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Effects of Cream Hardener on Optimal Formulation of Snail Shell-Based Auto Body Filler

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ABSTRACT

Snails' shells, which are byproducts of the dining industry from restaurants, cafes, and snail vendors, represent a considerable environmental challenge with minimal commercial value. Their effective utilization could lead to substantial economic benefits. This study aims to investigate the effects of cream hardener on optimal formulation of snail shell-based auto body filler for potential industrial applications. The formulation of auto body filler was carried out using constrained D-optimal mixture experimental design. The formulation yielding the highest desirability index of 0.363comprised12%snail shell, 80% unsaturated polyester resin, 2.96% toluene, 2.22% xylene,2.82% Cobalt Naphthanate (Accelerator), and a particle size of 106.5 µm, which was also combined with cream hardener designated as samples snail shell auto body filler (SSBdfA and SSBdfB) respectively. The findings indicated that samples SSBdfB exhibited a quicker drying time of 10 minutes, while samples SSBdfA had longer curing times starting from 16 minutes and above; additionally, sample SSBdfB showed good adhesion and flexibility on metal surfaces. The physical and mechanical properties of the SSBdfA and SSBdfB samples were also evaluated. The optimal product quality characteristics revealed that SSBdfA exhibited a density of 1.03 g/cm³, a hardness of 0.7316, and a tensile strength of 0.0459 MPa, while SSBdfB demonstrated superior physical properties with a density of 1.22 g/cm³, a hardness of 0.96, and a tensile strength of 0.0931 MPa. Validation testing results for the produced samples (SSBdfA and SSBdfB) indicated optimal product quality properties with conditions of 0.97 g/cm³ density, 0.8066 hardness, and 0.0459 MPa tensile strength for SSBdfA, compared to 1.20 g/cm³ density, 0.973 hardness, and 0.0962 MPa tensile strength for SSBdfB. The research outcomes suggest that cream hardener influences the properties of snail shell auto body filler, making it suitable for industrial applications such as fillers in the automotive sector. The analysis considered a 95% confidence level, which allows for a 5% margin of error and represents 99% of the population.

KEYWORDS: Snail shell, unsaturated polyester resin, cream hardener, auto body filler, D-optimal mixture.

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1 | INTRODUCTION

Land snails are species of snail that live among wet vegetation which are mostly available during rainy seasons and are most active at night [1]. There are different breeds of edible land snails found in Nigeria. The two giant land snails commonly found in Nigeria: Achatina marginata and Achatina achatina. Achatina marginata has no definite shell coloration and it is wider at the posterior end compared to others. The foot is usually dark brown in color. Achatina achatina has a shell with conspicuous zigzag streaks and a narrow apex. The foot is grey in color. It is the most common breed found in South South Nigeria. Other breeds of snail include; Achatina fulica is of small size and the fleshy part could be whitish or dark brown [2]. The distinctive characteristic of snail shells lies in their significant calcium carbonate composition [3,4], which can be utilized to enhance organic waste as a functional material for creating environmentally friendly and economical products. It also finds relevance in the treatment of anemia, hypertension, high blood pressure and other fat-related ailments [5]. Due to their high calcium carbonate content, snail shells have a variety of applications in science and technology. Numerous researchers have tested the use of snail shells for various purposes such as adsorbents in wastewater treatment [6,7], metal adsorbents [8,9], textile dye adsorbents [10], heterogeneous catalysts [11,12,13], fillers in the ceramics industry [14], reinforcement composites [15,16], and in biomaterials and pharmaceuticals [17,18]. The life span of snails is decreasing due to humans destroying their habitat and due to pollution [19]. Snail shells are utilized as engineering raw materials across multiple industries, including chemical, construction, and automotive sectors.

A typical Nigerian car is subjected to long periods of use, requiring some type of care in order to maintain its shape, value, and roadworthiness. Nigerian cars are subjected to unnecessary stress as a result of the country's poor economy, bad roads, and harsh driving culture, lowering their aesthetic value. The majorities of the time, the reasonably used cars imported into the country are dented and require repair. As a result, the need of keeping Nigeria's autos in good shape becomes clear. Auto body fillers are undercoat compositions that fill dents/holes, porosity, or imperfections in a vehicle to produce a consistent surface for the top coat/paints to adhere to [20, 21]. The fillers are a mixture of resins and filler materials that are expected to have a very tiny particle size and have been changed to allow them to function as needed [22,23]. And also body fillers are made up of a polyester resin and a cream hardener that combine to form a putty-like substance that is used to restore the smooth surface of a vehicle's body after minor damage. Consider how spackle is used to conceal nails and smooth out walls in house repairs. Their consistency and application are comparable, as is the procedure that the surface they're put to goes through. In the country, there are only a few companies that make body car fillers. Nigeria imports about 90% of the fillers it uses [24]. The broad goal of this study is to use snail shell waste as renewable alternative to produce good quality auto body filler that will replace the imported and enhance the nation’s economic growth.

