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Improving the Groundnut Oil Extraction Efficiency using RSM and Central Composite Design (CCD) Optimization Techniques

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Abstract

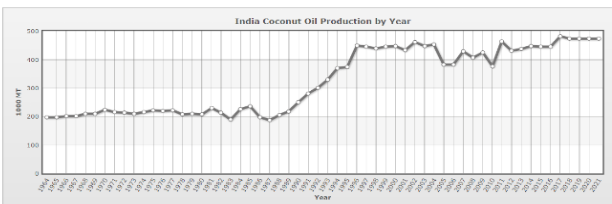
Extracting groundnut oil from the groundnut seeds without modifying its quality become a critical task nowadays. This study utilized direct press method to extract groundnut oil from the seeds, then second-order response surface methodology (RSM) experiment is employed in conjunction with a five-level factorial Central Composite Design (CCD) for optimization. The interactions between the process factors are investigated, including pressure (A), groundnut size (B), Steam flow rate (C) and time (D). At a pressure of 80 MPa, a peanut size of 0.33 mm, a steam flow rate of 10 kg/h, and a time of 75 minutes, the maximum oil extraction efficiency of 55% is reached. Similarly, Saponification factor of 198 is reached at a pressure of 80 MPa, groundnut size of 0.3 mm, steam flow rate of 10 kg/h and a period of 60 minutes, whereas Iodine value 98 is achieved at a pressure of 80 MPa, groundnut size of 3 mm, steam flow rate of 10 kg/h and time of 75 minutes. The experimental R^2 results show that the surface model prediction model is highly accurate, with an R^2 value of 0.98. Overall, RSM in conjunction with the CCD will assist in identifying the critical operational parameters for extracting oil using a press type extraction equipment. The weighted K nearest neighbouring algorithm is also used in this work to predict the oil extraction efficiency (target output) based on the training data sets of pressure, groundnut size, Steam flow rate and time as input factors.

Keywords: Ground nut seed; Oil extraction; RSM method; Iodine value; Saponification factor

1. Introduction

The most common oil nut is groundnut seed (Arachis hypogea), often known as peanut or earthnut, which is farmed as an annual crop on around 19 Million hectares of land in tropical, sub-tropical and warm temperature regions of the world [1]. One of the country's most significant sources of edible oil become the groundnut (Arachis hypogaea) which is a legume. The groundnut is one of the oil seeds that ranks as the world's second most valuable commodity. Groundnut seed edible oil (approximately 53%) includes up to 36% protein and 15% carbohydrate, as well as several critical elements including vitamin E, vitamin B, salt, calcium, potassium, phosphorus, magnesium, thiamine, and zinc. It is primarily produced for its cooking oil purpose and protein-rich seeds, which are the primary reasons for its cultivation. Depending on the type, the oil content ranges from 45-55%. Oil extraction, expelling, or expressing is used to extract the oil out from the groundnut seed [2][3]. Some of the methods of extracting oil from groundnut seed and other oil-bearing biological materials are mechanical, chemical and traditional method [4]. In mechanical and traditional methods, sufficient pressure would be applied either manually or with the use of specialized powered machine/equipment (screw press, hydraulic press, Ghani press and so on) in order to rupture the oil cells in the oil-bearing materials, thus leading to liberation of needed oil. Chemical method involves the use of special solvents that are capable of dissolving the oil in oil cells when they come in contact with oil bearing materials[5],[6]. The process of oil extraction is usually preceded with some form of pre-treatment operations (heat treatment, size reduction and moisture content adjustment); and variation of other process parameters like pressure, speed of machine, time of pre-treatment, type of machine and type of feed stock. The essence is to be able to get maximum oil yield and extraction efficiency, and minimum extraction loss coupled with oil of acceptable qualities after extraction [7],[8],[9].

Traditionally, INDIA is the 4th largest oil consumption country in the world. From the past experience, the growth of consumption and the production of oil has been increased gradually. The consumption and the production rate as follow, which are invariably the same to one another [10][11].



