Performance Evaluation Of Gari Frying Machine

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Abstract— **In this work, performance evaluation of gari frying machine is presented. The major component parts of the gari frying machine include frying pot, electric heater, steering arms, geared electric motor, main frame, rotary frame, contactors, toothed pulley, roller bearing and control panel. A 3×3 Box Behnken Design of response surface methodology was adopted for the machine performance test experiments. Based on preliminary tests and literature, performance of the machine was evaluated at three levels of frying temperature, (50, 65 and 80℃); frying time, (10, 20 and 30 mins.); and steering speed, (40, 80 and 120 rpm) to determine the best machine throughput, machine efficiency and percentage material loss. Analysis of variance (ANOVA) for the effects of frying temperature, frying time and steering speed on throughput capacity indicate that the p-value for the frying temperature, frying time and steering speed are 0.001, 0.0001 and 0.006 respectively. Since the p-values for the selected gari frying process variables are less than the chosen α-level of 0.05, it implies that the effects of frying temperature, frying time and steering speed on the throughput capacity of gari frying machine are statistically significant. Similarly, ANOVA for the effects of frying temperature, frying time and steering speed on machine efficiency indicate that the p-values for the frying temperature, frying time and steering speed are 0.002, 0.0001 and 0.002 respectively. The p-values implies that the effects of frying temperature, frying time and steering speed on the efficiency of gari frying machine are statistically significant. Finally, the ANOVA for the effects of frying temperature, frying time and steering speed on the amount of material loss indicate that the p-value for the frying temperature, frying time and steering speed are 0.002, 0.0001 and 0.002 respectively. Again, the p-values result signifies that the effects of frying temperature, frying time and steering speed on the material loss of gari using are statistically significant.**

Keywords— Performance Evaluation, ANOVA ,Material Loss, Gari Frying Machine, Box Behnken Design, Throughput Capacity, response surface methodology , Functional Efficiency

1. INTRODUCTION

According to Food and Agriculture Organization (FAO), Nigeria produces about 54 million metric tons (MT) every year (FAO, 2013). However, in the international markets, Nigeria is not actively involved in cassava trade because most of her cassava is aimed at the domestic food market (Awoyemi, Adesokan, Kayode, Omotesho and Osasona, 2020; Ikuemonisan, Mafimisebi, Ajibefun and Adenegan, 2020; Onyenwok. and Simonyan, 2014). The prevailing cassava production approaches are crude and therefore needs to be modernised to facilitate production to industrial scale (FAO, 2013). Cassava roots has many applications to which is can be processed (Clearinghouse, 2022; Udoro, 2021; IITA 2012).

It is not possible to store fresh cassava roots for long as they rot within 48 h of harvest. They are voluminous with a humidity content of about 70% (Pornpraipech, Khusakul, Singklin, Sarabhorn and Areeprasert, 2017; Morgan and Choct, 2016; Kolawole, Agbetoye and Ogunlowo, 2011; Hahn, 1994). Cassava must therefore be processed in multiple forms to boost product shelf life, promote transportation and marketing, decrease the content of cyanide and enhance palatability. The nutritional content of cassava can also be made better through fortification with other protein-rich crops. Processing decreases food losses and stabilizes the crop's supply against seasonal changes. Cassava roots are traditionally processed into countless products using different techniques and used according to local customs and preferences in different ways (Onyenwoke and Simonyan, 2014; Hahn, 1994). The processing methods are not suitable for instrial scale production (Onyenwoke and Simonyan, 2014).

In any case, the traditional methods of cassava processing into gari has many challenges and they a limited in the quantity and quality of gari that can be produced. As such, gari frying machine has been designed as a viable solution. Accordingly, this work is focused on the performance evaluation of gari frying machine. The key variables that affect the quality of gari produced are identified and analyzed in the process of evaluating the machine's performance. In all, this work is essential as it provides requisite data and insights for optimal selection of the machine operating parameters.

2. METHODOLOGY

The focus in this work is to conduct performance evaluation of a gari frying machine. The major component parts of the gari frying machine include frying pot, electric heater, steering arms, geared electric motor, main frame, rotary frame, contactors, toothed pulley, roller bearing and control panel. Notably, some variables which affect the quality of gari produced are identified and analyzed in the process of evaluating the machine's performance. The following identified performance indicators were studied and statistically analyzed; throughput capacity, functional efficiency and material loss during frying (Sobowale, Adebiyi, & Adebo, 2016).

2.1 Throughput Capacity

The throughput capacity of the designed gari frying machine is the amount of gari processed by the machine over time. Specifically, it is the mass of gari in kilogram obtained from the machine per hour. Mathematically, the throughput capacity is given as;

$$C_T = \frac{M_O}{T} \quad (1)$$

Where C_T = Throughput Capacity in kg/hr; M_O = Output mass of gari from the machine in kilograms; and T = Time in hours

To evaluate the throughput capacity of the machine, a stopwatch was used to time the operation of the machine from the start of the operation to the end of operation after which the total mass of output gari from the machine was measured using and weighing scale. This process was repeated ten (10) times after which the average of these values was calculated. The average values were inserted into the equation above and calculated to obtain a throughput capacity.

2.2 Functional Efficiency

The functional efficiency of the machine designed was evaluated as the ratio of output to input as given in Equation 2.

$$F_E = \frac{M_O}{M_F} \times 100 \quad (2)$$

Where F_E = Functional efficiency of the machine; M_O = Output mass of gari from the machine in kilograms *and* M_F = Input mass of gari in kilograms

2.3 Material Loss

Material loss during frying operation here translates to moisture removal and is determined by subtracting the output mass of gari from the input mass. To evaluate the fraction of material loss, the difference in mass obtained is further divided by the input mass of gari.