In this research, D-optimal mixture design was applied to enhance the formulation of snail shell autobody filler to its optimal values. The findings from the mixture design facilitated the creation of models, which were then analyzed using ANOVA and subsequently validated. Response surface methodology (RSM) was employed to explore the interactions between the dependent and independent variables. The aim of utilizing this approach is to reduce the labor, time, and resources required to achieve a high-quality output at a lower cost, utilizing available snail shell waste, while also assessing the impact of cream hardener on the optimal values.

2.0 | MATERIALS AND METHODS

2.1 Collection of Sample

The snail shells used for this study are the shells of the Giant African land Snails (GALS) they were sourced from the kugbo Clan and Port Harcourt areas of Rivers State, in the Southern part of Nigeria as shown in figure 1.

Figure 1: Raw snail shell sample

Unsaturated Polyester resin, Toluene, Xylene, Cobalt Naphthenate (accelerator) and Cream Hardener dibenzoyl peroxide (catalyst), all were of commercial grade and were sourced from Dei- Dei international market Abuja Nigeria.

2.1.1 Preparation of Snail Shell Filler

The shells were first properly washed with clean water to remove any adherent dirt, and then sun dried for two days. Using a hammer mill, the dry shells were crushed to produce powdered snail shell (SSP). The powdered shells were then sieved using electric sieve shaker of 63µm, 75µm, 150µm sieve to obtain a fine smooth powder for this study as shown in figure 2. Then store in polyethylene bag.

63µm 75µm 150µm

Figure 2: Powdered snail shell after grinding and sieving

2.2 Optimization of the formulation parameters to produce the auto body fillers

Optimization is the minimization or maximization of a function subject to constraints on its variables. The Scheffe's mixture Process Model is the objective function subject to in equality constraints in the mixture proportion variables [25].

The Scheffe's mixture- Process Models are;

$$E(\gamma) = \sum_{i=1}^{p} \beta ixi + y_i z_i \quad (1)$$

$$E(y) = \sum_{i=1}^{p} \beta_{iXi} + \sum\sum_{i<j}^{p} \beta_{ij} X_I X_J + y_I Z_I \quad (2)$$

Full cubic

$$E(Y) = \sum_{i=1}^{p} \beta_{iXi} + \sum\sum_{i<j}^{p} \beta_{ij} X_I X_J + \sum\sum_{i<j}^{p} \beta_{ij} X_I X_J (x_i - x_j) + \sum\sum\sum_{i<j<k}^{p} \beta_{ijk} X_I X_j X_k + y_i z_i \quad (3)$$

Special Cubic

$$E(Y) = \sum\sum_{i<j}^{p} \beta_{ij} X_I X_J + \sum\sum_{i<j}^{p} \beta_{ij} X_I X_J + \sum\sum\sum_{i<j<k}^{p} \beta_{ijk} X_I X_j X_k + y_i z_i \quad (4)$$

Where,

βi = Expected response to the pure blend

X_j = 1 and X_j= 0 when i≠j

E (y) = Expected response

The portion $\sum_{i=1}^{p} \beta ixi$ is called the linear blending portion

$y_i z_i$ = Process factor

The design matrix and data for auto body filler is presented in Table 1.

The formulation constraints mixture variables are snail shell (12≤×1≤42), unsaturated polyester resins (50≤×2≤80), particle size (63≤×3≤ 150). Other constant components of the formulation are toluene (2.9%), xylene (2.2%) and cobalt and naphthenate (2.8%).

Table 1: Design matrix for auto body filler formulation study

Run	X_1[a] (%)	X_2[b] (%)	X_3[c] (%)	X_4[d] (%)	X_5[e] (%)	X_6[f] (%)	Y_1[g] (g/cm^3)	Y_2[h]	Y_3[*] (MPa)
1	34.9	57.1	2.96	2.22	2.82	150	1.16	0.2	0.0311
2	12	80	2.96	2.22	2.82	63	1.13	1.1	0.0249
3	12	80	2.96	2.22	2.82	150	0.96	0.8	0.0469
4	37.3	54.7	2.96	2.22	2.82	150	0.98	0.2	0.0350
5	42	50	2.96	2.22	2.82	63	0.98	0.2	0.0409
6	12	80	2.96	2.22	2.82	75	1.01	0.4	0.0474
7	27.1	64.9	2.96	2.22	2.82	150	1.04	1.8	0.0447
8	42	50	2.96	2.22	2.82	150	1.03	1.2	0.0502
9	19.1	72.1	2.96	2.22	2.82	150	1.02	0.2	0.0387
10	42	50	2.96	2.22	2.82	75	1.02	0.2	0.0373
11	35.5	56.6	2.96	2.22	2.82	63	1.01	0.1	0.0280
12	27.1	64.9	2.96	2.22	2.82	63	0.98	1.3	0.0373
13	26.9	35.1	2.96	2.22	2.82	75	0.98	0.3	0.0309
14	42	50	2.96	2.22	2.82	75	1.12	0.8	0.1035
15	42	50	2.96	2.22	2.82	63	1.11	0.8	0.0645
16	26.9	65.1	2.96	2.22	2.82	63	1.07	1.2	0.0246
17	19.7	72.3	2.96	2.22	2.82	75	0.95	1.3	0.0316
18	12	80	2.96	2.22	2.82	150	0.99	0.4	0.0796
19	12	80	2.96	2.22	2.82	75	0.98	1.4	0.0745
[**]Con							0.91	1.2	0.0311

