Optimization Of Process Parameters For An Electrically Powered Gari Fryer

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***Abstract*— his work presented optimization of process parameters for an electrically powered gari fryer. A Design Expert (version 11.0.1) software for design of experiments was used to analyse and generate model equations for machine throughput, machine efficiency and material loss. Four different models namely; linear, two factorial interactions (2FI), quadratic and cubic were used to analyse the responses. Specifically, data obtained from the experiments were analysed using Response Surface Methodology (RSM) to fit the quadratic polynomial equation generated by the Design-Expert software (DES). From the optimization process, the optimal frying temperature of 67.920C, frying time of 18.73 min and steering speed of 81.03 rpm were obtained. A test run under the optimal gari frying process conditions was carried out to validate the quadratic model for the Gari Fryer, an experimental machine throughput of 35.18 kg/h, machine efficiency of 77.55% and material loss of 22.13 % were obtained. The correlation between the predicted and the experimental values gave an R2 value of 0.8501 for the machine efficiency, 0.8913 for the machine throughput capacity and 0.9811 for the material loss. Hence, the generated quadratic model has the accuracy to predict the machine throughput, machine efficiency and material loss of the frying process using the developed gari frying machine.**

***Keywords*— Response Surface Methodology, two factorial interactions (2FI) model, quadratic model, Performance Optimization, Gari Fryer**

1. INTRODUCTION

Nigeria is one of the major cassava producers in the world with an average annual production of about 54 million tonnes (Musa, Samuel, Sani and Mari, 2022; Ikuemonisan, Mafimisebi, Ajibefun and Adenegan, 2020; FAO, 2013). However, a lot of the cassava produced in Nigeria are wasted due to poor storage and processing (Afolabi, Leonard, Osei and Blay, 2021; Ihemezie, Agu and Chiemela, 2020). Notably, cassava can be processed into different food and non-food products. Particularly, gari is one of the numerous distinct types of food which can be produced from cassava. Over the years, Nigerians have been using the traditional approach to produce gari from cassava (Musa, Samuel, Sani and Mari, 2022; Ndjouenkeu, Ngoualem Kegah, Teeken, Okoye, Madu, Olaosebikan and Fliedel, 2021; Awoyale, Alamu, Chijioke, Tran, Takam Tchuente, Ndjouenkeu and Maziya-Dixon, 2021). Among, other challenges, the traditional approach is inefficient, is not suitable for industrial scale production of gari and also due to high level of human involvement in the tradition gari production process, the quality of gari produced does not always meet international standard which is essential for export market.

As such, over the years, various gari frying machines have been developed and their performances analysed (Sobowale, Olatidoye, Omosebi and Agbawodike, 2023). The scope of this work is to present optimization of process parameters for an electrically powered gari fryer. Notably, the range of machine factors and frying process conditions such as frying temperature, frying time and stirring speed are considered for the performance test and optimization and experimental were carried out in other to obtain optimal throughput capacity, machine efficiency and material loss when using the electrically powered gari fryer. Remarkably, the development of such improved gari fryer will facilitate more investment in gari processing as it is less labour intensive, economical and safe to use. Also, an electrically powered gari fryer with optimal process parameters can be extended to large scale gari processing which invariably will lead to the growth of nation's economy, create labour and stimulate agricultural production by increasing cassava farming. Moreover, the quality of gari produced by this machine can also facilitate exportation of gari as it is easier to meet the international quality benchmark for gari due to the minimal contact by humans and the high hygienic standards that can be implement with the electrically powered gari fryer.

2. METHODOLOGY

This work is part of a wider study that considered the design, modelling, performance evaluation and optimization of an electrically powered gari fryer. The isometric drawing of the gari fryer as well as the 3D photo realistic rendering using Computer-Aided Design (CAD) tool are shown in Figure 1 and Figure 2. However, the focus of this work is to optimize the performance of the gari fryer.

