DETERMINATION AND MODELING OF ULTIMATE TENSILE STRENGTH OF BREADFRUIT PEEL-LOW DENSITY POLYETHYLENE COMPOSITE APPLYING BIGG'S EQUATION FOR DOOR PANEL PRODUCTION

Rabboni Mike Government*, Ayuba Solomon, Odiakaose Chili

Federal University Wukari, Taraba State, Nigeria
*Corresponding author, email: govt_4real@yahoo.com

doi: 10.17977/um063.v5.i9.2025.5

Keywords
Breadfruit Peel
Breadfruit Peel-Low Density Polyethylene Composite
Ultimate Tensile Strength
Chemical Modification
Bigg's Equation
Modeling

Abstract
This study was carried out to apply breadfruit peel (BRFP) waste in low density polyethylene (LDPE) for breadfruit peel-low density polyethylene (BRFP-LDPE) composite using statistical means to model ultimate tensile strength of the BRFP-LDPE composite using Bigg's model. The breadfruit peel at fraction of 0.5-.0.25 wt when it was not modified was blended with LDPE matrix (UNT). The BRFP was later modified with NaOH (NST), NaOH+CH_3COOH (AAT), NaOH+CH_3COOH+MAPE (MPT) impregnated in LDPE matrix to manufactured BRFP-LDPE composite by injection molding machine, respectively. After production, BRFP-LDPE composite was tested for the ultimate tensile strength. The results show that the Bigg's model was able to give the prediction of the maximum tensile strength of BRFP-LDPE composite with coefficient of correlation (R^2_M) for the model =0.994 for UNT, NST, AAT and MPT, respectively. Also, in the same vein, the coefficient of correlation as derived from the experiments (R^2) were 0.975, 0.978, 0.8 and 0.955 for the tensile strength of BRFP-LDPE composite which coincided for UNT, NST, AAT and MPT, respectively. Finally, the relative percentage deviation modulus between experiment and Bigg's equation (μ) <10. These statistical data seen confirmed highly prediction of ultimate tensile strength of experimental values using the Bigg's model.

1. Introduction

Generally, application of waste from agro-plants for polymer-fiber-composite and the need to manufacture engineering innovation to minimize fuel consumption, cost reduction of raw material in purchasing high density inorganic material and high accessibility of agro-waste in human sphere has lead to much increment. The resultant effect on a positive note has bring about production of agro-waste-polymer composite for car parts, printer parts, phone parts, television parts, computer parts, etc (Aimi et al., 2014; Atuanya et al., 2014; Azees, 2019; Azees et al., 2021; Azees et al., 2018; Catto and Santana, 2018; Dangani et al., 2016; Fortunati et al., 2019; Government and Ngabea, 2023a; b).

Breadfruit peel is commonly deposited as waste in Nigeria today. Most citizens in rural communities usually employed as fuel for cooking (Government and Ngabea, 2023b; Government and Okeke, 2023; 2024; Government et al., 2018a;2018b; Government et al., 2021 a;b). This leads to environmental hazard caused by smoke emission which stands as a potential risked for eye blindness (Government et al., 2021b; Government et al., 2019a-b). However, it is pertinent this waste is utilized for production of engineering materials when impregnated with polymer matrix for creation of wealth and circular economy (Government et al., 2019c; Government et al., 2022; Government et al., 2019d). Also, these prevent eye diseases and lung infections ultimately increasing wealth and development of engineering components for Nigeria and global accolade (Government et al., 2019b-c; Government et al., 2022; Government et al., 2019d; Harun and Geok, 2016; Homkhiew et al., 2016).

The matrix is an essential component of polymer composite. This signifies the binding compound which is the macro-constituent of a biomass-fiber polymer composite. The matrix infuses in the biomass polymer is proportional to the specific products in need (Government et al., 2019b-c; Government et al., 2022; Government et al., 2019d; Harun and Geok, 2016; Homkhiew et al., 2016; Kandar et al, 2016; Laadila et al., 2017). This means that if you want to manufacture heavy engineering material such as boat u need a strong polymer with high density such polyester to infuse with the fiber (Government et al., 2019c; Government et al., 2022; Government et al., 2019d; Harun and Geok, 2016; Homkhiew et al., 2016; Kandar et al, 2016; Laadila et al., 2017; Ng et al., 2019. If the request from the manufacturer is to produce a lighter components such printer parts the, low density polyethylene will be recommended to be compounded with the biomass for the production (Government et al., 2019c; Government et al., 2022; Government et al., 2019d; Harun and Geok, 2016; Homkhiew et al., 2016; Kandar et al, 2016; Laadila et al., 2017; Ng et al., 2019: Obasi et al., 2015).

