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# Optimization of Chicken Feather Fibre Reinforced Composite with Epoxy

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ABSTRACT

Chicken feather disposal has contributed significantly in the galloping elephantiasis in our society; hence this research work was targeted on recycling chicken feathers into a more useful material that would find its applications in virtually all discipline. These natural Fibres are low-cost with low density and good mechanical properties. This study uses Taguchi's robust design on the basis of the higher the better to investigate the effect of (A: Volume fraction, B: Fibre length and C: Fibre orientation) to determine the optimum Tensile strength, Flexural strength and Hardness strength of the chicken feather barbs (CFB) and chicken feather rachis (CFR) when reinforced with epoxy. The optimum tensile strength, flexural strength and hardness strength of the chicken feather barbs are (34.40MPa, 60.05MPa and 18.87MPa) while that of the chicken feather rachis are (34.00MPa, 70.30MPa and 19.1MPa), respectively. This study shows that the composite of the CFB are better in tensile, while the CFR are better both in flexural and hardness strength. The young's Moduli of the CFB ranges from 0.81GPa to 1.63GPa, while that of the CFR ranges from 0.58GPa to 1.90GPa. Higher proportion of the chicken feather barbs, however, showed significant reduction in the density and void fraction of the composite material. It can therefore be concluded that a low cost composite material could be processed from the chicken feather thereby reducing the risk of pollution and disease associated with it.



## Introduction

The strength of a material depends not only on their shapes but also on the components and materials which they are made from. Hence, design engineers must know the strength and properties of materials which they are using to meet up with the intended purpose. If not, the consequences may be disastrous. Composite materials is a synergistic combination of materials in such a way as to enable one to make better use of materials virtue while minimizing to some extent the effects of their deficiencies. This process of optimization can release a designer from the constraints associated with the selection and manufacture of conventional materials. The designer can make use of tougher and lighter materials, with properties that can be tailored to suit particular design requirements. Considering the ease with which complex shapes can be manufactured, the complete rethinking of an established design in terms of composites can often lead to both cheaper and better solutions to engineering problems. (Bryan, 1999)

Aziz, Ansell, Clark and Pantery (2005) submitted that manufacturing of high-performance engineering materials from renewable resources has been pursued by researchers across the world owning to the fact that renewable raw materials are eco-friendly and do not cause health problems.

## Aim and Scope of the Investigation

Chicken feather disposal has contributed significantly in the galloping elephantiasis in our society at large, hence this research work is targeted on recycling chicken feathers into a more useful material that would find its applications in virtually all discipline. This work considered both the barbs and rachis of the chicken feather of a poultry bird and their properties at different levels of interaction when combined with a matrix. Lastly, optimization of the control factors during the design stage was achieved using Taguchi's robust design which helps to optimize a quality product as quickly as possible and at low cost. In an attempt to convert waste into treasure, this report shows one of the methods of utilizing/disposing the billions of chicken feather waste into an increased usage of composites in a variety of industries. It also accommodates actions to address the technological gaps and barriers faced with the poultry industries in Nigeria.

## Material and Methods

The methodology of this research work uses Taguchi's robust design on the basis of the higher the better to optimize the tensile strength of the chicken feather fibre composite. Waste chicken feathers were collected from a commercial processing market in Awka, Anambra State. Waste feathers were washed several times with water mixed with laundry detergent to remove blood, manure and extraneous materials. The clean feathers were then spread on a galvanized iron sheet and allowed to dry under the sun for five days. The dried feather fibre barbs were obtained manually by cutting off the rachis with a scissors as show in Fig 1

**Fig 1a. Chicken Feather Barbs**

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**b. Chicken Feather Rachis**

**Fabrication of Composite**

The barbs and rachis are cut into various lengths (5-15mm) in steps of 5mm with a scissors. The fibre weight fraction of the chicken feather fibre was computed using the rule of mixture proposed by Jones & Barbero (1998). The fibre mat was achieved using polyvinyl acetate as the binding agent and allowed to dry for 3 days under ambient temperature. The fibre mat was then saturated with the calculated volume of resin using the manual roll out technique at room temperature into a mold of 300mm by 300mm by 3.2mm with a compressive pressure of 0.5MPa. The composite material produced was allowed to cure for 24 hours. Replicated samples of chicken feather composite were prepared under the same conditions of temperature and pressure. The mechanical test was carried out in Hounsfield tensometer with 31.5kgf and magnification of 4:1.