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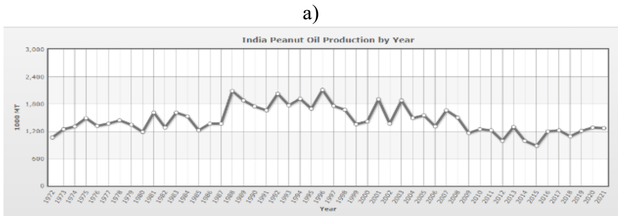

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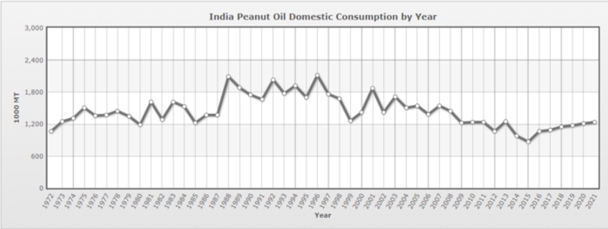

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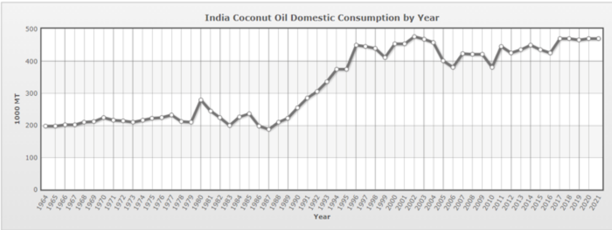


d)

Fig. 1. Oil consumption until 2021. a) India Peanut oil production until 2021 [12], b) India Coconut oil production until 2021, c) India Peanut oil Consumption until 2021 and d) India Coconut oil Consumption until 2021

Figure 1a, b,c and d shows the oil consumption rate which increases year by year due to increase in population. The extraction methods of edible oil play a major role in increasing production and oil quality. With the increase in production rate say 450 tonnes in 2021 year approximately the same amount has been consumed [13]. As the groundnut oil consumption rate increases on the other hand suitable high performance oil extraction methods have been increasing. At recent times, the machineries used to extract the oil is processed by supplementing with additives and at high temperature, which result in loss of odour and other benefactor properties of oil moreover, it can extract the 99% of the actual outcome though with reduced nutrition content, which leads us to depend on other countries for machineries. Different types of edible oil extraction machines and its performances are detailed below.

Indigenous method (Traditional Domestic Methods) is one of the oldest methods, where the seeds are soaked inside the water, it is allowed to boil and let it cool down over a time period to separate the oil and fat contents. From this method, only 40% of the oil is separated from the water-oil emulsion, to enhance the separation rate, salt is used for the proper separation as a catalyst. This is also known as the aqueous extraction method [3]. The extraction of oil through refinery process uses temperature that go up to 230°C and chemical solvents are used to extract nearly 99% of oil from seed. So, normally the natural nutrients are lost, properties of the oils are altered, oil is deodorized to make it smell like what is not expected. The rotary type extraction takes more time and energy to extract the oil [14].

Semi-Automatic coconut oil press machine is used for minimum oil extraction process. This machine is mechanically operated, but the speciality is that, the oil seeds are compressed to express the oil when the screw is rotated to plunge out the oil from the cylindrical bay through large number of small holes which will be collected in a drum. Enzyme Assisted Aqueous Extraction by cold press is one of the modern technologies by which the production rate has been increased by 27% approximately but the fact is that, the usage of enzymes results in the loss of the ingenuous property of the extracted oil [15]. The automatic hydraulic oil press machine is one of the most advanced equipment and it is considered as the best choice instead of hand-operated mechanism. This design is not applicable for higher pressure and high loading capacity. It is considered to be the most efficient method among all the traditional methods and also even the new methods which has emerged. The only drawback is that it requires rigid support so that it will be immobilized, which enhances the pressure generation, moreover the fluid used shouldn't come in contact with the food particles else it will be toxic [16] [17]. The main challenge in the hydraulic press is to provide a closed loop control mechanism with respect to pressure applied to the press, temperature, pre heating the ground nut seed with steam and holding time of the hydraulic press with respect to the quality and quantity of oil extraction. The central composite design (CCD) technique is one of the methods practiced in order to study the effect of the Fenton's peroxidation on the removal of organic pollutants from wastewater of olive oil production [2]. This paper focuses on optimizing the parameters involved in oil extraction efficiency using DOE (Design of Experts) [18 - 25] by considering the influencing input parameters such as size of the groundnut used, quatity of groundnut used in one cycle, temperature before and after processing of groundnut, hydraulic pressure applied through controller and time duration for one cycle. Similarly the output parameters such as extraction efficiency of the groundnut oil, safonification value of the extracted oil (which is one of the important quality measurement parameter) are optimized with Central Composite Design (CCD) design method also with advanced machine learning models[21][22][26].

