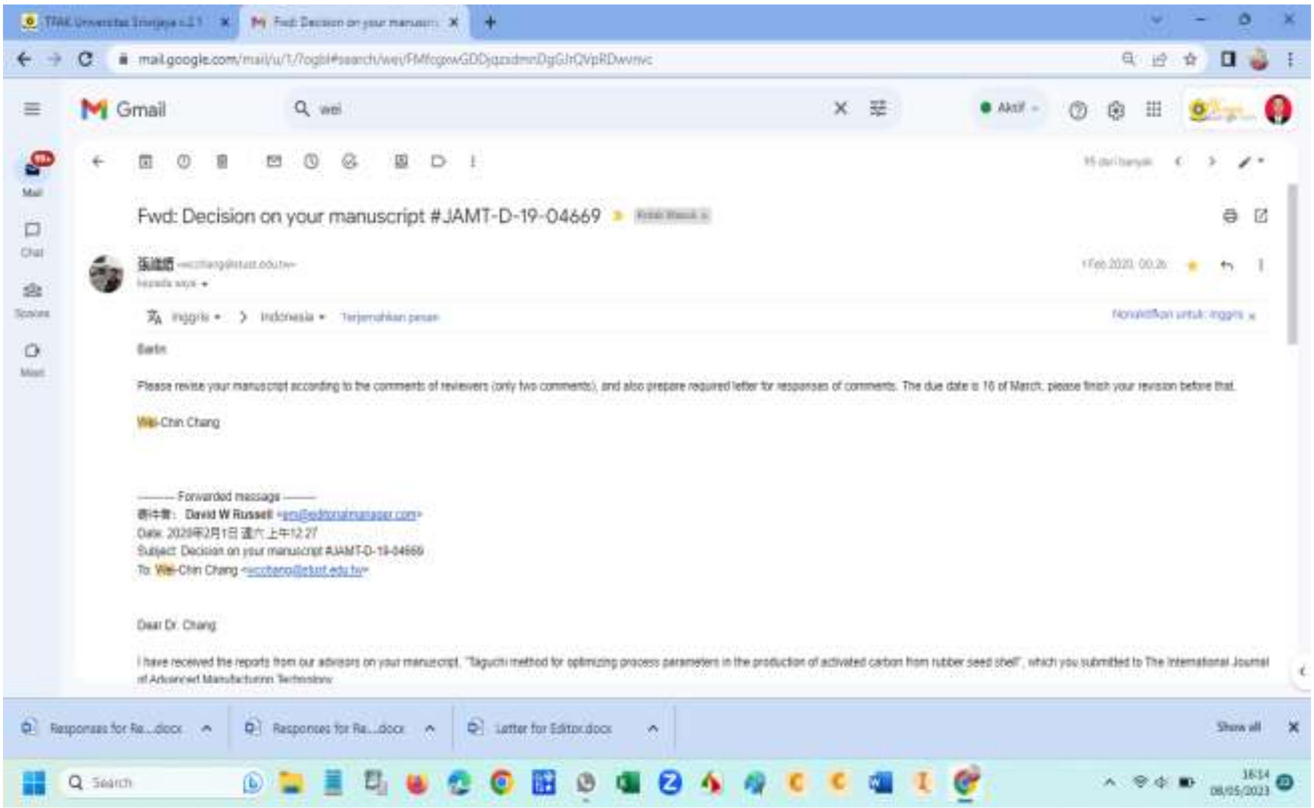

Fwd: Decision on your manuscript #JAMT-D-19-04669

1 Feb 2020, 00.26

Barlin

Please revise your manuscript according to the comments of reviewers (only two comments), and also prepare required letter for responses of comments. The due date is 16 of March, please finish your revision before that.

Wei-Chin Chang

---------- Forwarded massage ---------
寄件者: **David W Russell** <em@editorialmanager.com>
Date: 2020年2月1日 週六 上午12:27
Subject: Decision on your manuscript #JAMT-D-19-04669
To: Wei-Chin Chang <wcchang@ntust.edu.tw>

Dear Dr. Chang

I have received the reports from our advisors on your manuscript, "Taguchi method for optimizing process parameters in the production of activated carbon from rubber seed shell", which you submitted to The International Journal of Advanced Manufacturing Technology

David W Russell, PhD, FIMechE
Regional Editor

The International Journal of Advanced Manufacturing Technology

February 14, 2020

SUBJECT: Re-submission of manuscript to The International Journal of Advanced Manufacturing Technology

==

Dear David W Russell, PhD, FIMechE

Thank you for the opportunity to re-submit our manuscript entitled "Taguchi method for optimizing process parameters in the production of activated carbon from rubber seed shell", for your consideration.