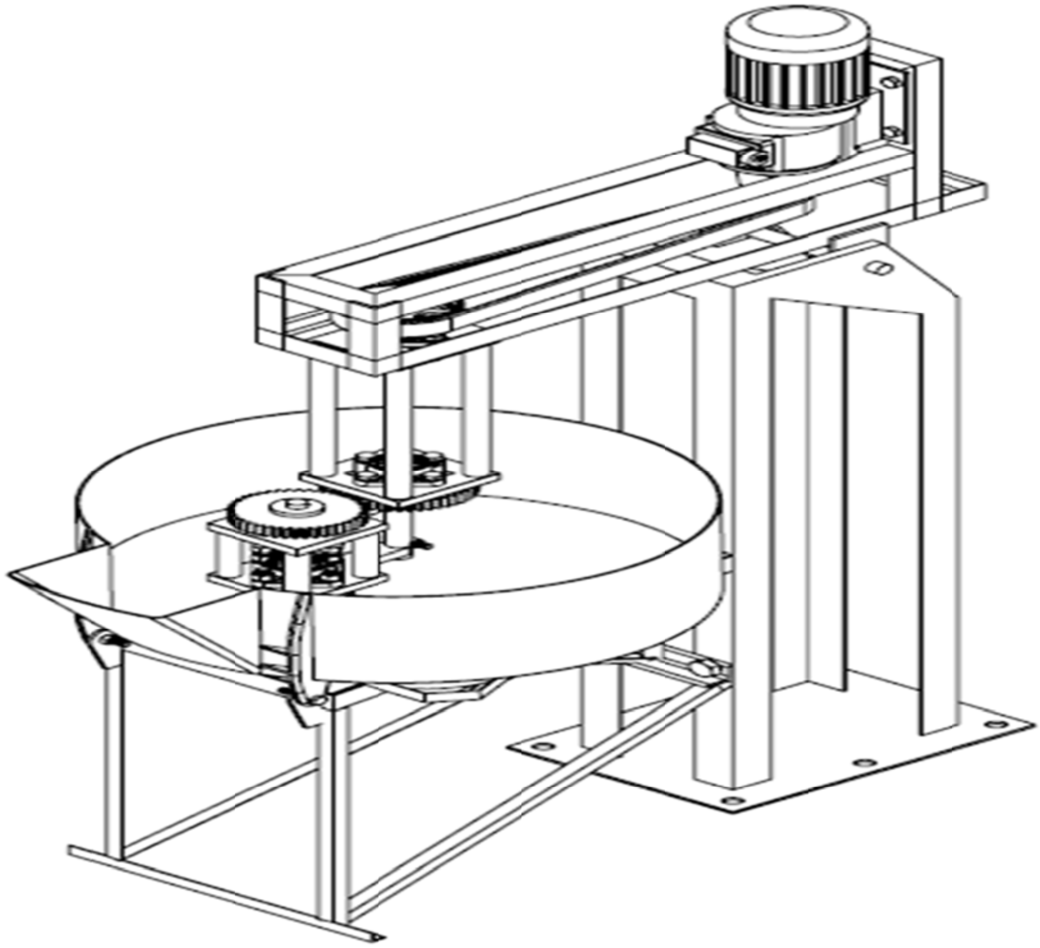

Figure 1 The Computer-Aided Design (CAD) isometric drawing of the gari fryer

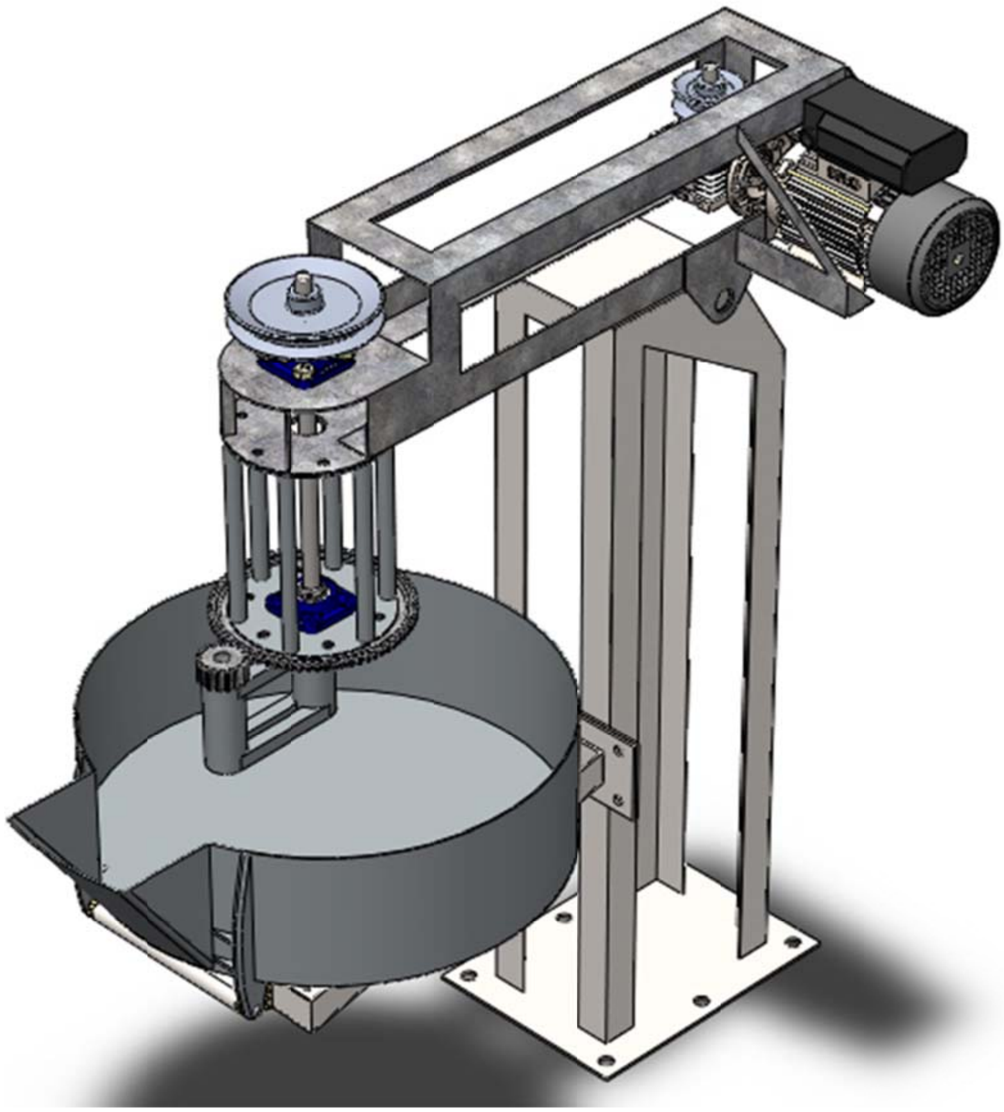

Figure 2 The Computer-Aided Design (CAD) 3D photo realistic rendering of the gari fryer

2.1 Statistical Analysis of the Gari Fryer

The experimental data analysis were conducted using RSM which fitted quadratic polynomial equation generated by the DES version 11.0.1. Also, ANOVA was used ascertain the significance and fitness to multiple regressions fitted on the data. Also, Minitab software was used to conduct statistical analysis on the data obtained to determine the significant difference in the gari frying process and their interactions at a 5% probability level.