2.Materials and Methods

This schematic diagram shown in Figure 2 is the modification made to the proposed design, which is fabricated and controlled by PLC with a feedback mechanism to properly express pressure greater than 50 MPa Pressure. The set-up is designed in such a way that a pulverisation unit is fixed before the raw materials are loaded into the main unit where the hydraulic press plays a major role. When the raw material is pulverised, it is the more effective way for extracting oil without any additives or heat treatments

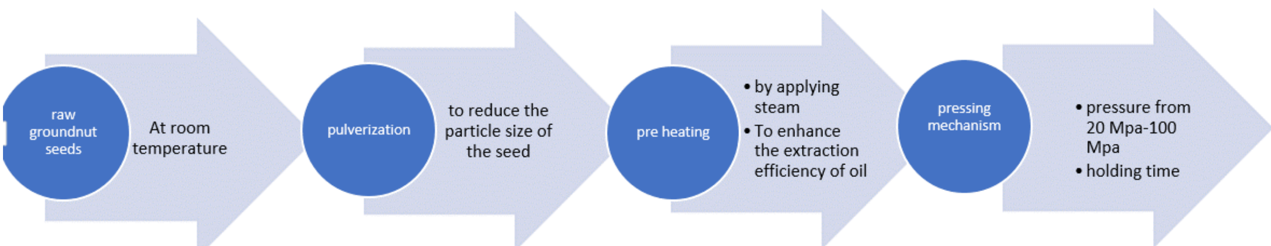
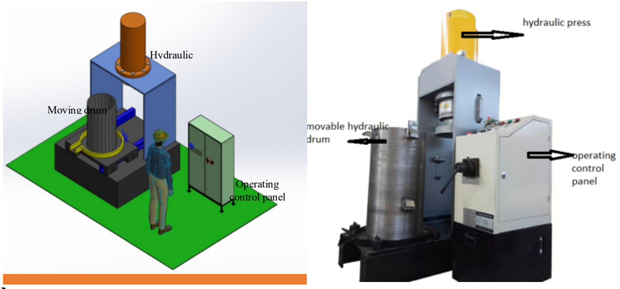


Fig. 2. Schematic flowchart for the sequences of process involved in oil extraction

Design, Modification and Fabrication of Hydraulic Press for Oil Extraction



`**Fig. 3**. Schematic diagram for the Hydraulic press for oil extraction

Figure 3a and b shows the schematic diagram of the designed extraction machine. 50 kg to 100 kg capacity of oil seeds are preloaded into the cylinder barrel. Control mechanism is used to apply the pressure on the hydraulic press (with the capacity of 10-50 MPa), so that the hydraulic cylinder arrangement starts come down. Based on the appropriate automatic regulated pressure, the extraction of oil is coming down as shown in the Figure 3.

The pulverized groundnut seeds transferred via a hopper into the cylindrical chamber ready for the hydraulic press. This hydraulic press will extract nearly 100% of the oil from the oilseeds, where the end product will be the debris cake which should be dry, leaving without any oil or fat content in it. The oil extracted through direct press will have a high nutrient value as compared to the existing extraction process.

Fig. 4. Control unit and oil extraction through moving hydraulic drum

For the improvement of oil extraction efficiency, a pulverizing unit was used for grinding the raw material at initial stage. In existing machine, pressure applied on the hydraulic machine (upto 30 MPa) is not sufficient and hence hydraulic press needs modification with respect to pressure applied to hydraulic press, quality and quantity of oil produced and raw materials used like sesame seeds, groundnut seeds and coconut. Figure 4 shows the experimental set up which has been tested from extraction of oil through manually operated hydraulic press which exceeds more than 20 MPa to produce natural and nutritional rich oil.

Table 1. Properties of extracted ground nut oil using direct press method

S.No	Oil property	Oil sample 1	Oil sample 2
1.	Refractive index	5.62	5.28
2.	Iodine value	4.92	4.68
3.	Moisture & insoluble Impurities	4.2	3.6
4.	Flash point	3.85	3.56
5.	Saponification value	5.12	5.32

Table 1 shows the preliminary laboratory test results obtained by the direct press mechanism which ensures the quality of the extracted oil. However, detailed study needs to be conducted further more to ensure the effectiveness. The oil extraction efficiency will be improved by modifying the pressing mechanism i.e the control panel will be redesigned in such a way that it has to withstand the pressing capacity more than 50MPa. When the pressure being regulated, the existing roller drum assembly also need to be modified so that the higher possibility of oil extraction.