We appreciate the time and efforts by the editor and reviewers in reviewing this manuscript.

In revising the paper, we have carefully considered your comments and suggestions, as well as those of the reviewers. After addressing the issues raised, we feel the quality of the paper is much improved and hope you agree.

I look forward to receiving your further communications.

Yours sincerely,

Dr. Wei-Chin Chang

Department of Mechanical Engineering, Southern Taiwan University of Science and Technology, Tainan 710, Taiwan

LIST OF RESPONSES OF COMMENTS FOR REVIEWER #1

No	Number of responses
1	Responses #1 (Page 27)
C1	I need to study data and calculations of Table 6
A1	Thank you for the comment.

Table 6 shows the values of product yield and amorphous content in activated carbons at optimal condition and one random condition. The values were found from experimental results (Exp.) and predicted values (Predicted.). The experimental values (Exp.) were obtained from experiments results. The predicted values (Predicted.) were obtained from Taguchi method and linear regression model. The error values were mentioned to show the difference values between experimental results and predicted values.

Table 6. Experimental results and predicted values for confirmation test. (Revised)

Level	Taguchi method			Linear regression		
	Exp.	Predicted.	Error (%)	Exp.	Predicted.	Error (%)
Product yield (%)						
$A_1B_1C_1$ (Optimal condition)	66.06	68.37	3.38	66.06	69.03	4.30
$A_3B_2C_1$ (Random condition)	67.3	61.37	8.81	67.3	53.13	21.05
Amorphous percentage (%)						
$A_1B_1C_3$ (Optimal condition)	85.7	91.61	6.45	85.7	96.47	11.16
$A_3B_2C_1$ (Random condition)	89.7	83.47	6.95	89.7	87.80	2.12

Table 2. The experimental results and S/N ratios for product yield and amorphous percentage

Test number.	Chemical reagent concentration, A (wt.%)	Activation temperature, B (° C)	Activation time, C (h)	Product yield (wt.%)	S/N ratio (dB)	Amorphous percentage (wt. %)	S/N ratio (dB)
1	25	600	1.0	69.4	36.827	92.8	39.3510
2	25	700	2.0	37.94	31.5819	92.9	39.3603
3	25	850	2.5	38.49	31.7070	94.1	39.4718
4	50	600	2.0	53.2	34.5182	92.9	39.3603
5	50	700	2.5	58.8	35.3875	93.4	39.4069
6	50	850	1.0	30.7	29.7428	83.8	38.4649
7	75	600	2.5	51.7	34.2698	93.2	39.3883
8	75	700	1.0	67.3	36.5603	89.7	39.0558
9	75	850	2.0	16.1	24.1365	89.8	39.0655

T_{Py} = total mean value = 47.07 and T_{Ap} = total mean value = 94.1

The total mean values of product yield (T_{Py}) and amorphous percentage(T_{Ap}) resulted from varied activation processes were 47.07% and 94.1% respectively. The values of T_{Py} and T_{Ap} are needed in calculation of predicted product yield and predicted amorphous percentage with Taguchi method (Eqs (7) and (8)).

Table 3. Table of response for S/N ratios.

Levels	Parameters					
	Product yields			Amorphous percentages		
	A (wt.%)	B (° C)	C (h)	A (wt.%)	B (° C)	C (h)
Level 1	**33.37**	**35.21**	**34.38**	**39.39**	**39.37**	38.96
Level 2	33.22	34.51	30.08	39.08	39.27	39.26
Level 3	31.66	28.53	33.79	39.17	39.00	**39.42**
Delta	1.72	6.68	4.30	0.32	0.37	0.47
Rank	3	1	2	3	2	1

Table 3 shows the response for S/N ratios. The optimal conditions (levels) were found based on the response for S/N ratios. Based on the highest of response for S/N ratios, the optimal condition for maximum product yield and amorphous percentage were **$A_1B_1C_1$** and **$A_1B_1C_3$**.