**Experimental Design and Statistical Analysis**

In parametric design, there are two types of factors that affect a product's functional characteristic: control factors and noise factors. Control factors are those factors which can easily be controlled such as material choice, fibre orientation, temperature, volume fraction, etc. Noise factors are factors that are difficult or impossible or too expensive to control.

Hence, Taguchi's parameter design seeks to identify settings of the control factors which make the product insensitive to variations in the noise factors.

Design of experiments techniques specifically Orthogonal Arrays (OAs), are employed in Taguchi's approach to systematically vary and test the different levels of each of the control factors. Commonly used OAs includes the L4, L9, L12, L18, and L27, etc.

Degree of Freedom (DOF) for an orthogonal array should be greater than or equal to sum of chosen quality characteristics. Hence, (DOF) can be evaluated by the equation

$$(DOF)R = P \times (L-1) \quad 1$$

$$(DOF)R = 3(3-1) = 6 \quad 2$$

(DOF)R = degree's of freedom, P = number of factors, L = number of levels

Thus L9 orthogonal array was selected and applied in this research work.

**Table 1. Standard Taguchi's Orthogonal Array L9**

| Experimental Run | Parameter 1 | Parameter 2 | Parameter 3 |
|---|---|---|---|
| 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 |
| 3 | 1 | 3 | 3 |
| 4 | 2 | 1 | 2 |
| 5 | 2 | 2 | 3 |
| 6 | 2 | 3 | 1 |
| 7 | 3 | 1 | 3 |
| 8 | 3 | 2 | 1 |
| 9 | 3 | 3 | 2 |

The complete product array is used to test the interactions of the control factor settings over all combinations of noise factors, after which the mean response and mean standard deviation for each run was calculated using the following equations.

$$Mean\ Standard\ Deviation\ MSD = \frac{1}{n}\sum_{n_i}^{n}\frac{1}{y_i^2} \quad 3$$

$$SN\ Ratio = -10 log MSD \quad 4$$

**Results and Discussion**

This study investigates the tensile, flexural and hardness tests of the chicken feather composite reinforced with epoxy for optimum parametric setting of the control variables using Taguchi's robust design technique. The experimental outlay **and** the signal to noise ratio and the mean responses are calculated and presented below.

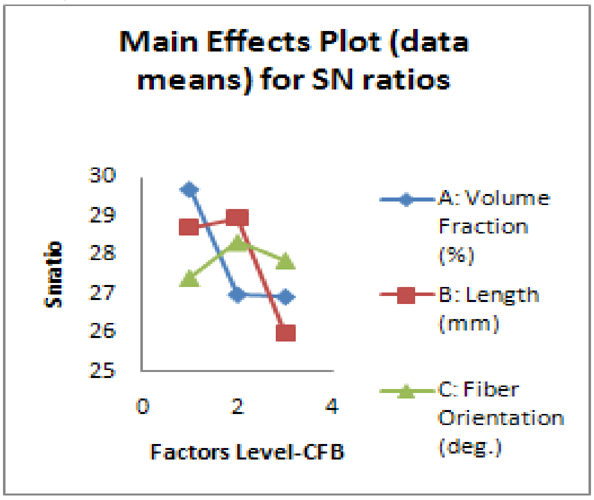
**Table 2. Experimental Outlay and Variable Set for Mechanical Properties**

| S/N | Processing Factors | Level | | | Unit |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | |
| **1** | **A: Volume Fraction** | **10** | **20** | **30** | **%** |
| 2 | B: Length | 5 | 10 | 15 | mm |
| 3 | C: Fibre Orientation | ±0 | ±30 | ±60 | Degree |

**Tensile Test**

ASTM standards were used to investigate the tensile properties of the chicken feather fibre, the rectangular specimen with dimension 160mmx19mmx3.2mm were cut from the composite board. The specimen were subjected to tensile load on a computer controlled Universal Testing Machine at a cross head speed of 1mm/min. this work utilizes the ultimate tensile strength at break point to obtained the effect of various parameter. Also the force extension curve were plotted as well as the stress strain curve of each of the composite produced, the ultimate strength, young's moduli of the materials were obtained.

The result of the tensile test carried out to analyze the effect of the fibre weight fraction fibre length and fibre orientation are as shown in Fig. 2. A close observation of the results leads to the conclusion that factor combination of $A_3$ $B_3$ $C_1$ gives the minimum strength while $A_1$ $B_2$ $C_2$ gives the maximum strength for the CFB, while factor combination of $A_3$ $B_3$ $C_3$ gives the minimum strength and $A_1$ $B_2$ $C_1$ gives the maximum strength respectively.