[a] Snail shell; [b] Unsaturated Polyester resin; [c] Toluene; [d] Xylene; [e] Cobalt naphthenate; [f] Particle size; [g] Density; [h] Hardness; [*] Tensile strength; [**] Control of Density, Hardness and Tensile Strength

In the formulation of the auto body filler, the mass of the polyester resin was varied with that of the snail shell while toluene, xylene, cobalt and naphthenate, were held constant to give a total of 100%. The adequacy test for the Scheffe mixture process models was evaluated using coefficients of determination, F-values, and model p-values at a significance level of 5%. The statistical errors and significance among the independent variables were examined through analysis of variance (ANOVA). ANOVA was utilized to validate the fit of the model. Furthermore, the models underwent a lack-of-fit test. The responses' fitted models were employed to create 3-D response surfaces, contour plots, and mix-process plots with the aid of statistical software (DESIGN EXPERT 11.0). To identify the optimal formulation with the desired responses, a numerical optimization approach based on the desirability function technique was implemented. The formulation that yielded the highest desirability index for snail shell vehicle body filler was determined through numerical optimization utilizing the desirability function.

2.3 Casting of the mixture

The mixture of the unsaturated polyester resin, snail shell, toluene, xylene and cobalt naphtane was poured into a mould and allowed to cure for two hours at a temperature of 20°C. This procedure was repeated for all 19 formulations. After curing, the samples were stripped from the mould as shown in figure 3**.**

Figure 3: Cast samples of unsaturated polyester/snail shell composite

2. 4 Characterization of the formulated Snail shell auto body filler (SSBdfA).

The samples were characterized for density. hardness, tensile strength, according to standard methods

2.4.1 Density test procedure

The density test of the samples was carried out using standard 25ml density bottle. A clean and dry bottle of 25ml capacity was weighed (W_0) and then filled with each sample, stopper inserted and reweighed to give (W_3) . The sample was substituted with water after washing and drying the bottle to give (W_2) of the samples was obtained from equation (5), Then

$$Density = \frac{mass\ of\ sample\ x}{\text{Volume of density bottle}} \quad (5)$$

2.4.2 Hardness test procedure

In order to obtain any relative change in the physiochemical quality characteristics of the auto body snail shell filler, the blend was analysed for quality attributes and also a control is made available.

In the Brinell hardness test procedure, an optical method, the size of indentation left by the indenter was measured. In contrast to the likewise optical Vickers method, which involves a pyramid-shaped indenter being pressed into a specimen, the Brinell method uses a spherical indenter. The larger the indent left in the surface of a workpiece (specimen) by the Brinell indenter with a defined ball diameter and a defined test force, the softer the tested material.

In order to determine the Brinell hardness (HB) according to ISO 6506, the spherical, hard metal

(tungsten carbide) indenter was pressed into a specimen (workpiece) with a defined test load (between 1 kgf and 3000 kgf).

The Brinell hardness (HB) results from the quotient of the applied test force (F in newtons (N)) and the surface area of the residual indent on the specimen (the projection of the indent) after withdrawing the test force. To calculate the surface area of the residual spherical indentation, the arithmetic mean (d) of the two perpendicular diagonals (d1 and d2 in mm) is used, because the base area of Brinell indents is frequently not exactly round. The measurement is gotten by transforming the physical hit to an electric signal which is then detected by the amplifier and then displayed.

2.4.3 Tensile strength test procedure

The tensile test was performed using an Instron universal testing machine operated at a cross-head speed of 10mm/min. The tensile test specimen preparation and testing procedures were conducted in accordance with ASTM D41 standard. Sample for the test was di-cut (dumbbell shape). In each sample, the thickness of nineteen evenly distributed points with different types of auto body filler was measured and the average was found. The piece was placed in the grips of the testing machine. Care is being taken to see it symmetrically positioned in order that tension will be distributed uniformly over the cross section, the machine was then started. The maximum force and distance between the inside edges of the two reference lines was measured immediately prior to the test piece.

3 | RESULTS AND DISCUSSIONS

3.1 Experimental Design

The formulation of auto body filler was performed using constrained D-optimal mixture experimental design and response surface methodology to optimize and evaluate the variables that have significant effects on the desired properties of autobody filler. The formulation constraints mixture variables were snail shell, unsaturated polyester resins and particle size. Other constant components of the formulation were toluene, xylene and cobalt and naphthenate. The constraints are as listed in Table 1. The experimental design employed Design Expert software (Version 11.0, Stat-Ease Inc., Minneapolis, USA) which resulted in 19 randomized experimental runs.

3.2 Experimental Data

A preliminary study on the independent variables according to the constraint limit was performed utilizing the D-optimal mixture design as illustrated in Table 2. This table presents the mixing design with numerical identifiers relevant to 19 distinct formulations. The component ratios were represented as mixed fractions, with the sum of ($x_1 + x_2 + x_3 + x_4 + x_5$) totalling 100 wt.%.