Mathematically, the material loss is given as;

$$M_L = \frac{M_F - M_O}{M_F} \times 100 \quad (3)$$

Where M_L = Material loss during operation, M_O = Output mass of gari from the machine in kilogramsandM_F = Input mass of gari in kilograms.

2.4 Experimental Design

The testing of the gari fryer was conducted using the design-Expert software. The three-level-three factor Box Behnken Design (BBD) of response surface methodology (RSM) with 17 (i.e. $2^k + 2k + n$) test runs were performed for fermented sifted cassava cake. Frying temperature, frying time and steering speed were selected as independent factors for the machine performance test. The selection of the levels for the machine performance conditions was based on preliminary experiments and literature in which 3 levels each of frying temperature, f_T (50, 65 and 80^{0}C); frying time, f_t (10, 20 and 30 mins.); and steering speed, s_s (40, 80 and 120 rpm) were chosen.

The coded and actual values of the levels of the machine performance conditions are presented in Table 1, while the experimental setup for the independent variables is presented in Table 2. The coded values were designated by –2 (minimum), −1, 0 (centre), +1, +2 (maximum).

Table 1: Coded and actual values of different machine performance variables for the Gari Fryer

Factors	Unit	Code	Level		
			-1	0	1
Frying Temperature	°C	X_1	50	65	80
Frying Time	min	X_2	10	20	30
Steering Speed	rpm	X_3	40	80	120

Table 2: Experimental matrix transformation at various interactions of the machine performance test conditions

Runs Order	Coded factors			Actual factors		
	X_1	X_2	X_3	Temperature (℃)	Frying Time (min)	Steering Speed (rpm)
1	-1.000	0.000	1.000	50	20	120
2	0.000	0.000	0.000	65	20	80
3	1.000	0.000	1.000	80	20	120
4	0.000	0.000	0.000	65	20	80
5	0.000	0.000	0.000	65	20	80
6	1.000	-1.000	0.000	80	10	80
7	1.000	1.000	0.000	80	30	80
8	1.000	0.000	-1.000	80	20	40
9	0.000	0.000	0.000	65	20	80
10	0.000	-1.000	-1.000	65	10	40
11	0.000	-1.000	1.000	65	10	120
12	0.000	1.000	1.000	65	30	120
13	-1.000	0.000	-1.000	50	20	40
14	-1.000	1.000	0.000	50	30	80
15	0.000	0.000	0.000	65	20	80
16	-1.000	-1.000	0.000	50	10	80
17	0.000	1.000	-1.000	65	30	40

2.4.1 Sample Preparation

Freshly harvested cassava tubers were manually peeled, washed to rid them of dirt, grated into the mash and stored in the receptacle. It was allowed to ferment for 2 days. The cassava mash was then transferred from the storage tank to porous bags which allowed the water to sip off. The bagged cassava mash was mechanically pressed to remove water to desired moisture content wet basis and sifted mechanically to remove lumps. A randomized design was used with three replicates.

The variables used in the experimental design included the moisture content, the stirring speed of the stirrer, and frying temperature. All these parameters were varied to find the optimum operating parameters which will give the lowest frying time with the highest quality of output gari.

It is necessary to reduce the moisture content to the acceptable range when processing cassava roots into HQCF and this must be done quickly to avoid lowering product quality (Onyenwoke and Simonyan, 2014). Keeping other parameters constant, the moisture content of the cassava mash fed into the gari frying machine was varied between 40% and 54%. Eight samples, each of 5 kg mass were collected from the mechanical press at a different but regular time interval to obtain samples with varying moisture content. The samples were collected and tested for moisture content using a drying oven and balance after which the average moisture content of each sample was recorded as shown in Table 3. The gari was fried till moisture content of 10% to 12% was achieved. This was the moisture final moisture content of each sample marked as acceptable for high-quality gari. The time duration for achieving a 10% to 12% moisture content was recorded.

2.4.2 Moisture Content

Table 3: Moisture Content of Samples

Sample No.	1	2	3	4	5	6	7	8
Moisture content	53.64	50.37	47.74	44.53	42.21	41.91	41.08	40.30

2.4.3 Steering Speed

To evaluate the effect of steering speed on the performance of the gari frying machine to further reduce the time of frying, the mash sample which gave the shortest time duration based on moisture content was fried at three (3) different speeds (40, 80 and 120rpm) to evaluate performance based on frying time. The experiment was repeated with sample no.8 at two speeds lower than the initial speed used in experiment no.1 and two speeds higher than that used in experiment no.1.

2.4.4 Frying Temperature

The frying temperature was varied to obtain the optimum frying temperature was varied between 40 and 100 degrees Celsius. For this experiment, five (5) different run was conducted, at 40, 55, 70, 85, and 100 degrees Celsius. For each run, 5 kg of cassava mash with approximately 40% moisture content was fried at the different temperatures to evaluate the best temperature at which the shortest frying time is achieved with high quality of gari.

3.0 RESULTS OF THE MACHINE PERFORMANCE TEST

The experimental results of the performance test analysis of the developed gari frying machine are presented in Table 3.The average summary of the machine performance results at the various gari frying process conditions and machine parameter combinations using 3 factors, 3 levels, factorial Central Composite Rotatable Design (CCRD) of Response Surface Methodology (RSM) is presented in Table 4. Notably, Table 4 shows the result for the machine capacity, efficiency and material loss of a gari frying machine at various levels combination of frying temperature, frying time and steering speed.