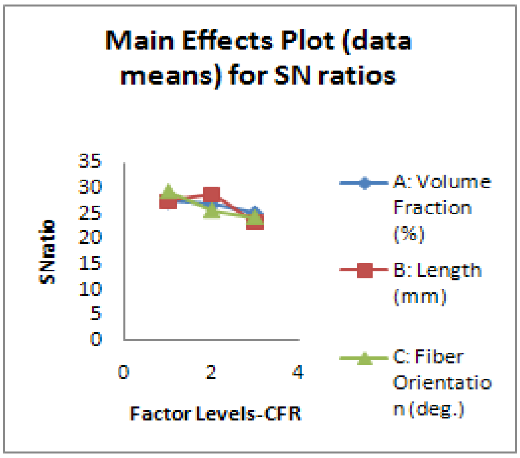



**Fig 2. Effect of control factors on the tensile strength of CFB and CFR (SN Ratio)**

**Flexural test**

3-point SBS test as per ASTM D2344-84 using Hounsfield universal Monsanto Tensomete, Span length of 300mm and the cross head speed of 1 mm/min was adopted for the study of the flexural behavior of the CFB and CFR composite.

From fig.3, it is evident that factor combination of A3 B2 C1 gives the minimum strength and A1 B2 C1 gives the maximum strength for the CFB while factor combination of A3 B1 C1 gives the minimum strength while A1 B3 C3 gives the maximum strength

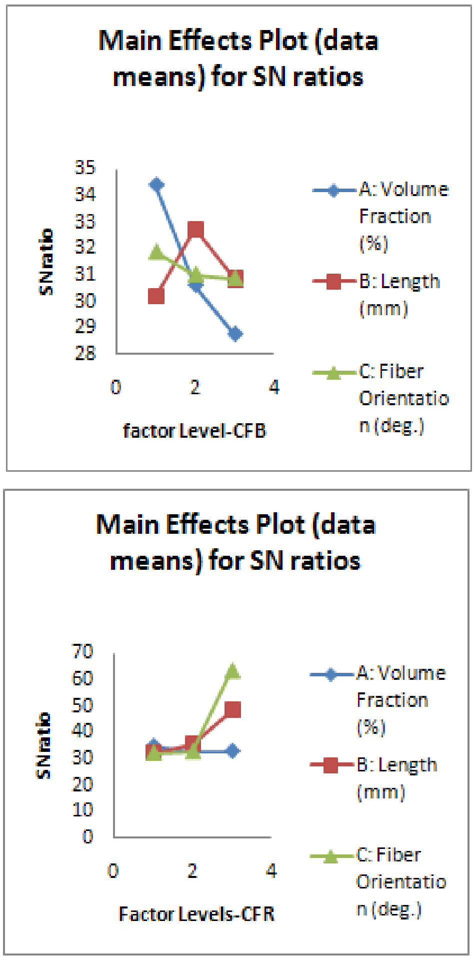



**Fig 3. Effect of control factors on the tensile strength of CFB and CFR (SN Ratio)**

Brinell hardness test was adopted in accordance with the ASTM to investigate the hardness property of the CFB and CFR composite. The Brinell hardness number is a function of the test force divided by the curved surface area of the indent. The indentation is considered to be spherical with a radius equal to half the diameter of the ball. Fig. 4 shows that factor combination of $A_3$ $B_2$ $C_2$ gives the minimum strength while $A_2$ $B_1$ $C_3$ gives the maximum strength while factor combination of $A_3$ $B_3$ $C_2$ gives the minimum strength while $A_1$ $B_2$ $C_3$ gives the maximum strength.

***Void*** is a very significant property that determines the fatigue strength and behavior of the composite material. Its effect cannot be negated though it can be reduced. The void fraction was computed using the equation proposed by Agarwal and Broutman (1990). The result shows that the void fraction decreases with an increase in fibre content. It can therefore be concluded that the more the fibre content the better the composite material produced in terms of fatigue strength.