2.2 Model Selection for Optimization of the Performance of the of the Gari Fryer

The design of experiments application, DSE package was used to analyse and generate model equations for machine throughput (MT), machine efficiency (ME) and material loss (ML). Four different models namely linear, two factorial interactions (2FI), quadratic and cubic were used to analyse the responses and the models were fitted to the experimental data using DES.

3.0 RESULTS AND DISCUSSION

3.1 Model Selection for Optimization of the Machine Performance using Machine Throughput

The result used for the comparison of the four models (linear, 2FI, quadratic and cubic) for machine throughput during the performance analysis of the Gari Fryer is shown in Table 1. Considering the model with the highest R^2 value and lower standard deviation, a quadratic model was selected to predict the machine throughput capacity using the developed Gari Fryer. The final regression model for machine throughput (MT) is given in Equation 1 as:

$$MT = -35.83 + 2.87F_T - 2.58F_t + 0.309S_S - 0.0199{F_T}^2 + 0.0262{F_t}^2 - 0.00256{S_S}^2 - 0.0052F_TF_t - 0.00055F_TS_S + 0.007F_tS_S \quad (1)$$

Where $MT =$ Machine Throughput, kg/h ; $F_T =$ Frying Temperature, ℃ ; $F_t =$ Frying Time, $min. S_S =$ Steering Speed, rpm. The ANOVA result for the selected model for machine throughput capacity is presented in Table 2, while Table 3 present the test of between-subjects effects of machine parameters on the machine throughput.

Table 1: Model comparison for Throughput Capacity (kg/h)

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	4.14	4.35	0.8145	0.2253
Mean	32.00	32.00	32.00	32.00
C.V.	12.95	13.59	2.55	0.7042
PRESS	428.98	811.51	71.38	NA
R^2	0.8623	0.8834	0.9971	0.9999
Adjusted R^2	0.8305	0.8135	0.9935	0.9995
Predicted R^2	0.7355	0.4995	0.9560	NA$^{(1)}$
Adequate precision	14.8096	11.3970	50.899	168.4278

Table 2: ANOVA for response surface quadratic model for Throughput Capacity (kg/h)

Source of Variation	Sum of Squares	df	Mean Square	F-value	Prob > F
$Model$	1616.92	9	179.66	270.79	< 0.0001
FT	25.56	1	25.56	38.53	0.0004
Ft	1372.62	1	1372.62	2068.87	< 0.0001
SS	0.0903	1	0.0903	0.1361	0.7231
$FT \times Ft$	2.45	1	2.45	3.69	0.0961
$FT \times SS$	0.4422	1	0.4422	0.6665	0.4412
$Ft \times SS$	31.36	1	31.36	47.27	0.0002
FT^2	85.24	1	85.24	128.48	< 0.0001
Ft^2	28.97	1	28.97	43.66	0.0003
SS^2	71.02	1	71.02	107.05	< 0.0001
$Residual$	4.64	7	0.6635		
$Lack\ of\ Fit$	4.44	3	1.48	29.15	0.0035
$Pure\ Error$	0.2031	4	0.0508		
$Cor\ Total$	1621.56	16			

Table 3: Test of between-subject effects of gari frying process conditions on Throughput Capacity (kg/h)

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	1621.359[a]	12	135.113	2660.756	0.0001	1.000
Intercept	13425.690	1	13425.690	264389.333	0.0001	1.000
FT	25.561	1	25.561	503.372	0.0001	0.992
Ft	1372.618	1	1372.618	27030.682	0.0001	1.000
SS	0.090	1	0.090	1.779	0.253	0.308
FT * Ft	2.449	1	2.449	48.232	0.002	0.923
FT * SS	0.442	1	0.442	8.709	0.042	0.685
Ft * SS	31.360	1	31.360	617.566	0.0001	0.994
FT * Ft * SS	0.0001	0	.	.	.	0.0001
Error	.203	4	0.051			
Total	19027.642	17				
Corrected Total	1621.562	16				

a. R Squared = 1.000 (Adjusted R Squared = 0.999)

FT = Frying Temperature (°C); Ft = Frying Time ($min.$); SS = Stirring Speed (rpm)

In Equation 1, the positive terms signify the direct relationship between the gari frying process conditions and their interactions with machine throughput (MT), while the negative terms signify an inverse relationship between them. It was observed that all the oil expression process conditions have a direct relationship with MT. This implies that MT exhibited an increase with the increase in the expression process conditions. Frying time was found to be the most significant parameter which affects MT.

The Model F-value of 270.79 implies that the model is significant. There is only a 0.01% chance that a "Model F-value" this large could occur due to noise. Values of "Prob > F" less than 0.05 indicate model terms are significant. In this case, *FT, Ft, Ft×SS,* FT^2, Ft^2, SS^2 are significant model terms, where *FT, Ft* and *SS* represent frying temperature, frying time and steering speed respectively (Table 2). This implies that the frying temperature, frying time and steering speed all have significant effects on the machine throughput capacity with the frying time having the greatest influence on the machine throughput. Therefore, the three gari frying process conditions influenced the throughput capacity of the cassava cake using the developed Gari Fryer. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may be applied to improve the model. However, that is not necessary for the selected model as there are several significant terms (Table 2).