Table 3: Experimental matrix transformation at various interactions of the machine performance test conditions

Runs Order	Actual factors			WWC (kg) W_{wc}	WDG (kg) W_{dg}	Responses		
	FT (°C)	Ft (min)	SS (rpm)			Throughput Capacity (kg/h) $TP_C = \frac{W_{dg}}{Frying\ Time\ (h)}$	Machine Efficiency (%) $M_E = \frac{W_{dg}}{W_{wc}} \times 100$	Material Loss (%) $M_L = \frac{W_{wc} - W_{dg}}{W_{wc}} \times 100$
1	50	20	120	1.5	0.832	24.96	55.47	44.53
2	65	20	80	1.5	1.172	35.15	78.12	21.88
3	80	20	120	1.5	0.938	28.13	62.52	37.48
4	65	20	80	1.5	1.153	34.60	76.88	23.12
5	65	20	80	1.5	1.159	34.76	77.25	22.75
6	80	10	80	1.5	0.796	47.78	53.09	46.91
7	80	30	80	1.5	1.070	21.41	71.35	28.65
8	80	20	40	1.5	0.937	28.12	62.48	37.52
9	65	20	80	1.5	1.155	34.64	76.97	23.03
10	65	10	40	1.5	0.834	50.05	55.61	44.39
11	65	10	120	1.5	0.737	44.20	49.11	50.89
12	65	30	120	1.5	1.110	22.21	74.03	25.97
13	50	20	40	1.5	0.787	23.62	52.49	47.51
14	50	30	80	1.5	0.983	19.66	65.53	34.47
15	65	20	80	1.5	1.164	34.92	77.59	22.41
16	50	10	80	1.5	0.715	42.90	47.67	52.33
17	65	30	40	1.5	0.843	16.86	56.21	43.79

FT = Frying Temperature ; Ft = Frying Time; SS = Stirring Speed; WWC = Weight of wet cake and WDG = Weight of dried garri

Table 4: Machine capacity, Efficiency and Material loss of a gari fryer at various frying processes Conditions

Runs Order	Frying Temperature (°C)	Frying Time (min)	Steering Speed (rpm)	Throughput Capacity (kg/h)	Machine Efficiency (%)	Material Loss (%)
1	50	20	120	24.96	55.47	44.53
2	65	20	80	35.15	78.12	21.88
3	80	20	120	28.13	62.52	37.48
4	65	20	80	34.60	76.88	23.12
5	65	20	80	34.76	77.25	22.75
6	80	10	80	47.78	53.09	46.91
7	80	30	80	21.41	71.35	28.65
8	80	20	40	28.12	62.48	37.52
9	65	20	80	34.64	76.97	23.03
10	65	10	40	50.05	55.61	44.39
11	65	10	120	44.20	49.11	50.89
12	65	30	120	22.21	74.03	25.97

13	50	20	40	23.62	52.49	47.51
14	50	30	80	19.66	65.53	34.47
15	65	20	80	34.92	77.59	22.41
16	50	10	80	42.90	47.67	52.33
17	65	30	40	16.86	56.21	43.79

3.1 Effects of gari frying process conditions on Machine Throughput

The throughput capacity of the gari frying machine ranges from 16.86 to 50.05 kg/h (Table 4). This compares favourably with the maximum throughput capacities of other developed gari frying machines by Gbabo, Oyebamiji and Gana (2020), Ajayi, Olukunle and Dauda (2014), Sobowale, Adebiyi and Adebo (2014), Adegbite, Asiru, Salami, Nwaeche, Ebun and Ogunbiyi (2019), amongst others. Figure 1, Figure 2 and Figure 3 show the effects of gari frying process conditions on the throughput capacity.

In Figure 4, an increase in frying time leads to a decrease in the throughput capacity, while the increase in frying temperature leads to a corresponding increase in the throughput. A similar trend was reported by Gbabo *et al.* (2020) while working on the Design, Fabrication and Testing of a Horizontal Gari Fryer and Ajayi*et al.*(2014) while working on Performance evaluation of an automated gari fryer.

In Figure 5, an increase in steering speed with frying time leads to a corresponding increase in the machine throughput capacity, and then the throughput decreases at higher frying temperatures. Overall, the maximum throughput capacity of the machine of 50.05 kg/h was obtained at a frying temperature of 65°C, frying time of 10 min and steering speed of 40 rpm.

In Figure 3, an increase in steering speed with frying time leads to a corresponding increase in the throughput; however, at higher frying time, throughput decreases.

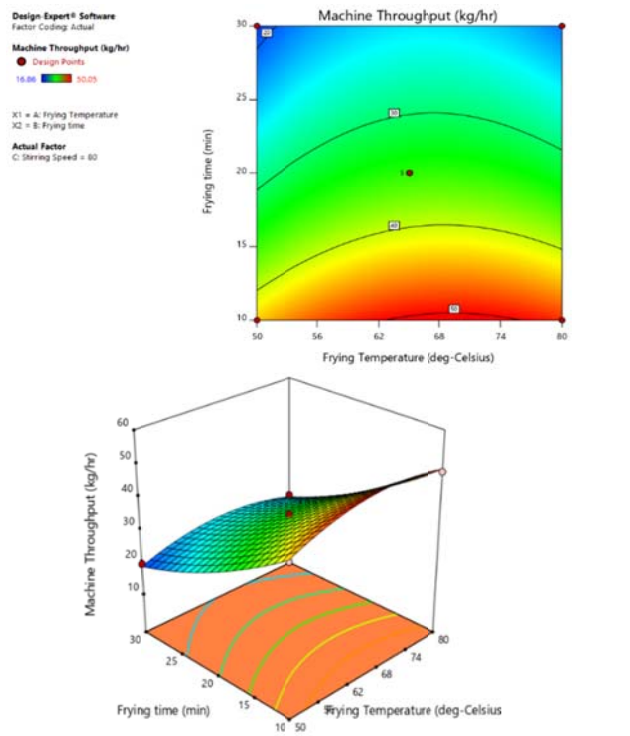

Figure 1: Contour and response surface plots of frying time and frying temperature on Throughput Capacity