Table 3. Processing parameters for product yield

Parameters	Symbol	Level 1	Level 2	Level 3
Chemical reagent concentration	A	**25**	50	75
Activation temperature	B	**600**	700	850
Activation time	C	**1.0**	2.0	2.5

Table 3. Processing parameters for amorphous percentage

Parameters	Symbol	Level 1	Level 2	Level 3
Chemical reagent concentration	A	**25**	50	75
Activation temperature	B	**600**	700	850
Activation time	C	1.0	2.0	**2.5**

For optimal condition, based on Table 3, the processing parameters conditions for **$A_1B_1C_1$** is (25 wt.% of chemical reagent concentration, 600 °C of activation temperature, 1.0 hour of activation time) and **$A_1B_1C_3$** is (25 wt.% of chemical reagent concentration, 600 °C of activation temperature, 2.5 hours of activation time).

For confirmation test, the experiments were done with these two conditions i.e. **$A_1B_1C_1$ and $A_1B_1C_3$.**
$A_1B_1C_1$ = Parameter A at level 1, Parameter B at level 1, Parameter C at level 1.
$A_1B_1C_3$ = Parameter A at level 1, Parameter B at level 1, Parameter C at level 3.
The optimal product yield at **$A_1B_1C_1$** was 66.06 wt.% and the optimal amorphous percentage at **$A_1B_1C_3$** was 85.7 wt.%.

For checking the product yield and amorphous percentage at random condition, the test number 8 was selected. The level of processing parameters is **$A_3B_2C_1$**.
$A_3B_2C_1$ = Parameter A at level 3, Parameter B at level 2, Parameter C at level 1.
Based on table 2, the processing parameters conditions for **$A_3B_2C_1$** is (75 wt.% of chemical reagent concentration, 700 °C of activation temperature, 1.0 hour of activation time). This condition levels will be applied in calculating the product yield and amorphous percentage at random condition.

Calculations of Table 6

Calculation of predicted product yield and predicted amorphous percentage with Taguchi method

The predicted values (Predicted.) with Taguchi method was obtained with Eqs. (7) and (8).

$$P_{y,Predicted} = (A_1 - T_{py}) + (B_1 - T_{py}) + (C_1 - T_{py}) + T_{py} \quad (7)$$

where: $P_{y,Predicted}$ is the equation for predicted product yield.

$$A_{p,Predicted} = (A_1 - T_{Ap}) + (B_1 - T_{Ap}) + (C_3 - T_{Ap}) + T_{Ap} \quad (8)$$

where: $A_{p,Predicted}$ is the equation for predicted amorphous percentage.

T_{py} = total mean value = 47.07, T_{Ap} = total mean value = 94.1

T_{py} and T_{Ap} were calculated from the experimental results in Table 2.

A, B, and C are process parameters conditions. The values of A, B and C were summarized in Table 5.

Calculation of the optimum product yield and the optimum amorphous percentage

In calculation at the optimal condition, the level was obtained from mean response in table 5.

$A_1B_1C_1$, where A_1 = 48.61, B_1 = 58.1, C_1 = 55.80 for optimal product yield

$A_1B_1C_3$, where A_1 = 93.27, B_1 = 92.97, C_3 = 93.57 for optimal amorphous percentage

Table 5**.** Mean response table of product yield and amorphous percentage for the optimal condition

Levels	Control factors					
	Product yield			Amorphous percentage		
	A	B	C	A	B	C
Level 1	**48.61**	**58.10**	**55.80**	**93.27**	**92.97**	88.77
Level 2	47.57	54.68	35.75	90.03	92.00	91.87
Level 3	45.03	28.43	49.66	90.90	89.23	**93.57**
Delta	3.58	29.67	20.05	3.23	3.73	4.80
Rank	3	1	2	3	2	1

Bold values indicates the levels for the optimal condition

The results of calculation of optimum product yield and amorphous percentage with Taguchi method using eqs. (7) and (8).

$A_1B_1C_1$	$Py_{Predicted}$ = ((48.61-47.07) + (58.1-47.07) + (55.8-47.07) + 47.07) = 68.37
$A_1B_1C_3$	$Ap_{Predicted}$ = (93.27-94.1) + (92.97-94.1) + (93.57-94.1) + 94.1 = 91.61

Calculation of the product yield and amorphous percentage at random condition

In calculation at the random condition, the level was obtained from mean response in table 5.