Also, the "Lack of Fit F-value" of 29.15 (Table 2) implies the Lack of Fit is significant. There is only a 0.35% chance that a "Lack of Fit F-value" this large could occur due to noise. Significant lack of fit is bad as the aim is for the model to fit. ‘‘Adeq Precision’’ measures the signal-to-noise ratio. A ratio greater than 4 is desirable. Therefore, for the Quadratic model, the ‘‘Adeq Precision’’ ratio of 50.899 indicates an adequate signal (Table 4). This model can be used to navigate the design space. The model was significant with a low probability value of < 0.0001 and a satisfactory coefficient of determination, R^2 of 0.9971 (Table 1). The high coefficient of determination showed an excellent correlation between the independent variables (frying temperature, frying time and steering speed). This value indicates that the response (machine throughput capacity) model can explain 99% of the total variability in the response.

The statistical analysis of the two and three factors interaction effects of the independent variable on the throughput capacity of the developed Gari Fryer as presented in Table 3 showed that all the factors and their interactions were significant except that of steering speed. This implies that all the extraction process variables have significant effects on the throughput capacity during the performance test of the machine. This indicates that all the machine and crop parameters (frying temperature, frying time and steering speed) used for the machine performance testing are very important and must be controlled to increase the throughput capacity of the developed Gari Fryer.

3.2 Model Selection for Optimization of the machine performance using Machine Efficiency

The comparison of four models (linear, 2FI, quadratic and cubic) for the machine efficiency during the performance testing of the developed Gari Fryer is shown in Table 4. Considering the model with the highest R^2 value and lower standard deviation, a quadratic model was selected to predict the machine efficiency using the developed gari fryer. The final regression model for machine efficiency (ME) is given in Equation 2 as:

$$ME = -185.87 + 5.65F_T + 3.002F_t + 0.810S_S + 0.00066F_TF_t - 0.00122F_TS_S + 0.0152F_tS_S - 0.041{F_T}^2 - 0.0873{F_t}^2 - 0.00619{S_S}^2 \quad (2)$$

Where $ME =$ Machine Efficiency, % ; $F_T =$ Frying Temperature, ℃ ; $F_t =$ Frying Time, $min. S_S =$ Steering Speed, rpm

The ANOVA for the selected model for machine efficiency of the gari fryer is presented in Table 5, while Table 6 present the test of between-subjects effects of the machine and crop parameters on the frying efficiency of the gari fryer.

Table 4 : Model comparison for Machine Efficiency (%)

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	11.17	11.17	2.00	0.5062
Mean	64.26	64.26	64.26	64.26
C.V.	17.39	17.38	3.11	0.7878
PRESS	2255.34	2960.97	431.38	NA
R^2	0.0000	0.3758	0.9860	0.9995
Adjusted R^2	0.0000	0.0012	0.9681	0.9979
Predicted R^2	-0.1289	-0.4821	0.7841	NA
Adequate precision	NA	3.8473	19.9988	67.0723

Table 5 : ANOVA for response surface quadratic model for Machine Efficiency (%)

Source of Variation	Sum of Squares	df	Mean Square	F-value	Prob > F
$Model$	1969.92	9	218.88	54.94	< 0.0001
FT	99.97	1	99.97	25.09	0.0015
Ft	474.94	1	474.94	119.22	< 0.0001
SS	25.70	1	25.70	6.45	0.0387
$FT \times Ft$	0.0400	1	0.0400	0.0100	0.9230
$FT \times SS$	2.16	1	2.16	0.5424	0.4854
$Ft \times SS$	147.87	1	147.87	37.12	0.0005
FT^2	358.40	1	358.40	89.96	< 0.0001
Ft^2	320.60	1	320.60	80.48	< 0.0001
SS^2	412.34	1	412.34	103.51	< 0.0001
$Residual$	27.89	7	3.98		
$Lack\ of\ Fit$	26.86	3	8.95	34.94	0.0025
$Pure\ Error$	1.03	4	0.2563		
$Cor\ Total$	1997.81	16			

Table 6: Test of between-subject effects of gari frying process conditions on Machine Efficiency (%)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1996.783[a]	12	166.399	649.310	0.0001	0.999
Intercept	50243.185	1	50243.185	196055.664	0.0001	1.000
FT	99.970	1	99.970	390.096	0.0001	0.990
Ft	474.936	1	474.936	1853.265	0.0001	0.998
SS	25.704	1	25.704	100.302	0.001	0.962
FT * Ft	0.040	1	0.040	0.156	0.713	0.038
FT * SS	2.161	1	2.161	8.432	0.044	0.678
Ft * SS	147.866	1	147.866	576.991	0.0001	0.993
FT * Ft * SS	0.0001	0	.	.	.	0.0001
Error	1.025	4	0.256			
Total	72190.292	17				
Corrected Total	1997.808	16				

a. R Squared = 0.999 (Adjusted R Squared = 0.998)

FT = Frying Temperature (°C); Ft = Frying Time ($min.$); SS = Stirring Speed (rpm)

In Equation 2, the positive terms signify the direct relationship between the gari frying process conditions and their interactions with machine efficiency (ME), while the negative terms signify an inverse relationship between them. It was observed that all the gari frying process conditions have a direct relationship with ME. This implies that I exhibited an increase with the increase in the frying process conditions. Frying time was found to be the most significant parameter which affects ME.

The Model F-value of 54.94 (Table 5) implies the model is significant. There is only a 0.01% chance that a "Model F-value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case, FT, Ft, $Ft \times SS$, FT^2, Ft^2, SS^2 are significant model terms, where FT, Ft and SS represent frying temperature, frying time and steering speed respectively (Table 5). This implies that the frying temperature, frying time and steering speed all have significant effects on the machine efficiency with the frying time having the greatest influence on machine efficiency. Therefore, the three gari frying process conditions influenced the machine efficiency of the developed Gari Fryer. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may be employed to improve the model. However, that is not necessary for the selected model as there are several significant terms (Table 5).

