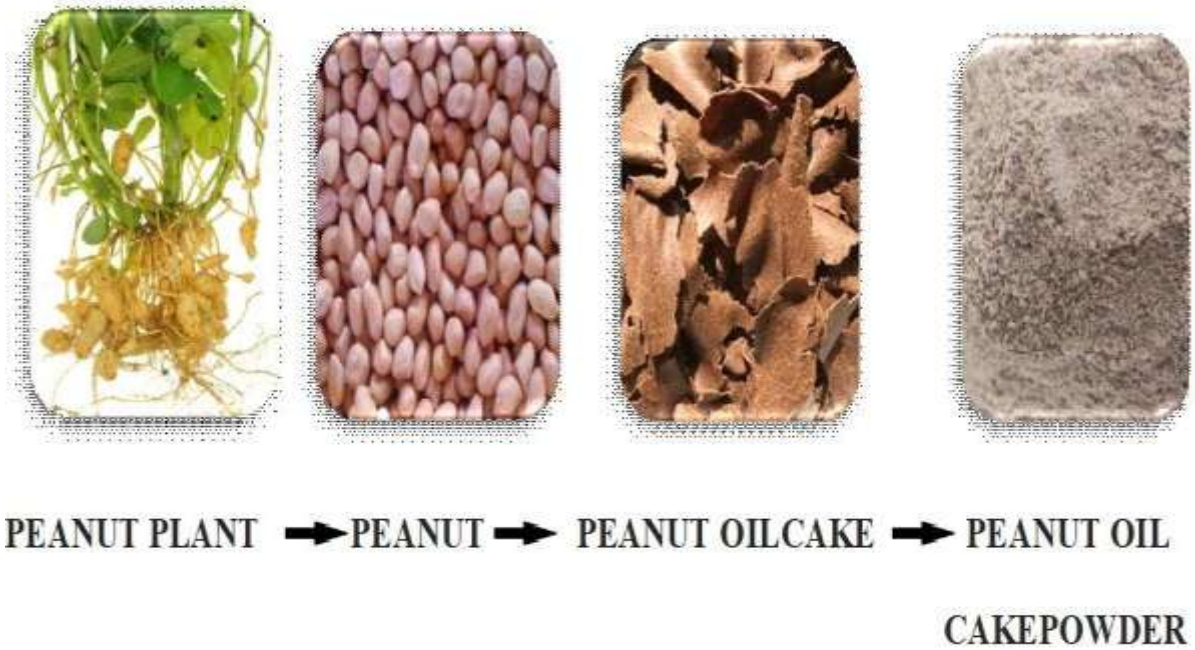


Fig. 1 Extraction procedure of peanut oil cake powder from peanut plant



Fig. 2 Extraction procedure of Rice straw fibre mate from Rice husk

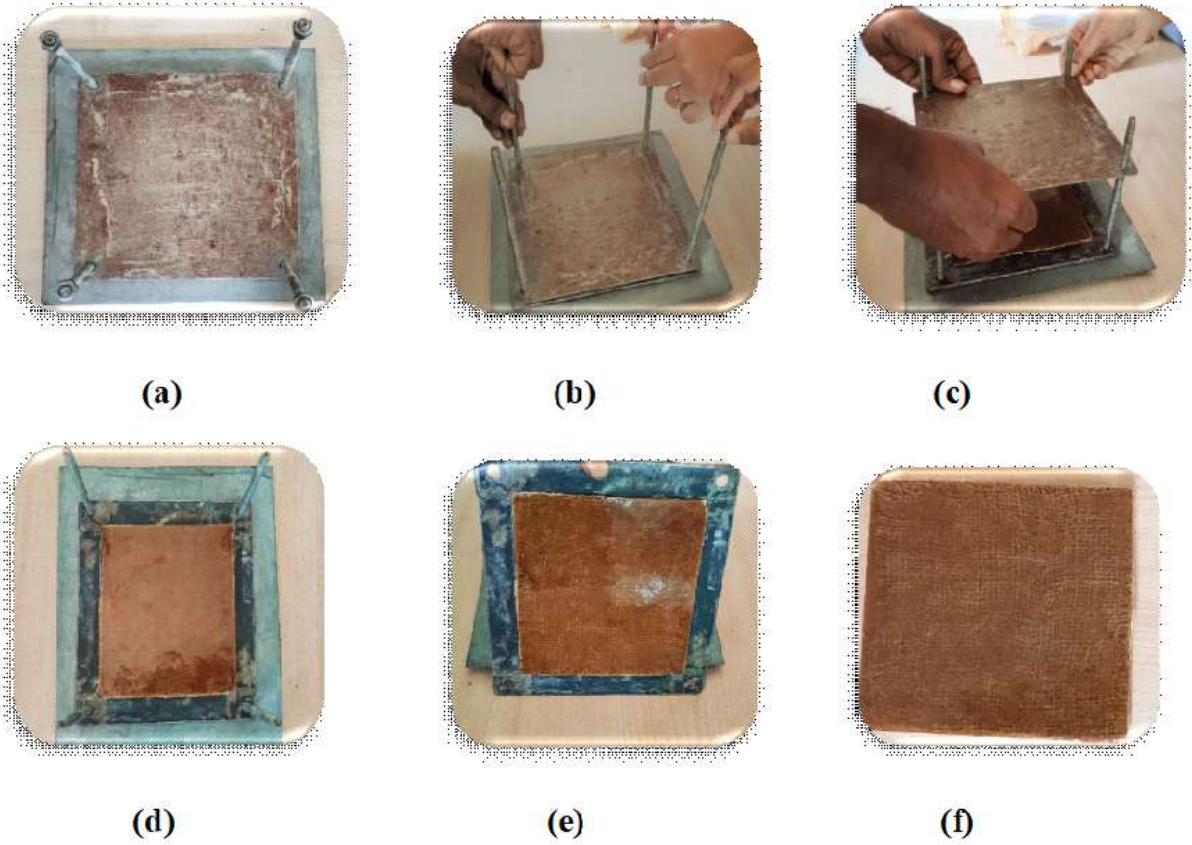


Fig. 3 Fabrication Procedures of the Peanut oil cake powder and novel combinations of Peanut oil cake powder and Rice