3.2.1 Formulation of Snail Shell for Automotive Body Filler Production

Table 2: Constraints of the independent variable from D-optimal mixture design

Low Limit (wt %)		Constraint		High Limit (wt %)
12.000	≤	x_1: Snail shell	≤	42.000
50.000	≤	x_2: Polyester Resin	≤	80.000
		A: Toluene	=	2.960
		B: Xylene	=	2.220
		C: Cobalt Naphthenate	=	2.820
		A+B+C+x_1+x_2		100.000
63 μm	≤	x_3: Particle size	≤	150 μm

3.2.2 Examination of Variant

The models were established with a statistical significance threshold set at non-significant lack-of-fit ($p \leq 0.05$) while being significant at the 95% confidence interval. Each response for tensile strength, density, and hardness was analyzed through analysis of variance (ANOVA). The application of the ANOVA test, as indicated in Tables 3, 4, and 5, resulted in p-values exceeding 0.05, with lack of fit values of 0.5289, 0.5890, and 0.5300 for tensile strength, density, and hardness response variables, respectively. Furthermore, the analysis of variance revealed a predicted R^2 (R^2 pred.) value of -0.1142, which was consistent across all models and aligned with the adjusted R^2 (R^2Adj.) value of 0. The negative predicted R^2 indicates that the overall mean of the analysis serves as a more effective predictor for the tensile strength, density, and hardness of the snail shell auto body filler. According to L-Pseudo components and coded factors, the equations representing the response variable models for tensile strength, density, and hardness are given in equations 6,7, and 8, respectively; here, X_0 is the dummy variable representing the overall mean of the response variables.

Table 3: Analysis of the linear fit ANOVA for the experimental values of Tensile Strength for the formulation

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	0.0000	0			
Residual	0.0078	18	0.0004		
Lack of Fit	0.0067	15	0.0004	1.13	0.5289 not significant
Pure Error	0.0012	3	0.0004		
Cor Total	0.0078	18			
Std. Dev.	0.0209	R^2	0.0000		
Mean	0.0459	Adjusted R^2	0.0000		
C.V. %	45.52	Predicted R^2	-0.1142		Adeq Precision NA[1]

Table 4: Analysis of the linear fit ANOVA for the experimental values of Density for the formulation

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	0.0000	0			
Residual	0.0716	18	0.0040		
Lack of Fit	0.0595	15	0.0040	0.9793	0.5891 not significant
Pure Error	0.0122	3	0.0041		
Cor Total	0.0716	18			
Std. Dev.	0.0631	R^2	0.0000		
Mean	1.03	Adjusted R^2	0.0000		
C.V. %	6.15	Predicted R^2	- 0.1142		Adeq Precision NA[1]

Table 5: Analysis of the linear fit ANOVA for the experimental values of Brinell Hardness for the formulation

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	0.0000	0			
Residual	5.04	18	0.2801		
Lack of Fit	4.28	15	0.2854	1.13	0.5300 not significant
Pure Error	0.7600	3	0.2533		
Cor Total	5.04	18			
Std. Dev.	0.5292	R^2	0.0000		
Mean	0.7316	Adjusted R^2	0.0000		
C.V. %	72.34	Predicted R^2	-0.1142		Adeq Precision NA[1]

$$Y_{tensile\ strength} = 0.0459\ X_0 \quad (6)$$

$$Y_{density} = 1.03X_0 \quad (7)$$

$$Y_{hardness} = 0.7316X_0 \quad (8)$$

3.3 D-optimal Analysis

The influence of the snail shell mixture formulation on mechanical properties (tensile strength and hardness) and physical properties (density) was investigated through a mixture experimental design. The density of auto body filler affects its strength, hardness, and brittleness, rendering it appropriate for use. A three-dimensional surface mix-process plot (Figure 4) was created to illustrate the interactions among particle size, snail shell, and unsaturated polyester resin concerning the response variables. The satisfactory values for tensile strength, density, and hardness were compared to standard values. The scatter plots depicting the normal probability of externally studentized residuals for the responses of tensile strength, density, and hardness are presented in Figure 5. These plots indicate that nearly all points follow a linear trend, with the residual points effectively lining up along a straight line. For the response variables, most of the residual values fluctuated randomly around the mean lines, suggesting that the overall mean serves as the most reliable predictor.

3.4 Optimization Of D-Optimal Mixture Design

The desirability function was analyzed using Design-Expert software to determine an optimal formulation. The relationship between the independent variables was illustrated through D-optimal surface and contour plots. An ideal formulation for the snail shell auto body filler was developed by examining the interaction effects among independent variables and assessing the optimization constraints. This formulation included 12% snail shell, 80% unsaturated polyester resin, 2.96% toluene, 2.22% xylene, 2.82% cobalt naphthenate, and a particle size of 106.500 µm, as depicted in Figure 6. The overall desirability index was found to be 0.363 (Figure 7b), while the optimal quality characteristics of the resulting product are reported as a density of 1.03 g/cm3, hardness of 0.7316, and tensile strength of 0.0459 MPa (Figure 7a) based on the best formulation.