Biomass-polymer composite is characteristic is a product of age of plant, composition in terms of cellulosic content, polymeric matrix embedded, bonding agent, surface modification, etc. These variables are significant towards the success of mechanical properties of end-product of composite (Government et al., 2019c; Government et al., 2022; Government et al., 2019d; Onuegbu et al., 2014).

Chemical modification process is paramount to extract some of unwanted constituent of the fiber. This is due to agro-waste contains cellulose, lignin, hemicellose and other unwanted module which should be eliminated to have effective binding of the agro-waste fiber and the polymer (Onuegbu et al., 2014; Orji et al., 2020; Peng Chang et al., 2015; Rajak et al., 2019; Rashid et al., 2016; Rostamiyan et al., 2015; 2014a-b). Some pretreatment procedure that should be adopted for eradication of this constituent include: alkalization, acidification, binding agents, etc (Stood and Dwivedi, 2018; Tisserat et al., 2018; Turku et al., 2018; Turku et al., 2018; Zakaria et al., 2018; Government 2019e).

Several works on agro-waste had been carried out in polymer composite for commercialization stage. This include peanut shell (Government et al., 2022; Obasi et al., 2015), mongo seed shell (Government et al., 2019d)), date palm (Atuanya et al., 2014; Fortunati et al., 2019; Government and Ngabea, 2023b; Government et al., 2021a), avocado wood (Government and Ngabea, 2023a; Government and Okeke, 2024; Government et al., 20118a;2018b; Government et al., 2019a;2019c), flame of forest pod (Government et al., 2019b), etc.

This work entails the production of BRFP-LDPE composite, determination of tensile strength of the composite and applying Bigg's model to predict to tensile strength of BRFP-LDPE composite for industrial application.

2. Method

2.1. Preparation of BRFP

The BRFP was sourced in Enugu metropolis Market close to diamond estate G.R.A Enugu. The BRFP was placed in sun drying for a period of 14 days for moisture removal. The BRFP was later sieved for 100 mesh (150 μm). The pretreatment of BRFP occurred three different stages. Firstly, the BRFP was immersed in 6wt% NaOH solution for 16 hrs, rinsed with distilled water, filtered and subjected to drying for 10 hrs (NS). Next stage involved immersion of the NaOH process, the BRFP was pretreated in 4 vol% CH_3COOH at 1 hr, filtered, washed with distilled water and subjected to sun drying at 10 hrs. Final stage involved after pre-treated BRFP with NaOH and CH_3COOH, 5wt % maleated polyethylene was added. The mixture was properly mixed to obtain a homogenized compound (Government, 2019).

2.2. BRFP-LDPE Production

The BRFP of 0.5-.0.25 wt% fraction was infused in the matrix of LDPE of 0.95 to 0.75 wt%, respectively. It was mixed completely, the single mixture of both components was injected in injection molding machine at temperature of 130-170 0C for melting, blending and compounding of the BRFP-LDPE composite.. After compounding, the BRFP-LDPE composite was allowed to cool in the mold at a room temperature (Government, 2019e).

2.3. Ultimate Tensile Strength of the BRFP-LDPE Composite

The strength of BRFP-LDPE composite sample was sized on the basis of ASTM standard (ASTM D638). The BRFP-LDPE composite sample was placed in Houisefield tensile machine by English make with serial number of BSS1610, with model no. 8889. The sample at a size of 3.2mm x 19mm x 160 mm was inserted in the machine griped. The sample was subjected with fixed load which striked the sample till BRFP-LDPE composite fractured [45-49]. The tensile strength of BRFP-LDPE composite is evaluated using Eq. (1).

$$\boldsymbol{\sigma_{UT}} = \frac{\boldsymbol{f_{MUT}}}{\boldsymbol{A_1}} \quad (1)$$

The variables σUT, fMUT and A1 represents ultimate tensile strength, the ultimate force at tensile maximum tensile mode and cross-sectional area of the BRFP-LDPE composite, respectively.