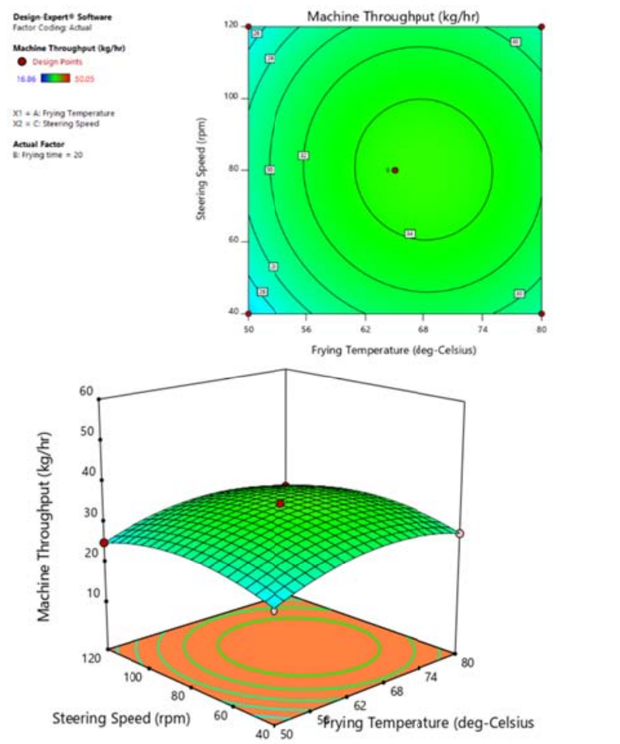

Figure 2: Contour and response surface plot of steering speed and frying temperature on Throughput Capacity

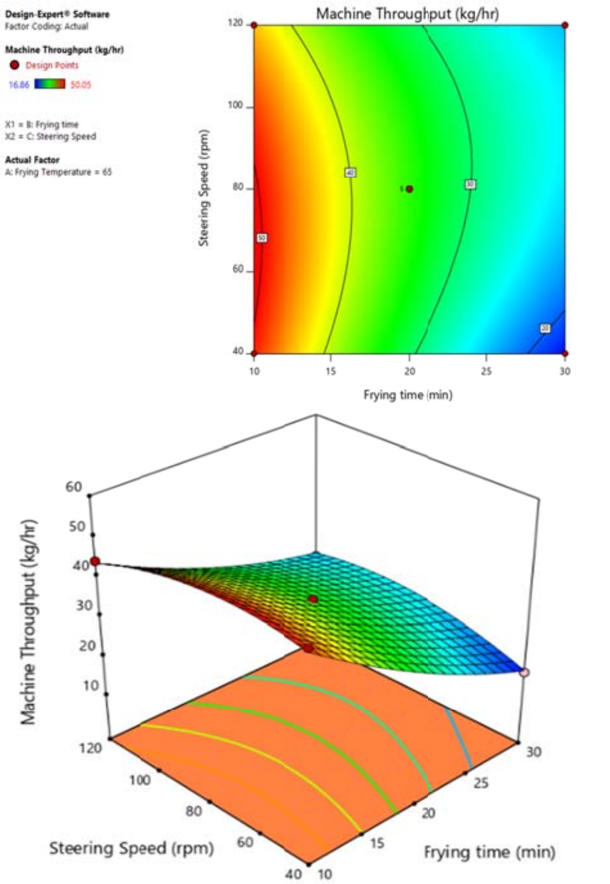

Figure 3: Contour and response surface plot of steering speed and frying time on throughput Capacity

3.1.1 Frying Temperature on Machine Throughput

An increase in frying temperature from 50 – 80 °C at frying time of 20 mins and steering speed of 40 rpm increases throughput capacity by 16%; while the increase in frying temperature from 50 – 80 °C at frying time of 10 mins and steering speed of 80 rpm increases throughput capacity by 10.21%. Similarly, an increase in frying temperature from 50 – 80 °C at frying time of 30 mins and machine steering speed of 80 rpm increases throughput capacity by 8.17%; while, increase in frying temperature from 50 – 80 °C at frying time of 20 mins and steering speed of 120 rpm increases throughput capacity by 11.27%.

3.1.2 Frying Time on Machine Throughput

An increase in frying time from 10-30 mins at a frying temperature of 50°C and steering speed of 80 rpm decreases the machine throughput by 54.17%; while the increase in the frying time from 10-30 mins at a frying temperature of 65°C and steering speed of 40 rpm decreases the throughput by 66.71%. Also, an increase in frying time from 10-30 mins at a frying temperature of 65°C and steering speed of 120 rpm decreases machine throughput by 49.75%; while the increase in frying time from 10-30 mins at a frying temperature of 80°C and steering speed of 80 rpm decreases throughput by 55.19%.

3.1.3 Steering Speed on Machine Throughput

An increase in machine steering speed from 40-120 rpm at a frying temperature of 65°C and frying time of 10 mins decreases the machine throughput by 11.69%; while the increase in the steering speed from 40-120 rpm at a frying temperature of 50°C and frying time of 20 mins increases throughput by 5.37%. Similarly, an increase in the steering speed from 40-120 rpm at a frying temperature of 80°C and frying time of 20 mins increases the machine throughput by 0.04%. Also, an increase in the steering speed from 40-120 rpm at a frying temperature of 65°C and frying time of 30 mins increases throughput by 24.09%.

Analysis of variance (ANOVA) for the effects of frying temperature, frying time and steering speed on throughput capacity is presented in Table 5. The results indicate that the *p*-value for the frying temperature, frying time and steering speed are 0.001, 0.0001 and 0.006 (Table 5) respectively. Since the *p*-values for gari frying process variables (frying temperature, frying time and steering speed) are less than the chosen α-level of 0.05. It implies that the effects of frying temperature, frying time and steering speed on the throughput capacity of gari frying machine are statistically significant.