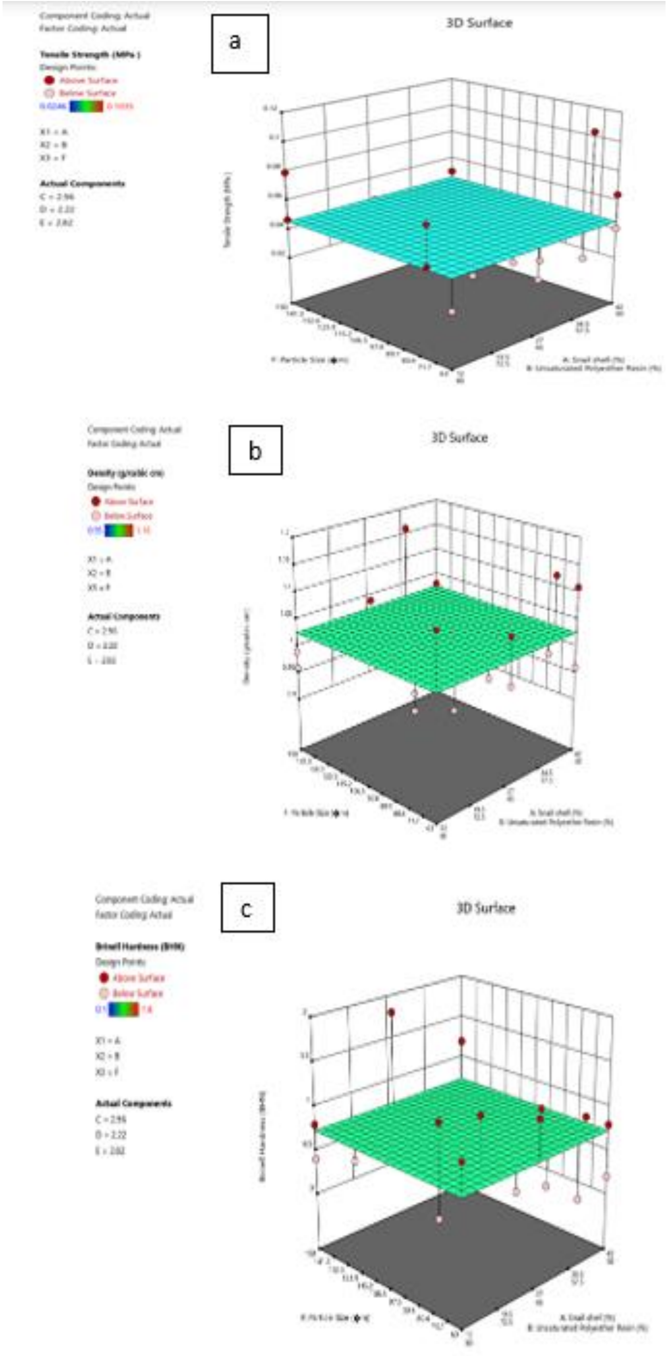

Figure 4: 3-D surface mix-process plot for (a) tensile strength (b)density and (c) hardness