The "Lack of Fit F-value" of 34.94 implies the Lack of Fit is not significant relative to the pure error. There is a 0.25% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good as the aim is for the model to fit. ''Adeq Precision'' measures the signal-to-noise ratio. A ratio greater than 4 is desirable. Therefore, the ratio of 19.999 indicates an adequate signal (Table 4). This model can be used to navigate the design space. The model was significant with a very low probability value of < 0.0001 and a satisfactory coefficient of determination, R^2 of 0.9860. The high coefficient of determination showed excellent correlations between the independent variables (frying temperature, frying time and steering speed). This value indicates that the response (machine efficiency) model can explain 98% of the total variability in the response.

3.3 Model Selection for Optimization of the Machine Performance using Material Loss

The comparison of four models (linear, 2FI, quadratic and cubic) for material loss during the performance analysis of the Gari Fryer is shown in Table 7. Considering the model with the highest R^2 value and lower standard deviation, a quadratic model was selected to predict the material loss using the developed Gari Fryer. The final regression model for material loss (ML) is given in Equation 3 as:

$$ML = 285.87 - 5.65F_T - 3.002F_t - 0.810S_S - 0.00067F_TF_t + 0.0012F_TS_S - 0.0152F_tS_S + 0.0410{F_T}^2 + 0.0873{F_t}^2 + 0.00618{S_S}^2 \quad (3)$$

Where $ML =$ Material Loss, %; $F_T =$ Frying Temperature, °C; $F_t =$ Frying Time, $min.$ $S_S =$ Steering Speed, rpm

The ANOVA for the selected model for machine material loss is presented in Table 8, while Table 9 present the test of between-subjects effects of machine parameters on the percentage material loss.

Table 7: Model comparison for Material Loss (%)

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	10.37	11.17	2.00	0.5062
Mean	35.74	35.74	35.74	35.74
C.V.	29.00	31.24	5.58	1.42
PRESS	2095.62	2960.97	431.38	NA
R^2	0.3006	0.3758	0.9860	0.9995
Adjusted R^2	0.1392	0.0012	0.9681	0.9979
Predicted R^2	-0.0490	-0.4821	0.7841	NA[(1)]
Adequate precision	4.4703	3.8473	19.9988	67.0723

Table 8: ANOVA for response surface quadratic model for Material Loss (%)

Source of Variation	Sum of Squares	df	Mean Square	F-value	Prob > F
$Model$	1969.92	9	218.88	54.94	< 0.0001
FT	99.97	1	99.97	25.09	0.0015
Ft	474.94	1	474.94	119.22	< 0.0001
SS	25.70	1	25.70	6.45	0.0387
$FT \times Ft$	0.0400	1	0.0400	0.0100	0.9230
$FT \times SS$	2.16	1	2.16	0.5424	0.4854
$Ft \times SS$	147.87	1	147.87	37.12	0.0005
FT^2	358.40	1	358.40	89.96	< 0.0001
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SS^2	412.34	1	412.34	103.51	< 0.0001
$Residual$	27.89	7	3.98		
$Lack\ of\ Fit$	26.86	3	8.95	34.94	0.0025
$Pure\ Error$	1.03	4	0.2563		
$Cor\ Total$	1997.81	16			

Table 9: Test of between-subject effects of gari frying process conditions on Material Loss

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1996.783[a]	12	166.399	649.310	0.0001	01.999
Intercept	21915.546	1	21915.546	85517.406	0.0001	1.000
FT	99.970	1	99.970	390.096	0.0001	0.990
Ft	474.936	1	474.936	1853.265	0.0001	0.998
SS	25.704	1	25.704	100.302	0.001	0.962
FT * Ft	0.040	1	0.040	0.156	0.713	0.038
FT * SS	2.161	1	2.161	8.432	0.044	0.678
Ft * SS	147.866	1	147.866	576.991	0.0001	0.993
FT * Ft * SS	0.0001	0	.	.	.	0.0001
Error	1.025	4	0.256			
Total	23716.292	17				
Corrected Total	1997.808	16				

a. R Squared = 0.999 (Adjusted R Squared = 0.998)

FT = Frying Temperature (°C); Ft = Frying Time ($min.$); SS = Stirring Speed (rpm)

In Equation 3, the positive terms signify the direct relationship between the gari frying process conditions and their interactions with material loss (ML), while the negative terms signify an inverse relationship between them. It was observed that all the gari frying process conditions have a direct relationship with ML. This implies that ML exhibited an increase with the increase in the frying process conditions. Frying time was found to be the most significant parameter which affects ML.

The Model F-value of 54.94 implies that the model is significant. There is only a 0.01% chance that a "Model F-value" this large could occur due to noise. Values of "Prob > F" less than 0.05 indicate model terms are significant. In this case, FT, Ft, SS, $Ft{\times}SS$, FT^2, Ft^2, SS^2 are significant model terms, where FT, Ft and SS represent frying temperature, frying time and steering speed respectively (Table 8). This implies that the frying temperature, frying time and steering speed all have significant effects on the percentage of material loss during gari frying process with the frying time having the greatest influence on the material loss. Therefore, the three gari frying process conditions influenced the percentage material loss of the cassava cake using the developed gari fryer. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may be applied to improve the model. However, that is not necessary for the selected model as there are several significant terms (Table 8).