Table 5: ANOVA for the Effects of gari frying conditions on Throughput Capacity (kg/h)

Source	DF	Sum of Square	Mean Square	F-Value	P-Value
Frying Temperature (°C)	2	110.81	55.403	14.24	0.001
Frying Time (min)	2	1401.59	700.793	180.17	0.0001
Stirring Speed (rpm)	2	71.11	35.556	9.14	0.006
Error	10	38.90	3.890		
Lack-of-Fit	6	38.69	6.449	126.99	0.0001
Pure Error	4	0.20	0.051		
Total	16	1621.56			

3.2 Effects of Gari Frying process conditions on Machine Efficiency

The efficiency of the gari frying machine ranges from 47.67 to 78.12% (Table 4). Figure 4, Figure 5 and Figure 6 show the effects of gari frying process conditions on machine efficiency. This compares favourably with the maximum efficiencies of other developed gari frying machines by Nwadinobi, Edeh and Mejeh (2019), Ogbuka and Odo (2018), Gbasouzor and Maduabum (2012), Olagoke, Olawale and Mohammed (2014), Ejiko, Oigbochie and Emmanuel (2019), amongst others.

In Figure 4, an increase in frying time and frying temperature leads to a corresponding increase in machine

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efficiency. However, at higher temperatures and prolonged frying time, the machine efficiency decreased. A similar trend was reported by Nwadinobi *et al.* (2019) while working on the design and development of a vertical paddle semi-automated gari frying machine, by Olagoke *et al.* (2014) while working on performance evaluation of an automated gari fryer, and Ejiko *et al.*(2019) while working on the design of a semi mechanize gari fryer

In Figure 5, an increase in steering speed with frying time leads to a corresponding increase in the machine efficiency, and then the efficiency decreases at higher frying temperatures. Heating the samples at prolonged times makes the seed tissues soft with a consequent reduction in moisture. Overall, the maximum machine efficiency of the machine of 78.12% was obtained at a frying temperature of 65^{o}C, frying time of 20 min and steering speed of 80 rpm. In Figure 6, an increase in steering speed with frying time leads to a corresponding increase in the machine efficiency; however, at higher frying time and increased steering speed, the machine efficiency decreases.

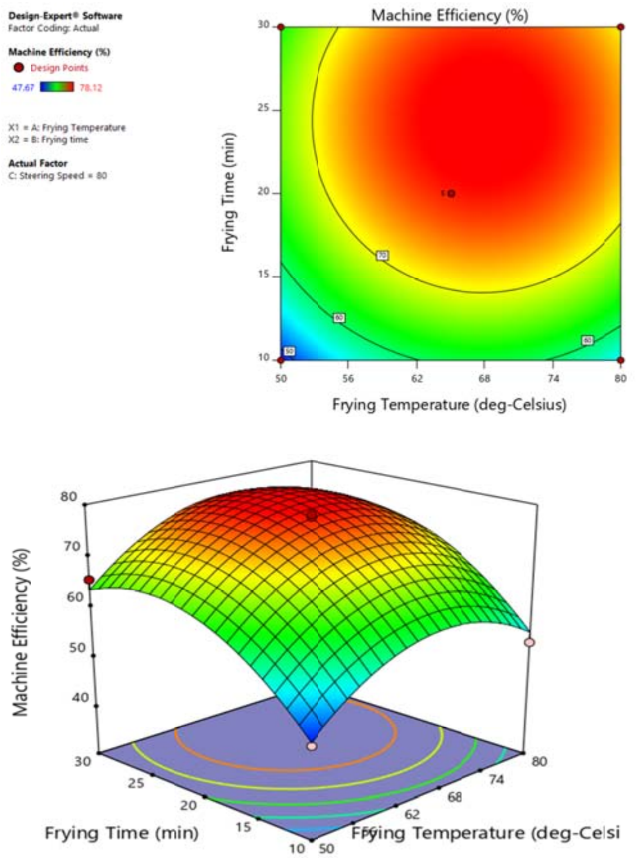

Figure 4: Contour and response surface plots of frying time and frying temperature on Machine Efficiency

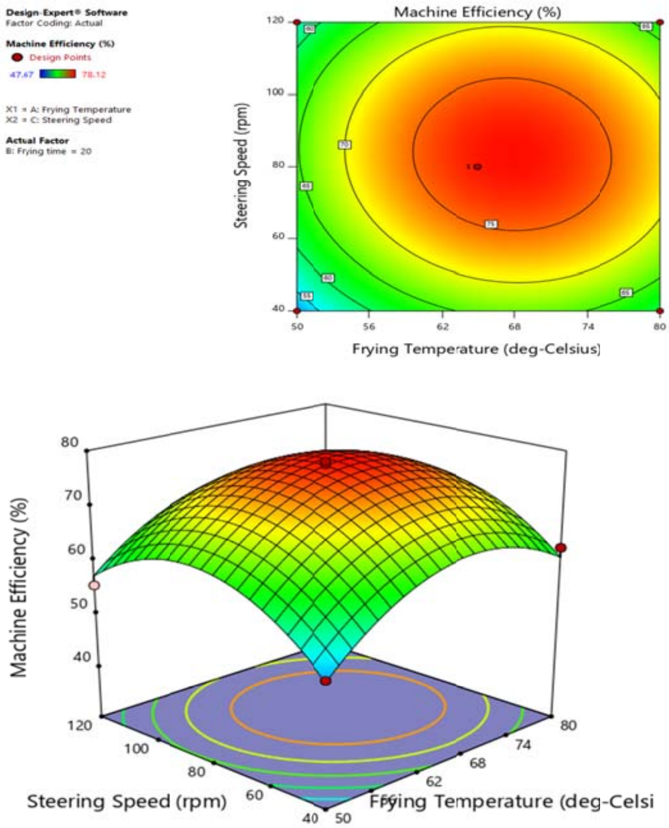

Figure 5: Contour and response surface plot of steering speed and frying temperature onMachine Efficiency