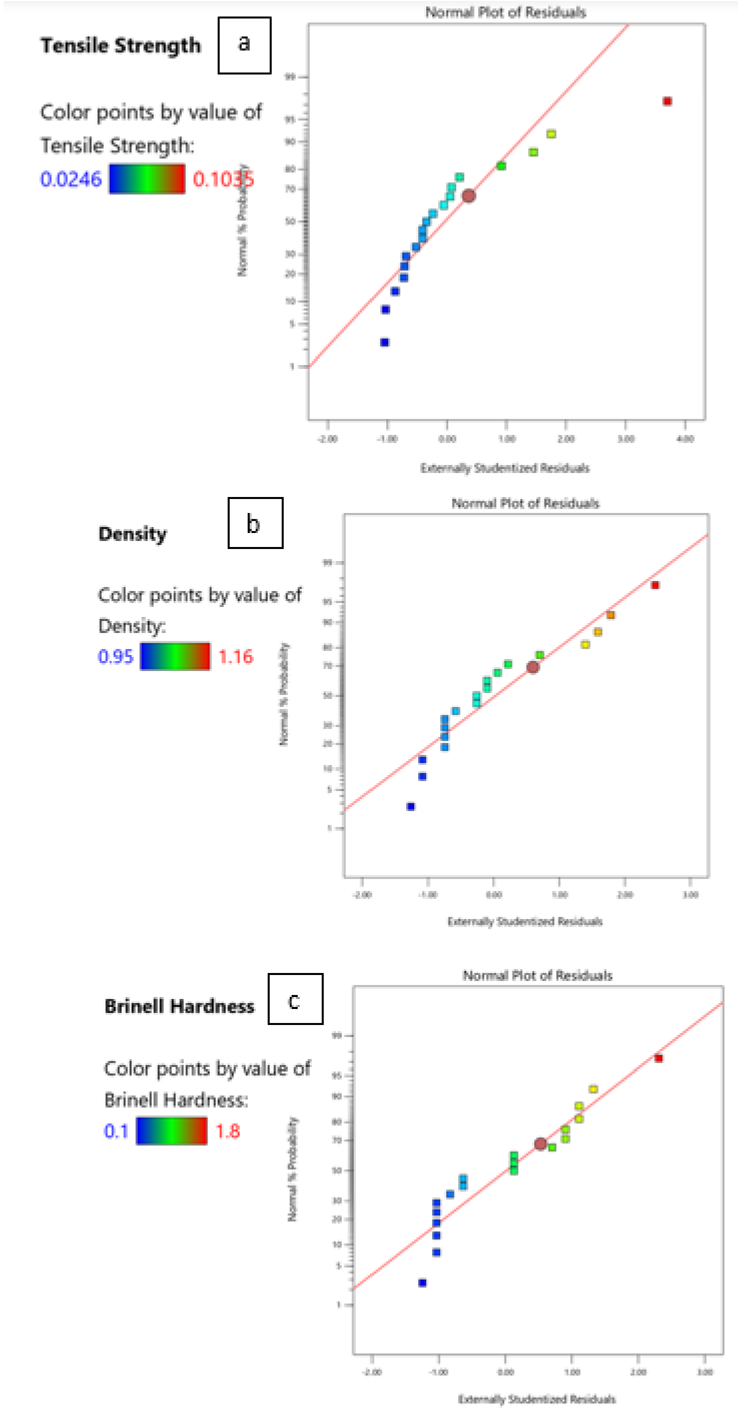

Figure 5: Normal probability plot for externally studentized residuals of (a) tensile strength (b)density and (c) hardness