The "Lack of Fit F-value" of 34.94 implies the Lack of Fit is significant. There is only a 0.25% chance that a "Lack of Fit F-value" this large could occur due to noise. Significant lack-of-fit is bad as the aim is for the model to fit. ‘‘Adeq Precision’’ measures the signal-to-noise ratio. A ratio greater than 4 is desirable. Therefore, the ratio of 19.999 indicates an adequate signal (Table 7). This model can be used to navigate the design space. The model was significant with a low probability value of < 0.0001 and a satisfactory coefficient of determination, R^2 of 0.9860. The high coefficient of determination showed an excellent correlation between the independent variables (frying temperature, frying time and steering speed). This value indicates that the response (material loss) model can explain 98% of the total variability in the response.

The statistical analysis of the two and three factors interaction effects of the independent variable on the percentage material loss of the developed Gari Fryer as presented in Table 9 showed that all the factors and their interactions were significant except that of steering speed. This implies that all the extraction process variables have significant effects on the throughput capacity during the performance test of the machine. This indicates that all the machine and crop parameters (frying temperature, frying time and steering speed) used for the machine performance testing are very important and must be controlled to reduce the percentage of material loss during the testing process of the developed Gari Fryer.

3.4 Optimization and Validation of the Gari Fryer Performance

The criteria variables were set such that the independent variables (frying temperature, frying time and steering speed) would be within a range or minimum from an economical point of view. The main criteria for constraints optimization were maximum possible machine throughput, maximum machine efficiency and minimum percentage material loss. The desired goals for each process parameter and response is shown in Table 10. To optimize the frying process conditions for the gari frying process by numerical optimization which finds a point that maximizes the desirability function; equal importance of `3' was given to all the three frying process parameters and the responses (MT, ME and ML).

The optimization of the gari frying process conditions; frying temperature, frying time and steering speed was carried out using the numerical technique in RSM (RSM) with the goals as presented in Table 10. The ramp of the optimization process is shown in Figure 3 with optimal gari frying process parameters; the frying temperature of 67.92^{0}C, frying time of 18.73 min and steering speed of 81.03 rpm. On the other hand, the machine throughput, machine efficiency, material loss and desirability of 36.70 kg/h, 76.59 %, 23.40 % and 0.814 respectively were also obtained.

Table 10: Criteria and output for numerical optimization of frying process parameters for the performance analysis of the Gari Fryer

Gari frying criteria	Unit	Lower limit	Upper limit	Optimization Goal	Relative Importance
Frying Temperature	^{o}C	50.00	80.00	Range	3
Frying time	min.	10.00	30.00	Range	3
Steering Speed	rpm	40.00	120.00	Range	3
Machine Throughput	kg/hr	16.86	50.05	Maximize	3
Machine Efficiency	%	47.67	78.12	Maximize	3
Material Loss	%	21.88	52.33	Minimize	3

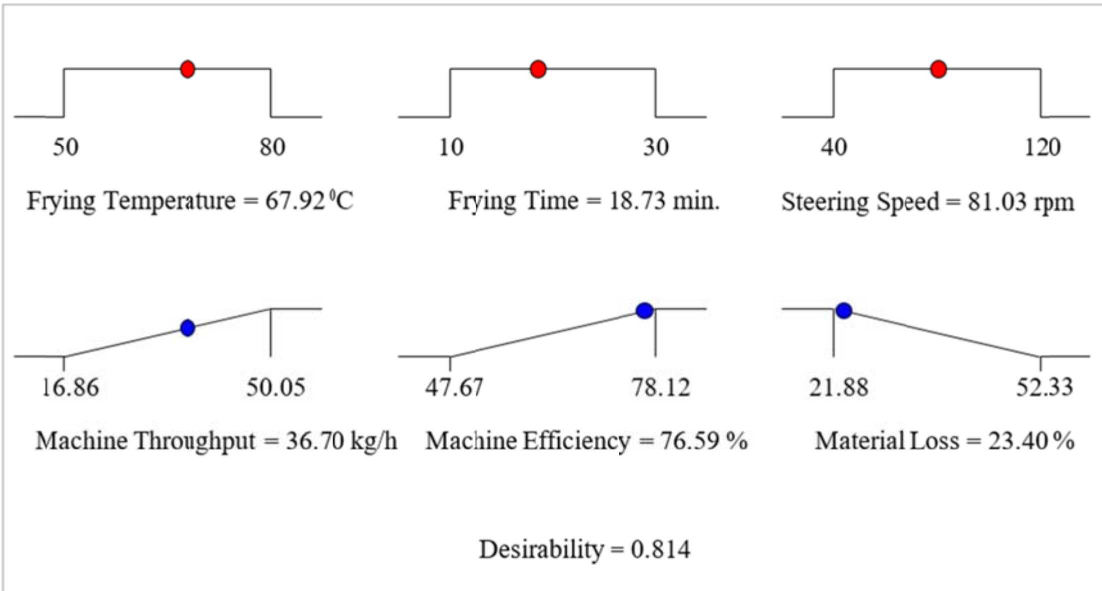

Figure 3: Ramp for optimization of gari frying process conditions for machine throughput, machine efficiency and material loss

3.4.1 Optimization and Validation of the Machine Performance for Machine Throughput

The optimization result for the determination of the optimum value of the machine throughput for the gari frying process during the performance testing of the developed Gari Fryer is shown in Figure 3. From the optimization result for the maximum optimum predicted values in the range of 50 – 80 ^{o}C for frying temperature, 10 – 30 min for frying time and 40 – 120 rpm for steering speed, the predicted optimum machine throughput of 36.70 kg/h and desirability of 81.4 % at optimal frying temperature of 67.92^{0}C, frying time of 18.73 min and steering speed of 81.03 rpm was obtained.