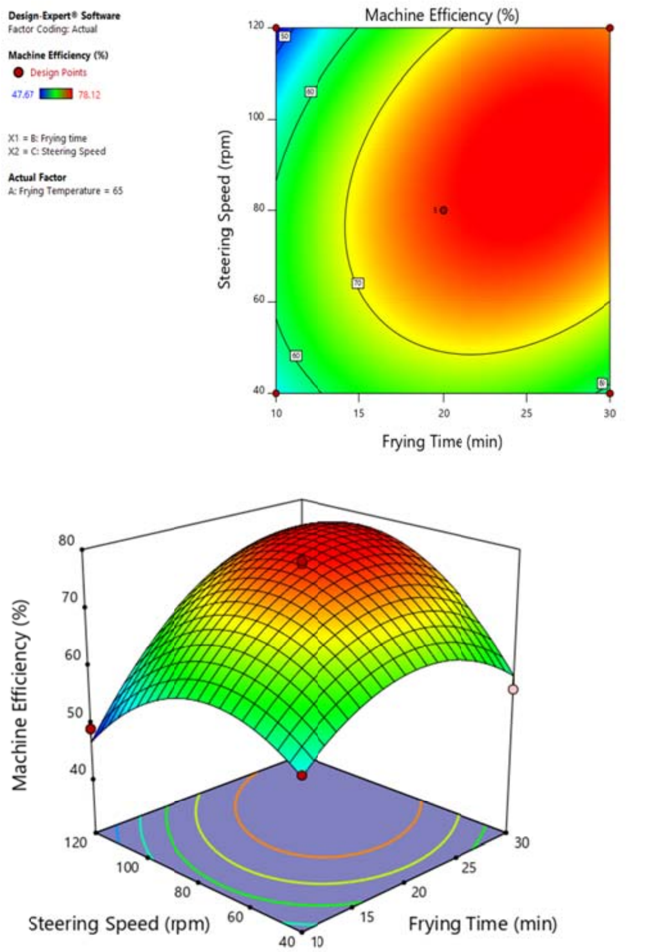

Figure 6: Contour and response surface plot of steering speed and frying time on machine efficiency

3.2.1 Frying Temperature on Machine Efficiency

Increase in frying temperature from 50 – 80 °C at frying time of 20 mins and steering speed of 40 rpm increases, the machine efficiency by 15.99%; while the increase in frying temperature from 50 – 80 °C at frying time of 10 mins and steering speed of 80 rpm increases efficiency by 10.21%. Similarly, an increase in frying temperature from 50 – 80 °C at frying time of 30 mins and machine steering speed of 80 rpm increases machine efficiency by 8.16%; while, increase in frying temperature from 50 – 80 °C at frying time of 20 mins and steering speed of 120 rpm increases efficiency by 11.28%. The trend in the results are similar to those obtained by Oti, Nwankwojike, Onuoha and Onuoha (2017); Oti, Olapeju, Dohou, Moutairou, Nankagninou, Komlaga and Loueke(2010) and Oti and Obi (2016).

3.2.2 Frying Time on Machine Efficiency

An increase in frying time from 10 – 30 mins at a frying temperature of 50°C and steering speed of 80 rpm increases the machine efficiency by 27.25%; while the increase in the frying time from 10 – 30 mins at a frying temperature of 65°C and steering speed of 40 rpm increases the efficiency by 1.07%. Also, an increase in frying time from 10 – 30 mins at a frying temperature of 65°C and steering speed of 120 rpm increases machine efficiency by 33.66%; while the increase in frying time from 10 – 30 mins at a frying temperature of 80°C and steering speed of 80 rpm increases efficiency by 25.59%.

3.2.3 Steering Speed on Machine Efficiency

An increase in machine steering speed from 40 – 120 rpm at a frying temperature of 65°C and frying time of 10 mins decreases the machine efficiency by 11.26%; while the increase in the steering speed from 40 – 120 rpm at a frying temperature of 50°C and frying time of 20 mins increases efficiency by 5.37%. Similarly, an increase in the steering speed from 40 – 120 rpm at a frying temperature of 80°C and frying time of 20 mins increases the machine efficiency by 0.06%. Also, an increase in the steering speed from 40 – 120 rpm at a frying temperature of 65°C and frying time of 30 mins increases efficiency by 24.07%.

Analysis of variance (ANOVA) for the effects of frying temperature, frying time and steering speed on machine efficiency is presented in Table 6. The results indicate that the *p*-values for the frying temperature, frying time and steering speed are 0.002, 0.0001 and 0.002 (Table 6) respectively. Since the *p*-values for gari frying process variables (frying temperature, frying time and steering speed) are less than the chosen α-level of 0.05, it implies that the effects of frying temperature, frying time and steering speed on the efficiency of gari frying machine are statistically significant.

Table 6: ANOVA for the Effects of gari frying conditions on Machine Efficiency (%)

Source	DF	Sum of Square	Mean Square	F-Value	P-Value
Frying Temperature (°C)	2	458.37	229.183	12.88	0.002
Frying Time (min)	2	795.54	397.769	22.35	0.0001
Stirring Speed (rpm)	2	438.04	219.022	12.31	0.002
Error	10	177.95	17.795		
Lack-of-Fit	6	176.93	29.488	115.07	0.0001
Pure Error	4	1.03	0.256		
Total	16	1997.81			

3.3 Effects of Gari Frying process conditions on Material Loss

The material loss recorded during the gari frying experiments using the machine ranges from 21.88 to 52.33% (Table 4). Figure 7, Figure 8 and Figure 9 show the effects of gari frying process conditions on material loss. This compares favourably with the percentage material losses of other developed gari frying machines of Owuamanam, Oguke, Achinewhu and Barimalaa (2011), Akinnuli, Osueke, Ikubanni, Agboola and Adediran (2015), amongst others.