$A_3B_2C_1$, where $A_3 = 45.03$, $B_2 = 54.68$, $C_1 = 55.80$ for random product yield

$A_3B_2C_1$, where $A_3 = 90.90$, $B_2 = 92.00$, $C_1 = 88.77$ for optimal amorphous percentage

Table 5. Mean response table of product yield and amorphous percentage for the selected random condition

Levels	Control factors					
	Product yield			Amorphous percentage		
	A	B	C	A	B	C
Level 1	48.61	58.10	**55.80**	93.27	92.97	**88.77**
Level 2	47.57	**54.68**	35.75	90.03	**92.00**	91.87
Level 3	**45.03**	28.43	49.66	**90.90**	89.23	93.57
Delta	3.58	29.67	20.05	3.23	3.73	4.80
Rank	3	1	2	3	2	1

Bold values indicates the levels for the selected random conditions

The results of calculation of product yield and amorphous percentage with Taguchi method at selected random condition

$A_3B_2C_1$	$Py_{Predicted} = ((45.03-47.07) + (54.68-47.07) + (55.8-47.07) + 47.07) = 61.37$
$A_3B_2C_1$	$Ap_{Predicted} = (90.9-94.1) + (92.0-94.1) + (88.77-94.1) + 94.1 = 83.47$

Calculation of predicted product yield and predicted amorphous percentage with multiple regression model

The predicted values (Predicted.) with multiple regression was obtained with Eqs. (5) and (6).

$$P_{y,Predicted} = 151 - 0.072A - 0.123B - 6.37C \quad (5)$$

where: $P_{y,Predicted}$ is the equation for predicted product yield.

$$A_{p,Predicted} = 98.8 - 0.0473A - 0.0152B + 3.19C \quad (6)$$

where: $A_{p,Predicted}$ is the equation for predicted amorphous percentage.

A, B, and C are process parameters conditions. The values of A, B and C were summarized in Table 1.

The multiple regression model obtained indicated that all the process parameters namely chemical reagent concentration (A), activation temperature (B), and activation time (C) influence the values of product yield and amorphous percentage.

Calculation of the optimum product yield and the optimum amorphous percentage

In the calculation the optimal condition, the level was obtained from table 5. Based on the highest mean response values, the levels for optimum product yield and amorphous percentages are $A_1B_1C_1$ and $A_1B_1C_3$, respectively.

$A_1 = 25$, $B_1 = 600$, $C_1 = 1.0$ for optimal product yield

$A_1 = 25$, $B_1 = 600$, $C_3 = 2.5$ for optimal amorphous percentage

The levels for optimal product yield and amorphous percentage

Designation	Chemical reagent concentration, A (wt.%)	Activation temperature, B (°C)	Activation time, C (h)	Remarks
$A_1B_1C_1$	25	600	1.0	Product yield
$A_1B_1C_3$	25	600	2.5	Amorphous percentage

The values of optimum product yield and amorphous percentage with multiple regression model

$A_1B_1C_1$	$Py_{Predicted} = 151 - (0.072*25) - (0.123*600) - (6.37*1.0) = 69.03$
$A_1B_1C_3$	$Ap_{Predicted} = 98.8 - (0.0473*25) - (0.0152*600) + (3.19*2.5) = 96.47$

Calculation of the product yield and amorphous percentage at selected random condition

In the calculation the selected random condition, the level was obtained from table 1.

$A_3 = 75$, $B_2 = 700$, $C_1 = 1.0$ for random product yield

$A_3 = 75$, $B_2 = 700$, $C_1 = 1.0$ for optimal amorphous percent

The results of calculation of product yield and amorphous percentage with Taguchi method at selected random condition

$A_3B_2C_1$	$Py_{Predicted} = 151 - (0.072*75) - (0.123*700) - (6.37*1.0) = 53.13$
$A_3B_2C_1$	$Ap_{Predicted} = 98.8 - (0.0473*75) - (0.0152*700) + (3.19*1.0) = 87.80$

Calculation of the errors

For the confirmation test, the developed linear regression equation and experimental values presented low percentage of error (< 20%) to indicate the accuracy. This study has provided quality evidences that the Taguchi method was an applicable and effective methodology with precise results for optimizing the parameters in activated carbon production.