A test run under the obtained optimal gari frying process conditions of a frying temperature of 67.92^{0}C, frying time of 18.73 min and steering speed of 81.03 rpm respectively, was carried out to validate the quadratic model for MT of the developed Gari Fryer, an experimental MT of 35.18 kg/h was obtained. In a comparison of the predicted and experimental results for the optimum MT, it can be seen that there was an excellent agreement between the experimental and predicted values for the machine throughput was obtained from the parity plot between the predicted and the actual values as shown in Figure 4.The correlation between the predicted and experimental values for the machine throughput capacity gave an R^2 value of 0.8913 which indicated that the predicted values and experimental values have a reasonable agreement. The deviation between predicted and experimental values is low and ranged between 0.01 – 0.40. Hence, the generated quadratic model has the accuracy to predict the MT of the frying process using the developed Gari Fryer.

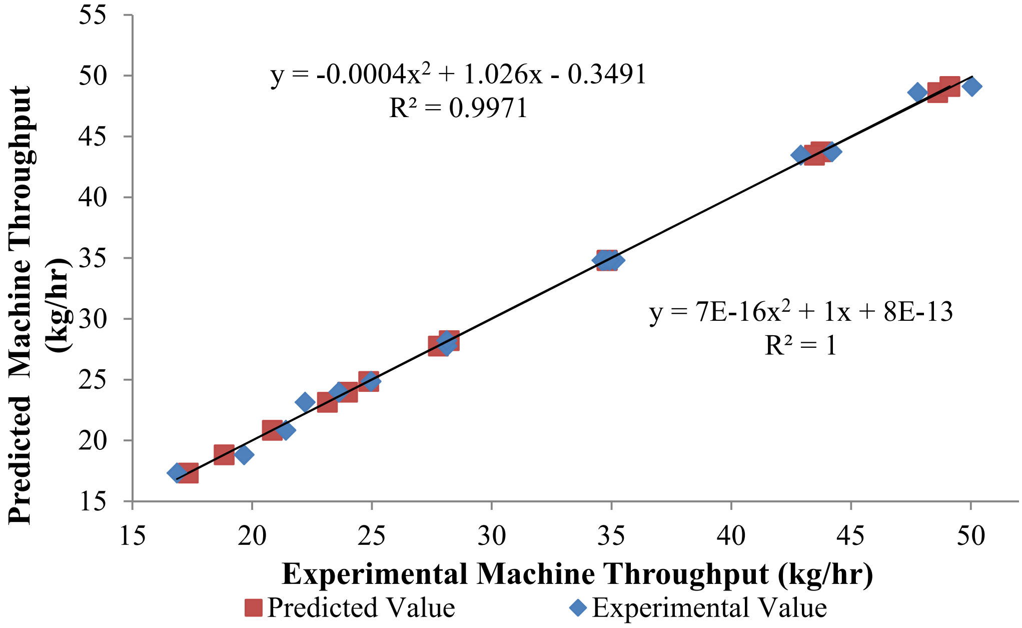

Figure 4: Comparison of the predicted and experimental values for the machine throughput

3.4.2 Optimization and Validation of the Machine Performance for Machine Efficiency

The optimization result for the determination of the optimum value of the machine efficiency (ME) for the gari frying process during the performance test of the developed frying machine is shown in Figure 5. From the optimization result for the maximum optimum predicted values in the range of 50 – 80 °C for frying temperature, 10 – 30 min for frying time and 40 – 120 rpm for steering speed, the predicted optimum machine efficiency of 76.59 % and desirability of 81.4 % at optimal frying temperature of 67.92^{0}C, frying time of 18.73 min and steering speed of 81.03 rpm was obtained.

A test run under the obtained optimal gari frying process conditions of a frying temperature of 67.92^{0}C, frying time of 18.73 min and steering speed of 81.03 rpm respectively, was carried out to validate the quadratic model for ME of the developed Gari Fryer, an experimental ME of 77.55% was obtained.

In a comparison of the predicted and experimental results for the optimum ME, it can be seen that there was an excellent agreement between the experimental and predicted values for the machine efficiency was obtained from the parity plot between the predicted and the actual values as shown in Figure 3.The correlation between the predicted and experimental values for the machine efficiency gave an R^2 value of 0.8501 which indicated that the predicted values and experimental values have a reasonable agreement. The deviation between predicted and experimental values is low and ranged between 0.01 – 0.60. Hence, the generated quadratic model has the accuracy to predict the ME of fried gari using the developed frying machine.