In Figure 4.7, an increase in frying time and frying temperature leads to a decrease in the amount of material loss, but with a further increase in frying temperature and frying time, there was a corresponding increase in the material loss.

In Figure 8, an increase in steering speed with frying time leads to a corresponding decrease in the amount of material loss, and then the material loss decreases at higher frying temperature and steering speed. Overall, the minimum amount of material loss during the machine performance evaluation experiment of 21.88% was obtained at a frying temperature of 65°C, frying time of 20 min and steering speed of 80 rpm. In Figure 9, an increase in steering speed with frying time leads to a corresponding decrease in the material loss; however, at higher frying time and steering speed, the amount of material loss further increased.

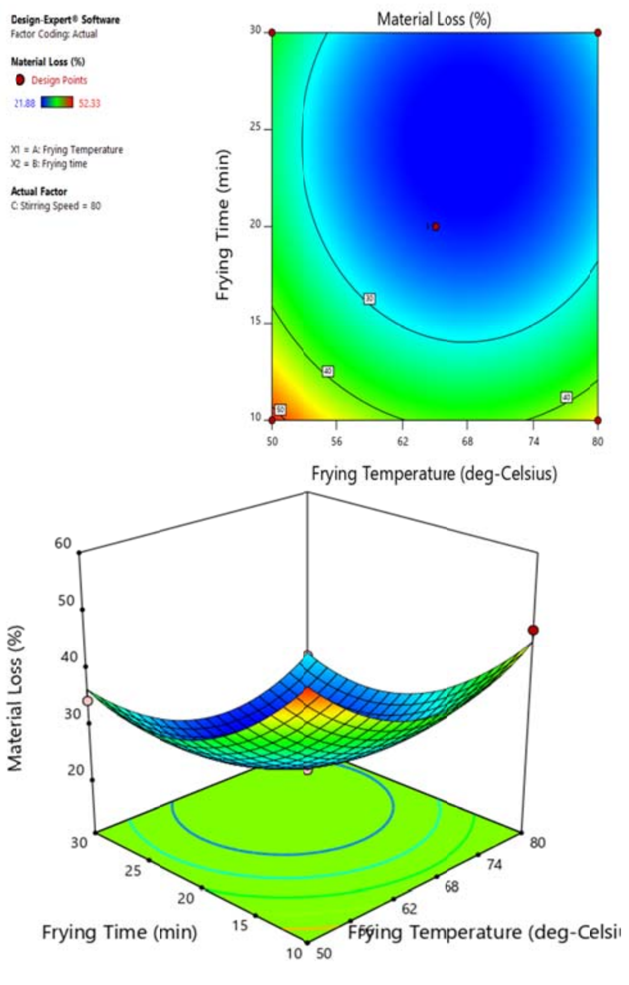

Figure 7: Contour and response surface plots of frying time and frying temperature on Material Loss

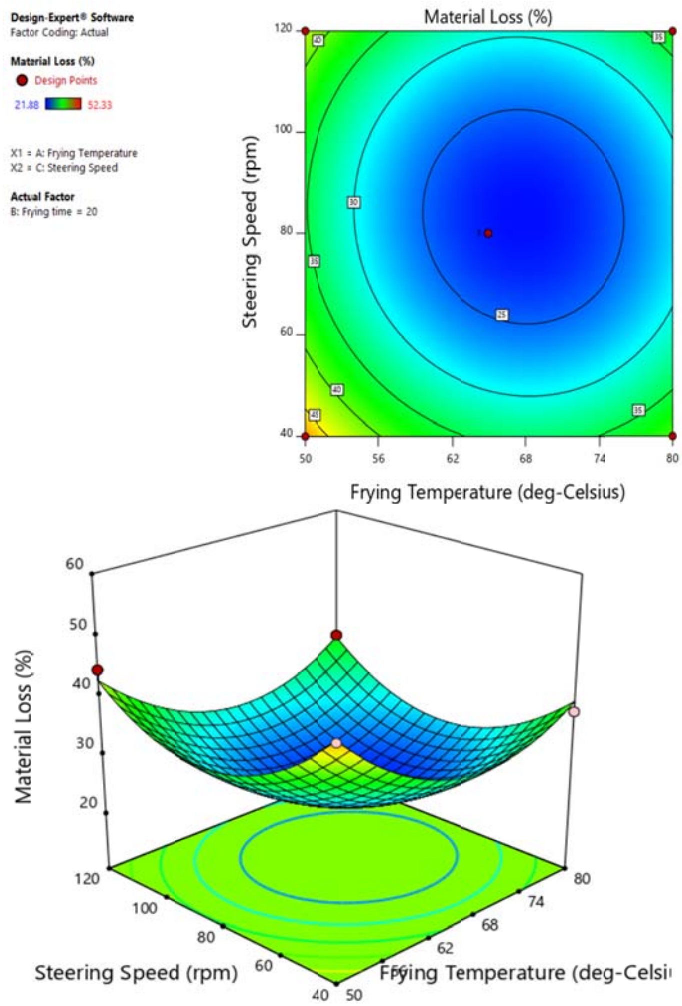

Figure 8: Contour and response surface plot of steering speed and frying temperature on Material Loss