Central Composite Design (CCD)

Response surface methodology (RSM) is a good mathematical and statistical technique that can be used in a lot of different engineering processes [14]. It can be used to design experiments and look at how variables interact with each other. In RSM, Central Composite Design (CCD) is the most common way to build a response surface quadratic model with the fewest number of experimental runs [2][15]. The total number of experiments in CCD design is evaluated by using the relation Eq 1,

$$N = F + 2\kappa + X_0 \quad (1)$$

Where, F denotes factorial points, 2k denotes axial points and X_0 denotes center points. The factorial and axial points are used to analyze the quadratic terms whereas central points used to determine the pure error of the model by repetition of central point [14] [23]. In this study, the influence of pressure, groundnut size, steam flowrate and time on the extraction efficiency, iodine value and saponification factor of the oil is investigated systematically using a five-level CCD with four parameters. The study range are set at 0.3 to 8 mm for ground nut size, pressure of 20 to 80 MPa, steam flow rate of 2 to 10 and time of 15 to 75 mins with a total of 30 experimental trials as tabulated in Table 2 and 3. The Eqn. 2 expresses the quadratic polynomial model used to analyze the impact of the extraction efficiency, saponification factor and iodine factor on the different processing variable [21].

Table 2. Experimental coded values for CCD design

Factor	Units	Symbol	Coded Values				
			-2	-1	0	+1	+2
Pressure	MPa	A	0	20	40	60	80
Groundnut Size	mm	B	0.33	2.505	3.165	6	8.835
Steam Flow Rate	Kg/h	C	2	4	6	8	10
Time	Mins	D	15	30	45	60	75

$$Y = \beta_0 + \sum_{i=0}^{\kappa} \beta_0 x_i + \sum_{1\le i\le j}^{k} \beta_0 x_i x_j + \sum_{i=1}^{k} \beta_0 x_i^2 + e \quad (2)$$

Here, y is the expected response variable; Bi is the linear coefficients; Bii is the quadratic coefficients; and B0 is the fixed coefficient There are two input parameters: xi and xj, which are the coefficients of the linear interaction between the independent variables. MINITAB 18 software has been used for both the trial design and data analysis. The R^2 coefficient of correlation was used to verify the secondary model's appropriateness, as well as the t - test is utilized to determine the model's statistical significance. To test for statistical significance, Fisher's F-test is performed to measure fitted adequacy of the predictive equation. Researchers used p-values and F-values to assess the relevance of the model as well as its terms [5][8].

3. Results and Discussion

Model Fitness

Using the CCD matrix in the oil extraction process, a 5-level experimental method with four variables and 30 trials has been constructed as shown in Table 3. The software's model summary statistics are utilised to conduct an analysis of the model in consideration of the experimental results. Linear, interactive, quadratic and cubic models are among the several types of models offered in the programme. Among these models, regression coefficients for linear and interaction models are less than or equal to 0.80 and 0.75, respectively. For CCD, the cubic model is discovered to be aliased. The quadratic model is chosen from among these models to investigate the effects of operational parameters on the oil extraction process. During the investigation, the following predictive quadratic equations for oil extraction efficiency, iodine value and saponification value are obtained: (Eq. 3-5)

$$\text{Efficiency (\%)}=0.89+0.4012\,A+ 0.201\,B+ 0.718\,C+ 0.1698\,D + 0.006405\,A*A+ 0.04498\,A*C+ 0.2490\,B*C \quad (3)$$

$$\text{Iodine value}=42.70+0.2905A+1.409B+0.935C+0.7413D-0.2133B*B+0.0714C*C-0.006508D*D+0.01543A*B \quad (4)$$

$$\text{Saponification value}=146.10+0.3146A+1.426B+0.662C+0.6483D0.1858B*B+0.0954C*C0.005720D*D0.02122\,A*B \quad (5)$$

Coefficients with a positive sign suggest a beneficial influence, whereas coefficients with a negative sign show an antagonistic effect. The linear coefficients of independent variables in the preceding equations have a beneficial influence on oil extraction efficiency, iodine, and saponification value. Quadratic terms have a detrimental influence on projected responses most of the while.