Calculations error with Taguchi method:

Product yield

$A_1B_1C_1$ (Optimal condition) = ((68.37-66.06)/68.37) *100) = 3.378 = 3.38

$A_3B_2C_1$ (Random condition) = ((67.3-61.37)/67.3) *100) = 8.811 = 8.81

Amorphous percentage

$A_1B_1C_1$ (Optimal condition) = ((91.61-85.7)/91.61) *100) = 6.451 = 6.45

$A_3B_2C_1$ (Random condition) = ((89.7-83.47)/89.7) *100) = 6.945 = 6.95

Calculations error with Linear regression model:

Product yield

$A_1B_1C_1$ (Optimal condition) = ((69.03-66.06)/68.37) *100) = 4.302 = 4.30

$A_3B_2C_1$ (Random condition) = ((67.3-53.13)/67.3) *100) = 21.054 = 21.05

Amorphous percentage

$A_1B_1C_1$ (Optimal condition) = ((96.47-85.7)/91.61) *100) = 11.164 = 11.16

$A_3B_2C_1$ (Random condition) = ((89.7-87.8)/89.7) *100) = 2.118 = 2.12

The results of calculation of error for confirmation test

Level	Taguchi method			Linear regression		
	Exp.	Predicted.	Error (%)	Exp.	Predicted.	Error (%)
Product yield (%)						
$A_1B_1C_1$ (Optimal condition)	66.06	68.37	3.38	66.06	69.03	4.30
$A_3B_2C_1$ (Random condition)	67.3	61.37	8.81	67.3	53.13	21.05
Amorphous percentage (%)						
$A_1B_1C_3$ (Optimal condition)	85.7	91.61	6.45	85.7	96.47	11.16
$A_3B_2C_1$ (Random condition)	89.7	83.47	6.95	89.7	87.80	2.12

Verification and validation of the multiple regression model

The developed multiple regression models (Eqs. 5 and 6) were verified and validated by comparing the values of product yield and amorphous percentage obtained via experiment with the predicted output of the multiple regression model.

Comparison of deviation values of product yield from the experiment and multiple regression model

Test number	Actual product yield (wt.%)	Predicted product yield (wt.%)	Deviation (wt.%)
1	69.4	69.03	0.37
2	37.94	50.36	12.42
3	38.49	28.725	9.765
4	53.2	60.86	7.66
5	58.8	45.375	13.425
6	30.7	36.48	5.78
7	51.7	55.875	4.175
8	67.3	53.13	14.17
9	16.1	28.31	12.21

Comparison of deviation values of amorphous percentage from the experiment and multiple regression model

Test number	Actual amorphous percentage (wt.%)	Predicted amorphous percentage (wt.%)	Deviation (wt.%)
1	92.8	91.6875	1.1125
2	92.9	93.3575	0.4575
3	94.1	92.6725	1.4275
4	92.9	93.695	0.795
5	93.4	93.77	0.37
6	83.8	86.705	2.905
7	93.2	94.1075	0.9075
8	89.7	87.8025	1.8975
9	89.8	88.7125	1.0875

In revised manuscript: we have added or modified some sentences and tables.

1. Tables 5 and 6 were added for validating and verifying the values between experimental results (actual) and predicted results obtained by the multiple regression models.
2. Figs 8 and 9 represented the comparison of the experimental results and predicted values for product yield and amorphous percentage.
3. Tables 12 and 13 were added with modified version from Table 6 in previous manuscript.

The hypothesis test of the multiple regression model

Multiple regression output from sofware for the product yield data

Regression Analysis: Product yield versus Chemical reagent concentration, Activation temperature, Activation time

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.802204358
R Square	0.643531832
Adjusted R Square	0.429650932
Standard Error	13.31990548
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1601.48019	533.8267	3.00883	0.133267377
Residual	5	887.0994104	177.4199		
Total	8	2488.5796			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	150.5681454	35.60310819	4.229073	0.00826	59.04744215	242.088849	59.0474422	242.0888486
Chemical reagent concentration	-0.07153333	0.217513146	-0.32887	0.75558	-0.630668675	0.48760201	-0.6306687	0.487602008
Activation temperature	-0.12312632	0.04321548	-2.84913	0.03586	-0.234215244	-0.0120374	-0.2342152	-0.01203739
Activation time	-6.37142857	7.119788963	-0.89489	0.41185	-24.67342875	11.9305716	-24.673429	11.93057161