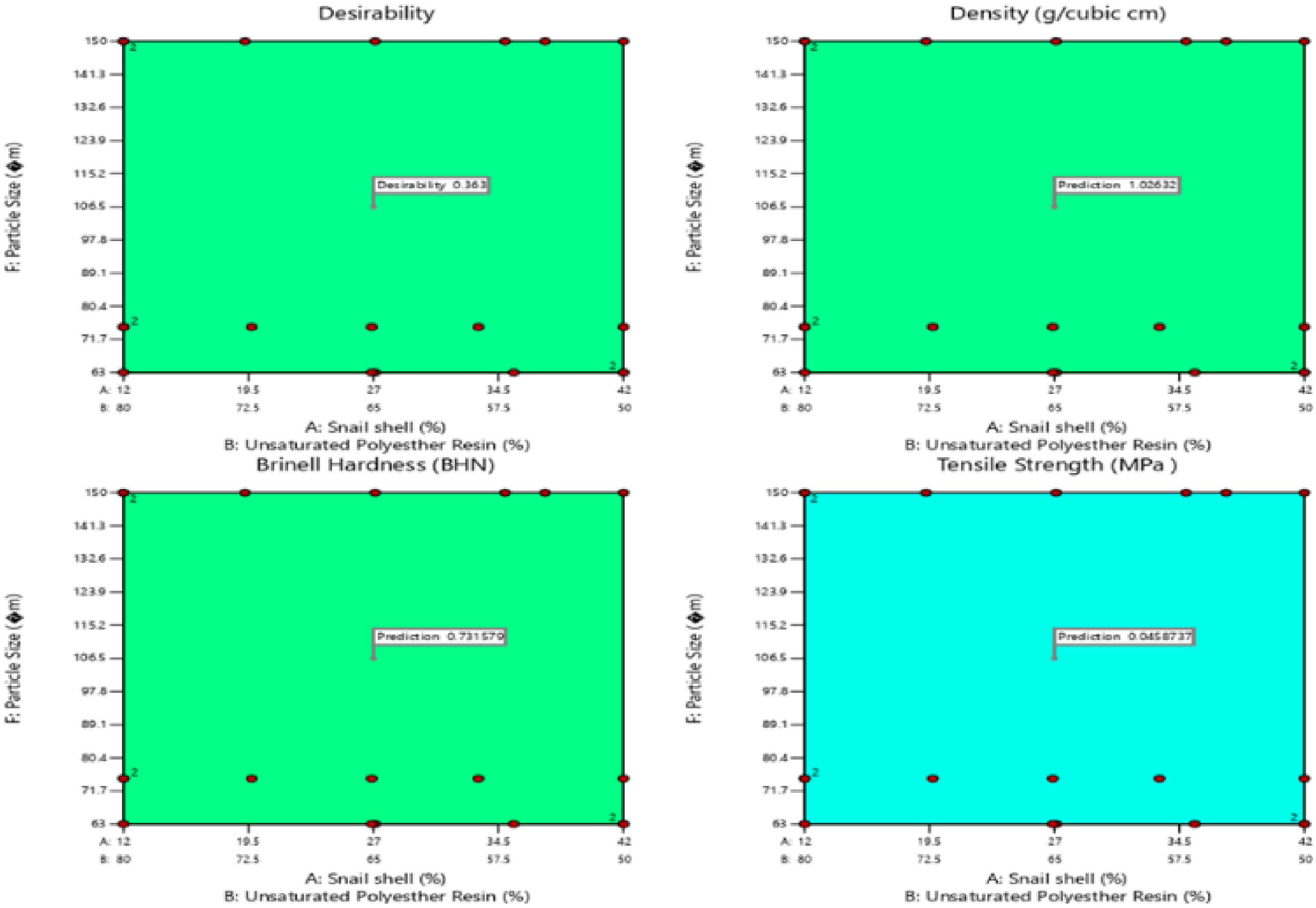

Figure 6: Mixture-Process Plot

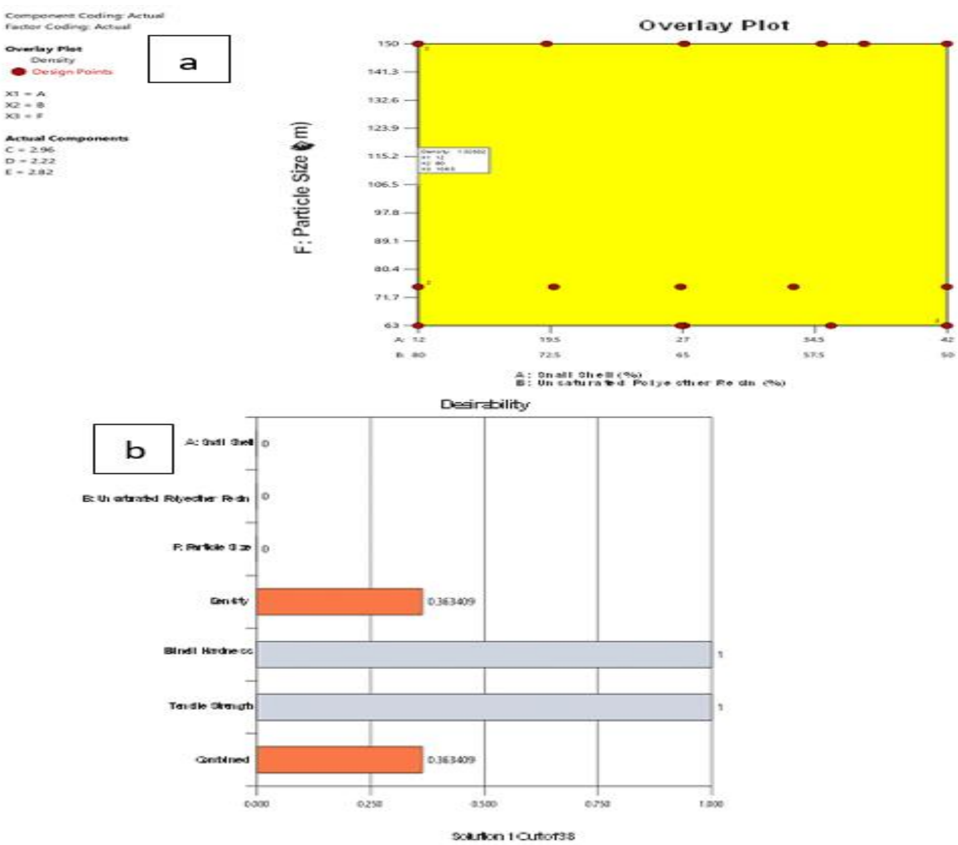

Figure 7: (a) Overlay and (b) desirability bar plots of the mixture formulation

3.5 Determination of the curing time of snail shell auto body filler (SSBdfA and SSBdfB) respectively

To assess the experimental curing time of the snail shell auto body filler, 15% of the optimal values (SSBdfA) was utilized. The mixtures were then applied to clean metal surfaces using a putty knife. The drying times for the mixtures were recorded. The applied mixtures hardened on the metal surfaces over time when exposed to the atmosphere at temperatures between 10°C and 20°C as shown in Table 6 and the procedure was also repeated with15% of the optimal values that were thoroughly mixed with 1% of dibenzoly peroxide, cream hardener (curing agent) (SSBdfB). as shown in Table 7.

Table 6: Curing time of the samples binder (SSBdfA) curing time (Min)

Binder	Sample	Curing time (Min)
Unsaturated Polyester resin	1	16min 34 sec
Unsaturated Polyester resin	2	16min 41 sec
Unsaturated Polyester resin	3	16min 35 sec

Table 7: Curing time of the samples (SSBdfB) binder curing time (Min)

Binder	Sample	Curing time (Min)
Unsaturated Polyester resin	1	10min 12 sec
Unsaturated Polyester resin	2	10min 17 sec
Unsaturated Polyester resin	3	10min 19 sec

The results of the curing time conducted on the produced samples indicated a drying time of 16, and 10 minutes for samples SSBdfA and SSBdfB [26]. The increased dryer content resulted in a shorter drying time. This is due to the fact that oxidation-based drying has the effect of increasing oxidation with increasing drying time, which results in a faster rate of oxidation. More specifically, a higher hardener content speeds up drying, but an excessive amount of hardener makes the auto body filler extremely brittle and susceptible to cracking. The samples created by SSBdfB adhered effectively and exhibited good flexibility on the mental surface, and has effect on the snail shell auto body filler.

3.6 Characterization of the optimal values mixed with cream hardener (SSBdfB)

15% samples of the optimal snail shell auto body filler (SSBdfB) were mixed with 1% cream hardener dibenzoyl peroxide (catalyst), and it was also measured by standard using a universal testing machine – Instron (MAS 14) according to ASTM D412. The tensile test was operated at a cross-head speed of 10mm/min. The density test of the samples was carried out using standard 25ml density bottle. The hardness test was done using Brinell's hardness testing machine according to ISO 6506 according to standard methods as shown in Table 8.