Table 3. Experimental trials as per CCD matrix

Run Order	Pressure (MPa)	Ground nut size (mm)	Steam flow rate (Kg/h)	Time (mins)	Extraction Efficiency (%)		Iodine value		Saponification factor		Error (%)		
					Actual	Predicted	Actual	Predicted	Actual	Predicted	Efficiency	Iodine value	Saponification value
1	20	0.33	4	30	6.50	6.73	71	70.11	171.00	171.18	3.57	1.25	0.10
2	60	0.33	4	30	16.45	18.38	82	81.53	184.00	183.48	11.71	0.57	0.28
3	20	6	4	30	3.00	2.23	69	68.70	170.25	170.19	25.79	0.44	0.04
4	60	6	4	30	12.97	13.87	77	76.61	178.00	177.68	6.94	0.50	0.18
5	20	0.33	8	30	12.50	12.87	78	77.28	179.00	178.41	2.98	0.92	0.33
6	60	0.33	8	30	32.45	31.71	89	88.70	191.00	190.71	2.27	0.34	0.15
7	20	6	8	30	4.20	2.72	76	75.86	178.00	177.42	35.25	0.18	0.33
8	60	6	8	30	19.26	21.56	84	83.78	185.00	184.91	11.95	0.26	0.05
9	20	0.33	4	60	12.23	11.82	75	74.78	176.00	175.18	3.32	0.29	0.46
10	60	0.33	4	60	23.65	23.47	85	86.20	186.00	187.49	0.77	1.41	0.80
11	20	6	4	60	7.12	7.32	73	73.36	175.00	174.19	2.79	0.50	0.46
12	60	6	4	60	17.96	18.96	81	81.28	182.00	181.68	5.58	0.35	0.17
13	20	0.33	8	60	17.46	17.97	81	81.95	182.00	182.41	2.89	1.17	0.23
14	60	0.33	8	60	36.00	36.81	94	93.36	196.00	194.71	2.24	0.68	0.66
15	20	6	8	60	8.58	7.81	81	80.53	181.00	181.42	8.95	0.58	0.23
16	60	6	8	60	26.00	26.65	88	88.45	189.00	188.91	2.51	0.51	0.05
17	40	3.165	6	45	14.12	13.74	83	83.05	184.00	183.65	2.67	0.06	0.19
18	40	3.165	6	45	14.12	13.74	83	83.05	184.00	183.65	2.67	0.06	0.19
19	40	3.165	6	45	14.12	13.74	83	83.05	184.00	183.65	2.67	0.06	0.19
20	40	3.165	6	45	14.12	13.74	83	83.05	184.00	183.65	2.67	0.06	0.19
21	0	3.165	6	45	7.12	8.75	73	73.38	174.00	173.75	22.87	0.52	0.14
22	80	3.165	6	45	42.00	39.23	93	92.71	194.00	193.54	6.59	0.31	0.24
23	40	2.505	6	45	21.35	21.07	79	79.36	181.00	181.07	1.30	0.45	0.04
24	40	8.835	6	45	6.45	6.41	73	73.02	174.00	174.28	0.56	0.03	0.16
25	40	3.165	2	45	8.24	6.83	77	77.02	178.00	177.95	17.15	0.03	0.03
26	40	3.165	10	45	21.45	20.66	91	91.36	192.00	192.40	3.69	0.39	0.21
27	40	3.165	6	15	9.40	8.65	71	72.52	174.00	174.50	7.97	2.15	0.28
28	40	3.165	6	75	19.12	18.84	83	81.86	182.65	182.50	1.49	1.38	0.08
29	40	3.165	6	45	12.92	13.74	83	83.05	182.65	183.65	6.37	0.06	0.55
30	40	3.165	6	45	12.92	13.74	83	83.05	182.65	183.65	6.37	0.06	0.55

ANOVA Analysis

ANOVA test determines if a model is a good match for the data [17]. ANOVA data for the response of extraction efficiency, iodine, and saponification value are shown in Table 4. According to these findings, the experimental data was fitted to the quadratic regression equation projected data, which had an R^2 value of 0.9870, an adjusted R^2 value of 0.9828, and a forecasted R^2 value of 0.9609. R^2, adjusted R^2, and the iodine value are all 0.9922, 0.9893, and 0.9741, respectively, whereas the saponification factor is 0.993, 0.989, and 0.984. P0.05 also reveals significant regression at a 95% confidence level, however p values larger than 0.10 are found to be inconsequential for the regression analysis across all replies. A quadratic equation is used by the RSM to figure out how much oil can be extracted. The F-value is 238.28 and the p-value is less than 0.0001. This also holds good for the values for iodine and saponification that have a higher F value and less of a p value, which are both good. Pressure, groundnut size, steam flow rate, and time all had p-values of 0.0001 in the ANOVA, demonstrating that these factors are critical for oil extraction operations. The lack of statistical significance of the Lack of Fit for all responses further illustrates that the anticipated model is very well with the empirical observations.