2.4. Tensile Modeling of BRFP-LDPE Composite

The Bgg's model as one of the micromechanical model was utilized for prediction of maximum strength of the BRFP-LDPE composite (Government, 2019e). The Bigg's model is defined applying Eq.(2).

$$\sigma_{BRFP-LDPE\ composite} = \sigma_{LDPE}(1 - b((V_f)^{2/3}) \quad (2)$$

Where σ_(BRFP-LDPE composite,) σ_LDPE, vf, and b are the predicted ultimate tensile strength of BRFP-LDPE, original ultimate tensile strength of LDPE and b is a term which is proportional to the level of adhesion. Generally, if level of b is 1.21 and above, this is an indication of lower adhesion between LDPE and BRFP phase, while b< 1.21 yielded good homogeneity of LDPE and BRFP.

To estimate the density of the two components in the composite, each of density of the fiber and polymer is tabulated through the application of Archimede's principle through Eq. (3) (Azees, 2019).

$$\rho = \frac{m}{V_1 - V_2} \quad (3)$$

Where V1, V2, m are the volume of water in the cylinder when no material is added, total volume when material is included in the cylinder and mass of the material, respectively.

The volume fraction of BRFP was determined by applying Eq. (4).

$$V_f = \frac{W_f}{W_f + (1 - W_f)\frac{\rho_f}{\rho_p}} \quad (4)$$

Where Wf ρ_f *and* ρ_p are weight fraction of BRFP, the density of BRFP and LDPE, respectively.

The graph of ultimate tensile strength of BRFP-LDPE composite adopted by Bigg's model prediction with weight fraction of BRFP is plotted. The validations for the predicted value using Bigg"s model and the one obtained via experimental results of BRFP-LDPE composite were estimated by adoption of correlation coefficient and modulus of relative mean percentage deviation.

The modulus of percentage relativity was evaluated adopting Eq. (5).

$$\mu = \frac{100}{n} \times \Sigma(\frac{|Ex - Mo|}{Ex}) \quad (5)$$

Where μ, Ex, Mo, n are mean modulus of relativity deviation, experimental ultimate strength, predicted ultimate strength by the model, n is the number of observation, respectively.

The verification deviation from one point between the experiment and the predicted model is giving in Eq. (6).

$$Dv = \frac{100}{1} \times \frac{|Ex - Mo|}{Ex} \quad (6)$$

Where Dv is the deviation of the modulus when considering each point between the model and the experiment. When μ<5 translated to good prediction, if 6<μ<10, it is considerable good prediction. and finally μ>10 becomes bad weak prediction (Government, 2019e).

3. Result and Discussion

Figure 1 indicates the plots of the ultimate tensile strength of experimental values and the Bigg's model with variation of weight fraction at 100 mesh (150 μm) for UNT, NST, AAT and MPT, respectively. As shown in these Figures, the tensile strength of BRFP-LDPE composite for both the experimental and Bigg's predicted model resulted in reduction as the weight fraction of BRFP increases for UNT, NST, AAT and MPT, respectively. Also, plots between the Bigg's model and experimental values indicated a close relationship as can be cited in Figure 1(a-d). This is an indication of better prediction of the experiment data with Bigg's model. Similar behavior was displayed by later scholarly works as carried out by Government et al. (2021b) and Government (2019e).