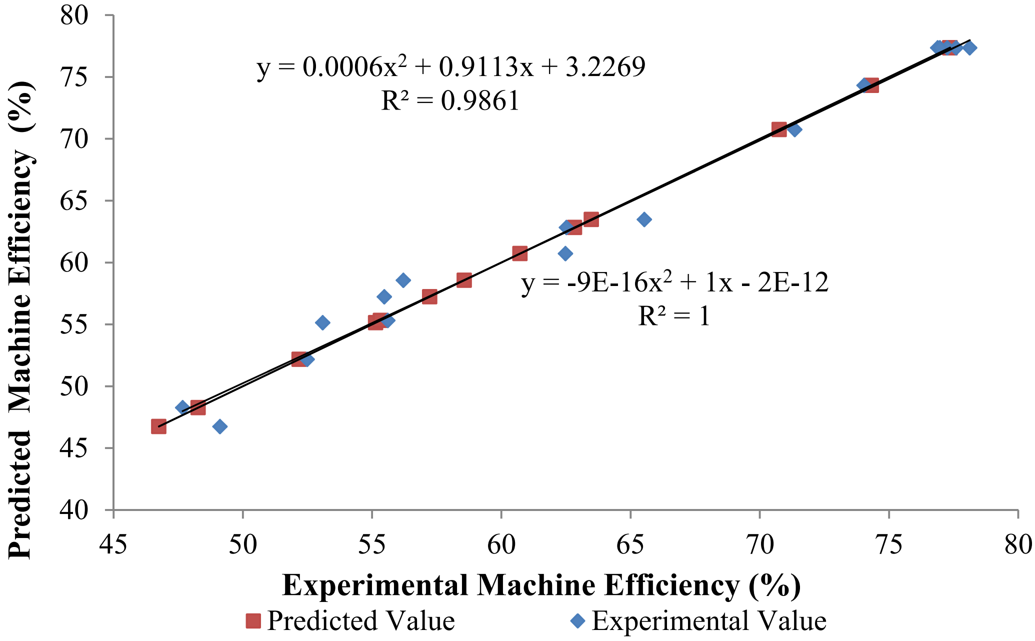

Figure 5: Comparison of the predicted and experimental values for the machine efficiency

3.4.3 Optimization and Validation of the Machine Performance for Material Loss

The optimization result for the determination of the optimum value of the material loss for the gari frying process during the performance testing of the developed Gari Fryer is shown in Figure 6. From the optimization result for the minimum optimum predicted values in the range of 50 – 80 °C for frying temperature, 10 – 30 min for frying time and 40 – 120 rpm for steering speed, the predicted optimum material loss of 23.40 % and desirability of 81.4 % at optimal frying temperature of 67.92^{0}C, frying time of 18.73 min and steering speed of 81.03 rpm was obtained.

A test run under the obtained optimal gari frying process conditions of a frying temperature of 67.92^{0}C, frying time of 18.73 min and steering speed of 81.03 rpm respectively, was carried out to validate the quadratic model for ML of the developed Gari Fryer, an experimental ML of 22.13 % was obtained. In a comparison of the predicted and experimental results for the optimum ML, it can be seen that there was an excellent agreement between the experimental and predicted values for the percentage material loss was obtained from the parity plot between the predicted and the actual values as shown in Figure 6.The correlation between the predicted and experimental values for the material loss gave an R^2 value of 0.9811 which indicated that the predicted values and experimental values have a reasonable agreement. The deviation between predicted and experimental values is low and ranged between 0.01 – 1.40. Hence, the generated quadratic model has the accuracy to predict the ML of the frying process using the developed Gari Fryer.

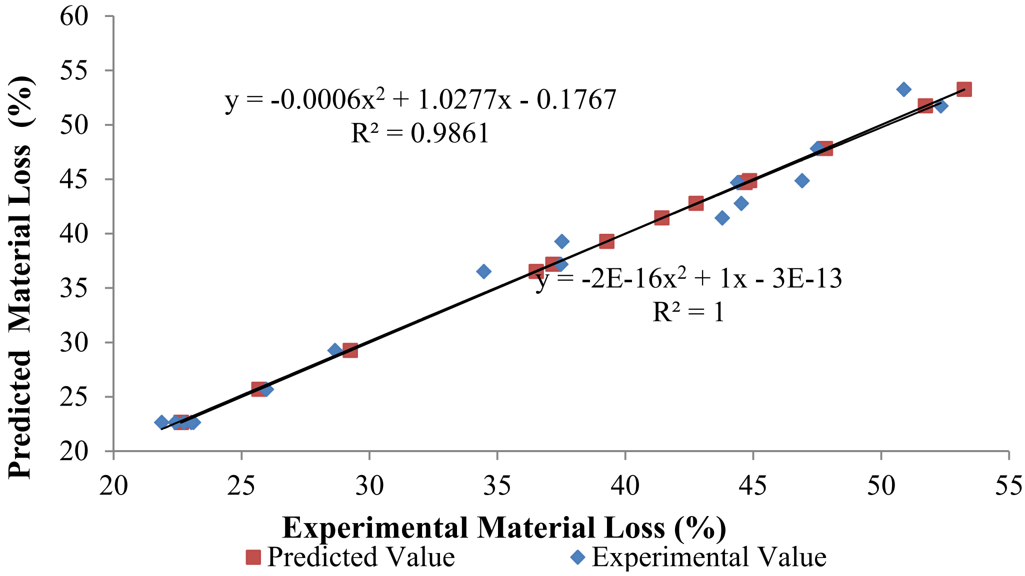

Figure 6: Comparison of the predicted and experimental values for the material loss

4. CONCLUSION

The optimization of a gari fryer process parameters is presented. The three parameters considered are machine throughput, machine efficiency and material loss. Design Expert software package was used to analyse and generate model equations the three parameters. Four different models namely linear, two factorial interactions (2FI), quadratic and cubic were used to analyse the responses and the models were fitted to the experimental data using DES. Specifically, the quadratic polynomial equation generated by the DES version was used for the optimisation process. From the optimization process, the optimal frying temperature of 67.92^0C, frying time of 18.73 min and steering speed of 81.03 rpm were obtained and the correlation between the predicted and the experimental values gave an R^2 values of above 0.85 for each of the three parameters. Hence, the generated quadratic model has the accuracy to predict the machine throughput, machine efficiency and material loss of the frying process using the developed gari frying machine.

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