Table 4. ANOVA analysis for responses

Oil Extraction Efficiency

Source	Seq SS	Contribution	Adj SS	Adj MS	F Value	P Value	Remarks
Model	2431.62	98.70%	2431.62	347.37	238.28	<0.0001	Highly Significant
A	1394.00	56.58%	1394.00	1394.00	956.23	<0.0001	Highly Significant
B	322.30	13.08%	322.30	322.30	221.09	<0.0001	Highly Significant
C	286.97	11.65%	286.97	286.97	196.85	<0.0001	Highly Significant
D	155.60	6.32%	155.60	155.60	106.74	<0.0001	Highly Significant
A*A	189.04	7.67%	189.04	189.04	129.67	<0.0001	Highly Significant
A*C	51.80	2.10%	51.80	51.80	35.54	<0.0001	Highly Significant
B*C	31.89	1.29%	31.89	31.89	21.88	<0.0001	Highly Significant
Error	32.07	1.30%	32.07	1.46			
LOF	32.07	1.30%	32.07	1.78		0.124	Not significant
Total	2463.69	100.00%					
R^2	98.70%			R^2 (adj)	98.28%		
R^2 (pred)	96.09%			PRESS	96.2170		

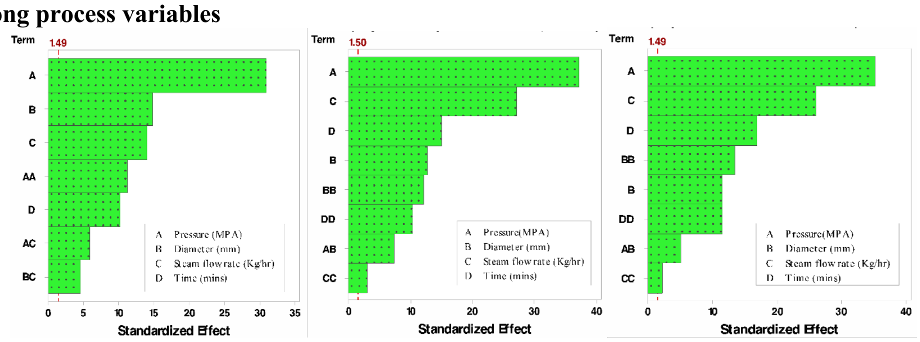
Iodine value

Source	Seq SS	Contribution	Adj SS	F Value	P Value	Remarks
Model	**1210.40**	**99.22%**	**1210.40**	**335.72**	**<0.0001**	**Highly Significant**
A	560.67	45.96%	560.67	1244.05	<0.0001	Highly Significant
B	60.17	4.93%	60.17	133.50	<0.0001	Highly Significant
C	308.17	25.26%	308.17	683.78	<0.0001	Highly Significant
D	130.67	10.71%	130.67	289.93	<0.0001	Highly Significant
				102.43	<0.0001	Highly Significant
B*B	72.20	5.92%	82.29	182.58	<0.0001	Highly Significant
C*C	6.25	0.51%	2.29	5.07	0.035	Significant
D*D	60.04	4.92%	60.04	133.21	<0.0001	Highly Significant
A*B	12.25	1.00%	12.25	27.18	<0.0001	Highly Significant
Error	9.46	0.78%	9.46			
LOF	9.46	0.78%	9.46		1.42	Not Significant
Total	1219.87	100.00%				
R^2	99.22%			R^2 (adj)	98.93%	
R^2 (pred)	97.41%			PRESS	31.5714	

Saponification value

Source	Seq SS	Contribution	Adj SS	Adj MS	F Value	P Value	Remarks
Model	1201.76	99.30%	1201.76	133.528	315.91	<0.0001	Highly Significant
A	587.57	48.55%	587.57	1.457	3.45	0.078	Not Significant
B	69.19	5.72%	69.19	266.630	630.81	<0.0001	Highly Significant
C	313.57	25.91%	313.57	587.565	1390.10	<0.0001	Highly Significant
D	96.20	7.95%	96.20	69.190	163.70	<0.0001	Highly Significant
A*A	55.86	4.62%	62.44	96.200	227.60	<0.0001	Highly Significant
C*C	8.37	0.69%	4.08	36.873	87.24	<0.0001	Highly Significant
D*D	46.38	3.83%	46.38	62.439	147.72	<0.0001	Highly Significant
				4.079	9.65	0.006	Significant
A*B	23.16	1.91%	23.16	46.382	109.73	<0.0001	Highly Significant
Error	8.45	0.70%	8.45	23.160	54.79	<0.0001	Highly Significant
LOF	8.45	0.70%	8.45	23.160	54.79	0.598	Not significant
Total	1210.21	100.00%		0.528			
R^2	99.30%		R^2 (adj)	98.99%			
R^2 (pred)	98.49%		PRESS	18.2743			

Interactions among process variables



a) b) c)

Fig. 5. Pareto chart analysis, a) Efficiency, b) Saponification and c) Iodine Value

Figures 5 a, b, and c are extremely important factors for extraction efficiency, iodine, and saponification value. Additionally, the quadratic factors A^2 for extraction efficiency, B^2 for iodine value, C^2 and D^2 for saponification value, as well as A^2, C^2, and D^2 for saponification value, are key model terms. For extraction efficiency and iodine value, pressure (A) is the most important parameter, with a 956.23 and 1244.05 F-value. In the same way, the F value of the saponification factor 1390.10 is the steam flow rate (C) because the steam flow rate is the most important factor. The groundnut size and steam flow rate have the minimal impact on oil extraction efficiency when two parameters interact, while the pressure and steam flow rate combination (AC) has the most impact. Similar to this, the interaction between pressure and groundnut size (AB) has the only term that has an effect on the iodine and saponification values.