Table 8: Characterization of the optimal values mixed with cream hardener (SSBdfB).

Run	Optimal Values (%)	Cream Hardener (%)	Density g/cm3	Brinell Hardness HR	Tensile Strength MPa
1	15	1	1.22	0.96	0.0931

The result of the optimal product mixed with cream hardener (SSBdfB) quality properties with these conditions are 1.22g/cm3 density, 0.96 hardness and 0.0931 MPa tensile strength. From the results it is concluded that the samples SSBdfB contains higher physical properties compared to (SSBdfA) that has a density of 1.03 g/cm³, a hardness of 0.7316, and a tensile strength of 0.0459 MPa,

3.7 Validation Test for snail shell auto body filler (SSBdfA and SSBdfB)

In the validation test of the auto body filler production samples SSBdfA and SSBdfB , the optimal value mass of the snail shell of 12% was varied with that of unsaturated polyester resin of 80% while toluene, xylene, cobalt and naphthenate, were held constant to give a total of 100%, The resulting mixture was vigorously agitated in a beaker with a stirrer for about two minutes to ensure an even dispersion of the extenders and pigment in the resin, the stirring was continuing until a homogeneous paste was obtained. Thereafter 2.96% toluene, 2.22% of xylene, and 2.82% cobalt naphthenate (accelerator) at intervals were added to the mixture and stirred for another 10 minutes as shown in Table 9 and 10.

Table 9: Validation Test SSBdfA

	X_1^a (%)	X_2^b (%)	X_3^c (%)	X_4^d (%)	X_5^e (%)	X_6^f (%)	Y_1^g (g/cm^3)	Y_2^h ()	Y_3^* (MPa)
S1	12	80	2.96	2.22	2.82	106.500	0.97	0.82	0.0456
S2	**12**	**80**	**2.96**	**2.22**	**2.82**	**106.500**	**0.97**	**0.79**	**0.0467**
S3	12	80	2.96	2.22	2.82	106.500	0.96	0.81	0.0454
Mean							**0.97**	**0.8066**	**0.0459**

Table 10: Validation Test SSBdfB

Run	X_1^a (%)	X_2^b (%)	X_3^c (%)	X_4^d (%)	X_5^e (%)	X_6^f (%)	Y_1^g (g/cm^3)	Y_2^h ()	Y_3^* (MPa)
S1	12	80	2.96	2.22	2.82	106.500	0.97	0.82	0.0456
S2	12	80	2.96	2.22	2.82	106.500	0.97	0.79	0.0467
S3	12	80	2.96	2.22	2.82	106.500	0.96	0.81	0.0454
Mean							**1.20**	**0.970**	**0.0962**

3.8 Model Validation

A comparison was made between the experimental values and those from the cream hardener (SSBdfA and SSBdfB) to evaluate the effectiveness of the D-optimal surface equation. The performance analysis of the samples produced indicated that the optimal product quality properties were achieved at 0.0459 MPa for tensile strength, 0.97 g/cm³ for density, and 0.8066 for hardness, as well as at 0.0962 MPa for tensile strength, 1.20 g/cm³ for density, and 0.970 for hardness. Tables 9 and 10 demonstrate that there was no significant difference between SSBdfA (Equations 9-11) and SSBdfB (Equations 12-14) under optimal conditions [27].

$$Y_{tensile\ strength} = 0.0459\ X_0 \quad (9)$$

$$Y_{density} = 0.97\ X_0 \quad (10)$$

$$Y_{hardness} = 0.8066\ X_0 \quad (11)$$

$$Y_{tensile\ strength} = 0.0962\ X_0 \quad (12)$$

$$Y_{density} = 1.20X_0 \quad (13)$$

$$Y_{hardness} = 0.970\, X_0 \quad (14)$$

4 | CONCLUSION

This study investigated how cream hardener affects the optimal proportions of snail shell auto body filler (SSBdfA and SSBdfB). A mixture experimental design was utilized to predict the optimal formulation for the autobody filler. The analysis of variance suggested that the overall mean was the most reliable indicator for both the mechanical (tensile strength, hardness) and physical (density) properties. Based on the experimental findings, empirical models and surface responses were developed to examine how the independent variables influenced the response variables. The highest quality product was used to produce samples that would confirm the formulation design. The use of cream hardener led to enhanced curing times and improved physical characteristics. It was clear that the cream hardener affects snail shell auto body filler and is suitable for industrial applications, including automotive fillers and the physical and mechanical properties of the SSBdfA and SSBdfB samples were also evaluated. The optimal product quality characteristics revealed that SSBdfA exhibited a density of 1.03 g/cm³, a hardness of 0.7316, and a tensile strength of 0.0459 MPa, while SSBdfB demonstrated superior physical properties with a density of 1.22 g/cm³, a hardness of 0.96, and a tensile strength of 0.0931 MPa. Validation testing results for the produced samples (SSBdfA and SSBdfB) indicated optimal product quality properties with conditions of 0.97 g/cm³ density, 0.8066 hardness, and 0.0459 MPa tensile strength for SSBdfA, compared to 1.20 g/cm³ density, 0.973 hardness, and 0.0962 MPa tensile strength for SSBdfB.

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