straw fibre mate based hybrid composite in hand lay-up technique

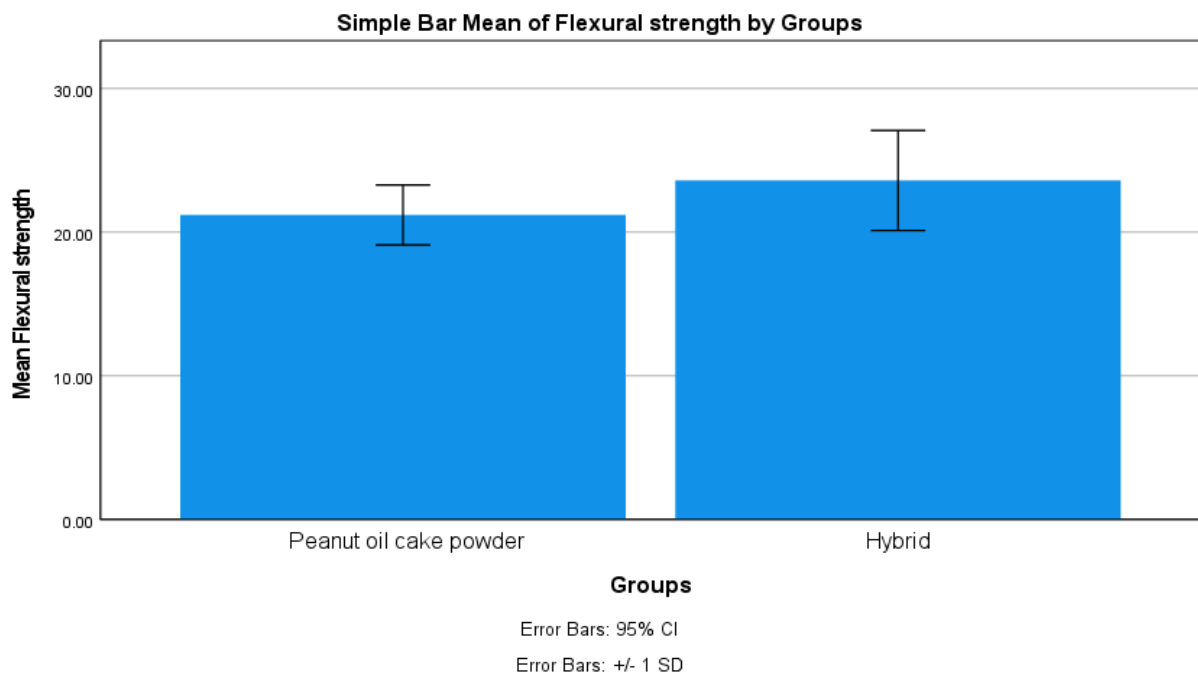


Fig. 4 The bar chart compares the flexural strength in terms of percentage between Peanut oil cake powder and Rice straw fibre mate. X axis : peanut oil cake powder and hybrid composites, Y-axis: Values of mean flexural strength with +/-1SD.