Figures 6a-f, 6a-f, and 7a-f depict the interaction influence of the process variables on the extraction efficiency, iodine level, and saponification factor. Figures 6a, 7a, and 8a demonstrate the influence of steam flow rate and duration on oil extraction efficiency, iodine level, and saponification value when all other factors are kept constant. The extraction efficiency of oil is minimum at a steam flow rate of 3 kg/h, but when the steam flow rate increases to 10 kg/h, the extraction efficiency rises to 45.67 %. As demonstrated in Figures 6a and 7a, similar results are achieved for both iodine and saponification value, with increasing the steam flow rate with regard to time having a substantial influence. This implies that the efficiency of oil extraction, the amount of iodine, and the saponification value are all dependent on the rate of steam flow.

The influence of groundnut diameter and duration on oil extraction efficiency, iodine, and saponification value is shown in Figures 6b, 7b, and 8b, whilst other factors are kept constant. The extraction efficiency is 33.12% at a low time of 30 minutes and a groundnut diameter of 0.5 mm; however, when the groundnut size grows to 8 mm and the duration increases to 60 minutes, the extraction efficiency drops to 18.3%. In general, efficiency increases as grain size decreases. Furthermore, as shown in Figures 6b and 7b, increasing the groundnut size above 4 mm reduces the iodine and saponification factor value. This means that by keeping the groundnut value between 0.2 and 5 mm, an iodine value of 95 and a saponification value of 200 may be obtained.

The interaction of steam flow rate and groundnut diameter on the oil extraction efficiency, iodine and saponification value are shown in Figure 6c, 7c and 8c. At size of 0.5mm and steam flow rate of 3 kg/h, oil extraction efficiency is found to be 21.31% and at maximum size of 8 mm and steam flow rate of 9 kg/h, high efficiency is obtained. This indicates that efficiency increases with decrease in groundnut size and increase in steam flow rate. Similarly, from Figure 6c and 7c, iodine and saponification value increases with increase in size of groundnut up to 5 mm and steam flow rate to 9 kg/h.

The effect of pressure and time is observed on the responses as shown in Figure 6d, 7d and 8d. High efficiency of more than 50% is obtained at higher pressing time of 70 mins and high pressure of 80MPa as shown in Figure 6d. However, efficiency diminishes as pressing time is lowered to 20 minutes and pressure to 10 MPa. As a result, considerable pressure and time will be required to attain high oil extraction efficiency. As seen in Figure 7d and 8d, similar findings are obtained for iodine and saponification factor.

The influence of steam flow rate and pressure on percentage oil yield is depicted in Figures 6e, 7e, and 8e. When the steam flow rate is increased to 9 kg/h and the pressure is increased to between 10 and 80 MPa, the oil extraction efficiency is 60%. Higher oil extraction efficiency is achieved when the steam flow rate and the pressure is higher. Figures 6e and 7e show how the increased steam flow rate and pressure benefit of the iodine and saponification values. The increase of diameter with respect to pressure also shows positive impact on the responses as shown in Figure 6f, 7f and 8f. The efficiency of 50%, iodine value of 95 and saponification value of 195 are achieved at the groundnut size of 0.5 mm and pressure of 60 MPa.