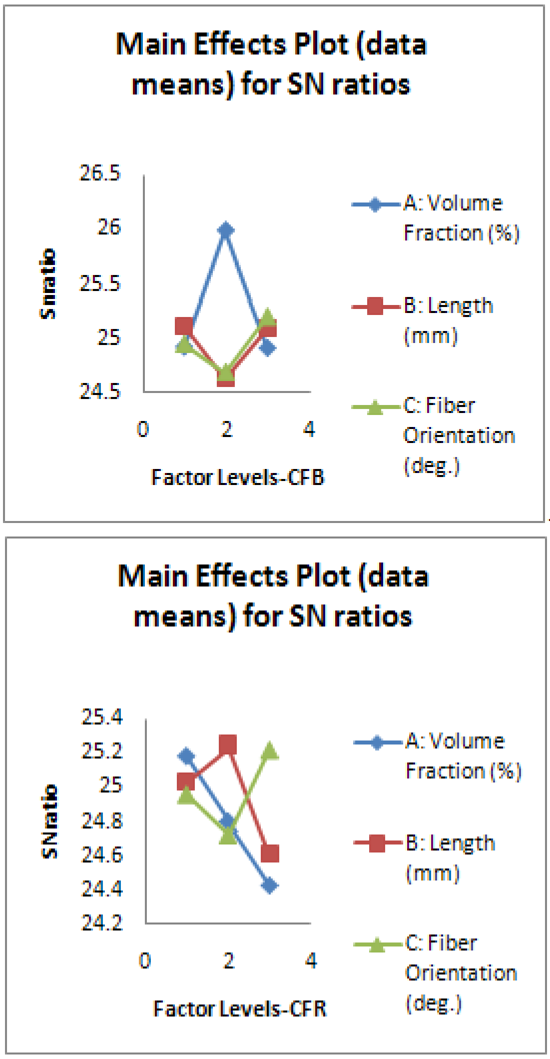



**Fig 4. Effect of control factors on the tensile strength of CFB and CFR (SN Ratio)**

**Confirmation of Experiment**

The last stage of Taguchi's robust technique is the confirmation of the experiment. According to Radharamanan and Ansui (2001), the expected response is estimated using the optimum control factor setting from the main effect plot; by using the response for signal-to-noise ratio and that of mean using equation below. The confirmation experiment is always carried out to prove the significance of the inference drawn during the design stage.

$$EV = AVR + (A_{opt} - AVR) + (B_{opt} - AVR) + (C_{opt} - AVR) + \cdots + (n_{opt}^{th} - AVR)$$

Where

$EV$ = Expected response

$AVR =$ Average response

$A_{opt} =$ Mean value of response at optimum setting of factor A

$B_{opt} =$ Mean value of response at optimum setting of factor B

$C_{opt} =$ Mean value of response at optimum setting of factor C

The experiment confirms that the chicken feather barbs reinforced composite has an optimum tensile strength of 34.40MPa when the control factors (Fibre volume fraction, Fibre length, and Fibre orientation) are set at (10%, 10mm and 30 deg. Respectively) while the chicken feather rachis composite has a tensile strength of 34.0MPa when the control factors (Fibre volume fraction, Fibre length, and Fibre orientation) are set at (10%, 10mm and 0 deg. respectively),the chicken feather barbs has an optimum flexural strength of 60.05MPa when the control factors (Fibre volume fraction, Fibre length, and Fibre orientation) are set at (10%, 10mm and 0 deg. respectively). While the chicken feather rachis has a flexural strength of 70.30MPa when the control factors (Fibre volume fraction, Fibre length, and Fibre orientation) are set at (10%, 15mm and 60 deg. respectively), the chicken fibre barbs has optimum hardness strength of 18.87MPa when the control factors (fibre volume fraction and fibre orientation) are set at (20%, 5mm and 60 deg. respectively) while the chicken feather rachis has optimum hardness strength of 19.1MPa when the control factors (fibre volume fraction and fibre orientation) are set at (10%, 10mm and 60 deg. respectively).

## Conclusion

The experimental investigation on the fibre content, fibre length, and fibre orientation on the mechanical properties of the chicken feather fibre and chicken feather rachis reinforced with epoxy were conducted, properties such as tensile strength, flexural strength and hardness strength were evaluated and presented in this research work. The experiment leads us to the following conclusions.

- The successful fabrication of a new class epoxy based composite with chicken feather fibre have been made using Taguchi's systematic techniques for identifying the most important control factors
- The composite of the chicken feather barbs are stronger in tension than the chicken feather rachis.
- The composite of the chicken feather rachis are stronger in flexural strength than that of the chicken feather barbs.
- This study shows that the composite of the chicken feather rachis are stronger in hardness than the chicken feather barbs.
- The young's moduli of each of the samples produced ranges from 0.81GPa – 1.63GPa for the chicken feather barbs and 0.58GPa – 1.90GPa
- This study also shows that by incorporating chicken feather barbs, the density and void fraction (porosity) of the composite decreases.

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