Product yield = 151 - 0.072*Chemical reagent concentration - 0.123*Activation temperature - 6.37*Activation time

Predictor	Coef	SE Coef	T	P
Constant	150.57	35.60	4.23	0.08
Chemical reagent concentration	-0.0715	0.2175	-0.33	0.756
Activation temperature	-0.12313	0.04322	-2.85	0.036
Activation time	-6.371	7.120	-0.89	0.412

In the ouput table, it can be seen that P-value of chemical reagent concentration, activation temperature and activation time are 0.756, 0.036 and 0.412, respectively. The p-value for activation time (0.036) is lower than the common alpa level of 0.05, which indicates that activation time is statistically significant. While, the p-value of chemical reagent concentration (0.756) and activation time (0.412) are greater than the common alpha of 0.05, which indicates not statistically significant.

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	1601.5	533.8	3.01	0.133
Residual Error	5	887.1	177.4		
Total	8	2488.6			

Table shows the ANOVA for testing significance of regression in multiple regression. The test is obatined to determine whether a linear relationship exist between the response variable i.e product yield and amorphous percentage and a subset of the regressor variables i.e chemical reagent concentrtaion, activation temperature and activation time. The appropriate hypothesis are $H_0 : \beta_1 = \beta_2 = \beta_3 = 0$. The testing significance shows that the p-value for product yield is considerably higher than $\alpha = 0.05$. The null hypothesis (H_0) is fail to rejected due to p-value>0.05.

Multiple regression output from sofware for the amorphous percentage data
Regression Analysis: Amorphous percentage versus Chemical reagent concentration, Activation temperature, Activation time

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.884691604
R Square	0.782679234
Adjusted R Square	0.652286774
Standard Error	1.913029457
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	65.90159148	21.96719716	6.00248845	0.041209045
Residual	5	18.29840852	3.659681704		
Total	8	84.2			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	98.82706767	5.113384237	19.32713504	6.84E-06	85.68269503	111.9714403	85.68269503	111.9714403
Chemical reagent concentration	-0.047333333	0.03123964	-1.51516896	0.190161471	-0.127637385	0.032970718	-0.127637385	0.032970718
Activation temperature	-0.015210526	0.006206687	-2.45066748	0.057888866	-0.031165324	0.000744271	-0.031165324	0.000744271
Activation time	3.185714286	1.022557257	3.115438538	0.026387951	0.557147175	5.814281397	0.557147175	5.814281397

Amorphous percentage = 98.8 - 0.0473*Chemical reagent concentration - 0.0152*Activation temperature + 3.19* Activation time

Predictor	Coef	SE Coef	T	P
Constant	98.827	5.113	19.33	0.000
Chemical reagent concentration	-0.04733	0.03124	-1.52	0.190
Activation temperature	-0.015211	0.006207	-2.45	0.058
Activation time	3.186	1.023	3.12	0.026

In the ouput table, it can be seen that P-value of chemical reagent concentrtaion, activation temperature and activation time are 0.190, 0.058 and 0.026, respectively. It can be seen that the predictor variables of activation temperature (0.058) and activation time (0.026) are significant because both of their p-values are lower than or equal to the common alpa level of 0.05. While, the p-value of chemical reagent concentration (0.190) is greater than the common alpha of 0.05, which indicates not statistically significant.

A low p-value (<0.05) indicates that the null hypothesis can be rejected. In other words, a predictor that has a low p-values is likely t be a meaningful addition to the model because changes in the predictor's value are related to changes the response variable. Conversely, a larger (insignificant) p-value suggest that changes in the predictor are not associated with changes in the response.

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	65.902	21.967	6.00	0.041
Residual Error	5	18.298	3.660		
Total	8	84.200			

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Table 4 shows the ANOVA for testing significance of regression in multiple regression. The test is obatined to determine whether a linear relationship exist between the response variable i.e product yield and amorphous percentage and a subset of the regressor variables i.e chemical reagent concentrtaion, activation temperature and activation time. The appropriate hypothesis are H_0 : $\beta_1 = \beta_2 = \beta_3 = 0$. The testing significance shows that the p-value for amorphous percentage is smaller than $\alpha = 0.05$. The null hypothesis (H_0) is rejected due to p-value<0.05 and concluded that at least one of the variables contributes significantly to the multiple regression model. This results confirms that activation temperature and activation time contributes significantly to the model for amorphous percentage.