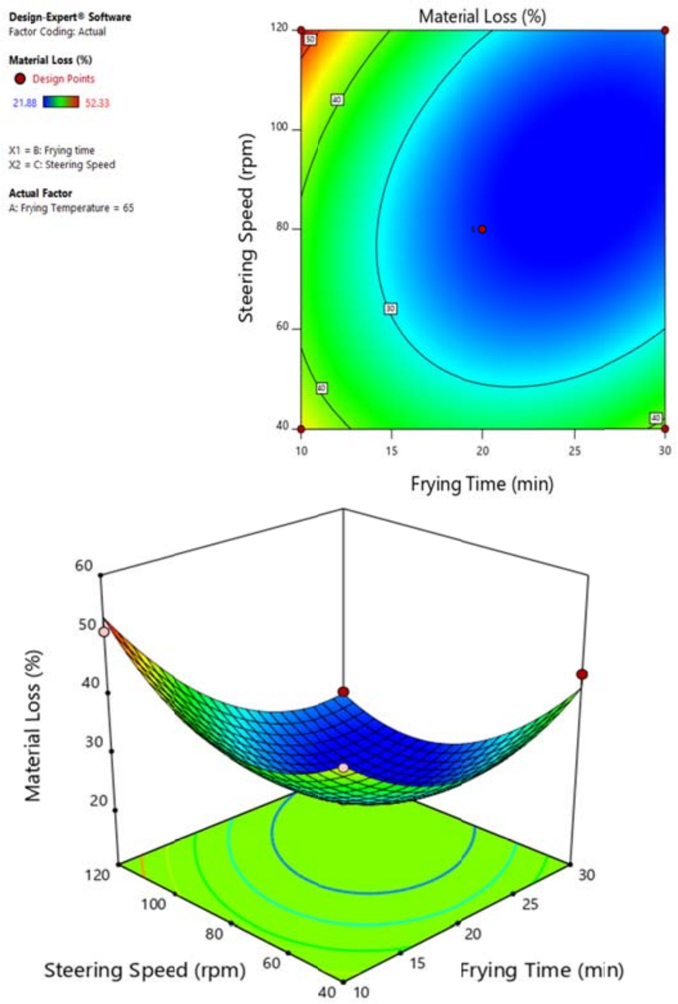

Figure 9: Contour and response surface plot of steering speed and frying time on Material Loss

3.3.1 Frying Temperature on Material Loss

An increase in frying temperature from 50 – 80 °C at frying time of 20 mins and steering speed of 40 rpm decreased the amount of material loss by 21.03%; while the increase in frying temperature from 50 – 80 °C at frying time of 10 mins and steering speed of 80 rpm decreases material loss by 10.36%. Similarly, an increase in frying temperature from 50 – 80 °C at frying time of 30 mins and machine steering speed of 80 rpm lead to a decrease in the material loss by 16.88%; while, increase in frying temperature from 50 – 80 °C at frying time of 20 mins and steering speed of 120 rpm further decreased the amount of material loss by 15.83%.

3.3.2 Frying Time on Material Loss

An increase in frying time from 10 – 30 mins at a frying temperature of 50°C and steering speed of 80 rpm decreases the material loss by 34.13%; while the increase in the frying time from 10 – 30 mins at a frying temperature of 65°C and steering speed of 40 rpm decreases the amount of material loss by 1.35%. Also, an increase in frying time from 10 – 30 mins at a frying temperature of 65°C and steering speed of 120 rpm decreases material loss by 48.97%; while the increase in frying time from 10 – 30 mins at a frying temperature of 80°C and steering speed of 80 rpm decreases the amount of material loss by 38.93%.

3.3.3 Steering Speed on Material Loss

An increase in machine steering speed from 40 – 120 rpm at a frying temperature of 65°C and frying time of 10 mins decreases the amount of material loss by 12.77%; while the increase in the steering speed from 40 – 120 rpm at a frying temperature of 50°C and frying time of 20 mins decreases material loss by 6.27%. Similarly, an increase in the steering speed from 40 – 120 rpm at a frying temperature of 80°C and frying time of 20 mins decreases the amount of material loss by 0.11%. Also, an increase in the steering speed from 40 – 120 rpm at a frying temperature of 65°C and frying time of 30 mins decreases material loss by 40.69%.

Analysis of variance (ANOVA) for the effects of frying temperature, frying time and steering speed on the amount of material loss is presented in Table 7. The results indicate that the *p*-value for the frying temperature, frying time and steering speed are 0.002, 0.0001 and 0.002 (Table 7) respectively. Since the *p*-values for garifrying process variables (frying temperature, frying time and steering speed) are less than the chosen α-level of 0.05 , this signifies that the effects of frying temperature, frying time and steering speed on the material loss of gari using the developed frying machine are statistically significant.

Table 7: ANOVA for the Effects of gari frying conditions on Material Loss (%)

Source	DF	Sum of Square	Mean Square	F-Value	P-Value
Frying Temperature (°C)	2	458.37	229.183	12.88	0.002
Frying Time (min)	2	795.54	397.769	22.35	0.0001
Stirring Speed (rpm)	2	438.04	219.022	12.31	0.002
Error	10	177.95	17.795		
Lack-of-Fit	6	176.93	29.488	115.07	0.0001
Pure Error	4	1.03	0.256		
Total	16	1997.81			

4. CONCLUSION

Gari frying machine performance can be affected by a number of factors. This work presents an approach for performance evaluation of a gari frying machine which has the following major component parts: frying pot, electric heater, steering arms, geared electric motor, main frame, rotary frame, contactors, toothed pulley, roller bearing and control panel. Specifically, throughput capacity, functional efficiency and material loss during frying are variables which are identified and analyzed in the process of evaluating the machine's performance. In all, the evaluation results and discussions are useful for optimal selection of the machine operating parameters.

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