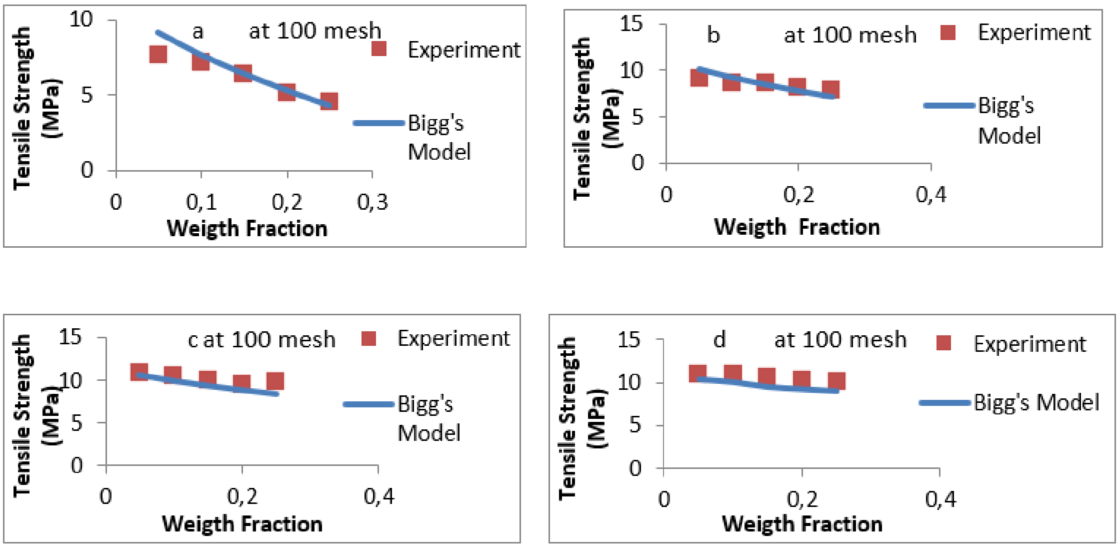

Figure 1. Weight Fraction of Filler on the Tensile Strength of LDPE/BBF Composite (a) UNT (b) NST (c)AAT (d) MPT

Table 1 present statistical variables analysis of validation and verification of Bigg's model with experimental ultimate tensile strength of BRFP-LDPE composite for UNT, NST, AAT and MPT, respectively. As observed in Table 1, μ% < 10 was noticed for tensile strength of BRFP-LDPE composite for UNT, NST, AAT and MPT, respectively. This can be concluded as superlative prediction of the strength of BRFP-LDPE composite applying this model.

Table 1. Statistical Parameters for the Validation of Bigg's Equation of BRFP-LDPE Composite

	Particle Size (mesh)	Particle Size (μm)	μ (%)	R^2_{BM}	R^2	b
UNT	100	150	7.296	0.994	0.975	2.5
NST	100	150	6.958	0.994	0.978	1.55
AAT	100	150	7.428	0.994	0.8	1.1
MPT	100	150	9.646	0.994	0.955	1.021

Meanwhile, the coefficient of determination displayed by Bigg/s model (R2BM) for UNT, NST, AAT and MPT was >0.99 while that of ultimate tensile strength of experiment data (R2) was 0.975, 0.978, 0.8 and 0.955, respectively. This means that there was huge positivity in the correlation. The variation between R2BM and R2 was <25 % showing very immense percentages of correlation. It was also sensed that R2BM and R2 were approximately close to unit which is an indication of efficient prediction of the tensile strength of BRFP-LDPE composite applying this model.

Finally, the extent of adhesiveness between BRFP and the LDPE matrix is described by constant, b. It was also captured in Table 1 that b for BRFP-LDPE composite tensile strength were 3.5, 1.55, 1.1 and 1.021 for UNT, NST, AAT and MPT , respectively. The parameter, b <1.12, covered enormous adhesiveness of the maximum tensile strength of BRFP-LDPE composite by adopting Bigg/s equation. Similar circumstances was seen by previous works (Government et al., 2021b; Government, 2019e).

4. Conclusion

The study of applying Bigg's equation for modeling the ultimate tensile strength of experimentally obtained data from BRFP-LDPE composite had been ascertained. The variation of weight fraction of BRFP on the composite decreased the tensile strength of BRFP-LDPE composite for UNT, NST, AST and MPT, respectively. Also, the model and experimentally related data were maintaining similar trend. The R2 and R2M were close to unity for the strength of BRFP-LDPE composite for UNT, NST, AST and MPT, respectively. Furthermore, the μ values between the σ_(BRFP-LDPE composite) and the experimentally generated data were small showing lesser error for the deviation among the model and that of the experimental data that produced ultimate strength of BRFP-LDPE composite for UNT, NST, AST and MPT, respectively. With these immense correlations of statistics parameters in examination of Bigg's equation, this is better judgment to ascertain that this model had forecast the ultimate strength of BRFP-LDPE composite for UNT, NST, AST and MPT, respectively. The outcome obtained from the modeling of BRFP-LDPE COMPOSITE indicated that BRFP is a low price novel material can be taking as a credible substitute to door panel.

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