In revised manuscript: we have added the hypothesis test of the multiple regression model.

1. Hypothesis test of the multiple regression model
2. Tables 7 and 8 showed the summary output from software
3. Discussion about findings from table 7 and 8.
4. Tables 9 and 10 showed the ANOVA of the developed multiple regression model
5. Discussion about the results from ANOVA of the developed multiple regression model

Product yield (Py) = 151 - 0.072*A - 0.123*B - 6.37*C (5)

Amorphous percentage (Ap) = 98.8 - 0.0473*A - 0.0152*B + 3.19*C (6)

where A is chemical reagent concentration (in wt.%), B is activation temperature (in °C), C is activation time (in hours), Py is predicted prodcut yield (in wt.%), and Ap is predicted amorphous percentage (in wt.%).

Table 7. Summary output of multiple regression model product yield

Predictor	Coef	SE Coef	T statistic	P-value
Constant	150.57	35.60	4.23	0.08
Chemical reagent concentration	-0.0715	0.2175	-0.33	0.756
Activation temperature	-0.12313	0.04322	-2.85	0.036
Activation time	-6.371	7.120	-0.89	0.412

S = 13.3199 R-Sq = 64.4% R-Sq(adj) = 43.0%

Table 8. Summary ouput of multiple regression model for amorphous percentage

Predictor	Coef	SE Coef	T statistic	P-value
Constant	98.827	5.113	19.33	0.000
Chemical reagent concentration	-0.04733	0.03124	-1.52	0.190
Activation temperature	-0.015211	0.006207	-2.45	0.058
Activation time	3.186	1.023	3.12	0.026

S = 1.91303 R-Sq = 78.3% R-Sq(adj) = 65.2%

In Table 7, the regressin ouput for product yield is summarized. It can be seen that p-value of chemical reagent concentration, activation temperature and activation time are 0.756, 0.036 and 0.412, respectively. The p-value for activation temperature (0.036) is lower than the common alpa level of 0.05, which indicates that activation temperature is statistically significant. While, the p-value of chemical reagent concentration (0.756) and activation time (0.412) are greater than the common alpha of 0.05, which indicates not statistically significant.

Table 8 show the regressin ouput for amorphous percentage. It can be seen that p-value of chemical reagent concentrtaion, activation temperature and activation time are 0.190, 0.058 and 0.026, respectively. It can be seen that the predictor variables of activation temperature (0.058) and activation time (0.026) are significant because both of their p-values are lower than or equal to the common alpa level of 0.05. While, the p-value of chemical reagent concentration (0.190) is greater than the common alpha of 0.05, which indicates not statistically significant.

A low p-value (<0.05) indicates that the null hypothesis can be rejected. In other words, a predictor that has a low p-values is likely t be a meaningful addition to the model because changes in the predictor's value are related to changes the response variable. Conversely, a larger (insignificant) p-value suggest that changes in the predictor are not associated with changes in the response.

Table 9. ANOVA of the developed multiple regression model for product yield

Source	Degree of freedom	Sum of squares	Mean square	f_0	P-value
Regression	3	1601.5	533.8	3.01	0.133
Residual Error	5	887.1	177.4		
Total	8	2488.6			

Table 10. ANOVA of the developed multiple regression model for amorphous percentage

Source	Degree of freedom	Sum of squares	Mean square	f_0	P-value
Regression	3	65.902	21.967	6.00	0.041
Residual Error	5	18.298	3.660		
Total	8	84.200			

Table 9 and 10 shows the ANOVA for testing significance of regression in multiple regression. The test is obatined to determine whether a linear relationship exist between the response variable i.e product yield and amorphous percentage and a subset of the regressor variables i.e chemical reagent concentrtaion, activation temperature and activation time. The appropriate hypothesis are $H_0 : \beta_1 = \beta_2 = \beta_3 = 0$. The testing significance shows that the p-value for product yield is considerably higher than $\alpha = 0.05$. While the p-value for amorphous percentage is smaller than $\alpha = 0.05$. For the product yield, the null hypothesis (H_0) is fail to rejected due to p-value>0.05. Whereas for the amorphous percentage, the null hypothesis (H_0) is rejected due to p-value<0.05 and concluded that at least one of the variables contributes significantly to the multiple regression model. This results confirms that activation temperature and activation time contributes significantly to the model for amorphous percentage.