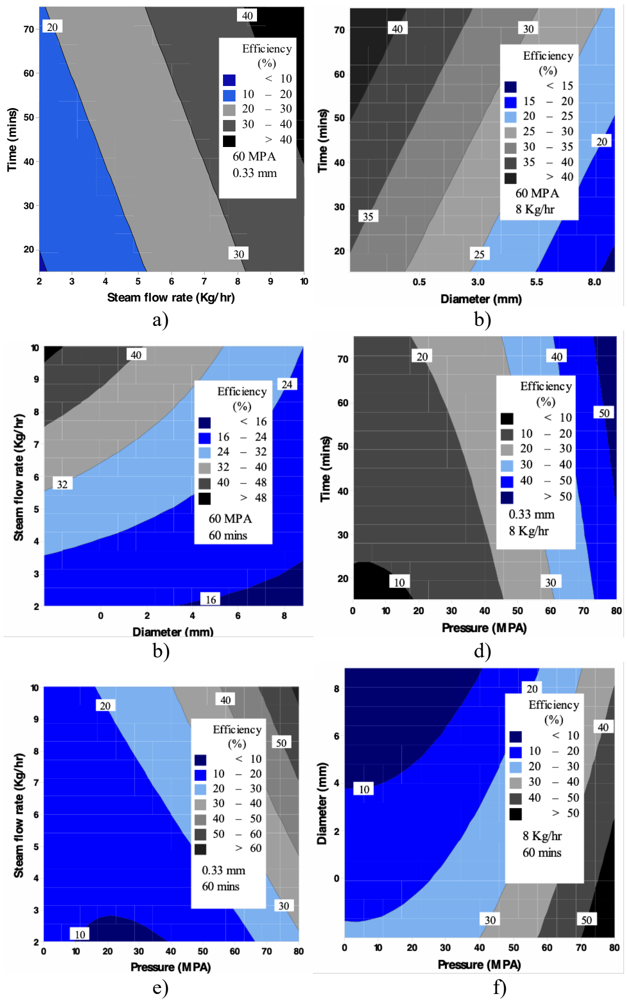


Fig. 6. Interaction between the efficiency and the factors that influence the oil extraction capacity

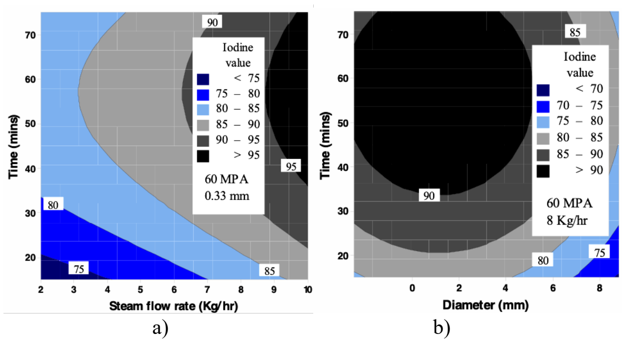
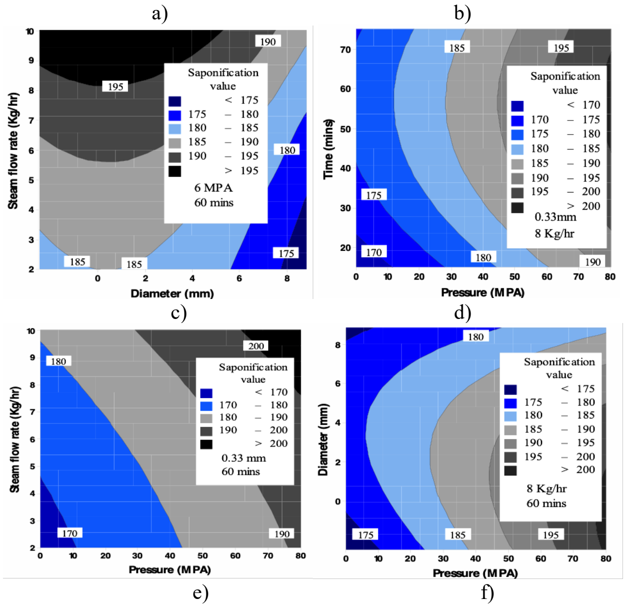


Fig. 7. Interaction between the Iodine value and the factors that influence the oil extraction capacity

As experimented using the CCD, the optimum results obtained to attain maximum saponification value, Iodine value, and oil extraction efficiency are achieved when the α = 0.15, which is the factor used to obtain quality oil when it is extracted from the oilseeds [24]. An oil extraction process using a response surface - BBD design achieves an oil extraction efficiency of 35.25 % with pressure (A) equal to 80 MPa, groundnut size (B) equal to 0.33 mm, steam flow rate (C) equal to 10 kg/h and pressing duration equal to 75 minutes. For iodine factor, the conditions are pressure (A) = 80 MPa, size of groundnut (B) = 0.33mm, steam flow rate (C) = 10 kg/h and pressing time = 75 mins. For saponification factor, the conditions are pressure (A) = 80 MPa, size of groundnut (B) = 0.3 mm, steam flow rate (C) = 10 kg/h and pressing time = 60 mins. Table 5 shows that the three replies had low errors of 1.23, 0.2, and 0.23 percent, as well as low standard deviations of 1.23, 0.2, and 0.23 percent, respectively. The predicted values are used in an experimental test. For all response parameters, the experimental results are in close agreement with the model.



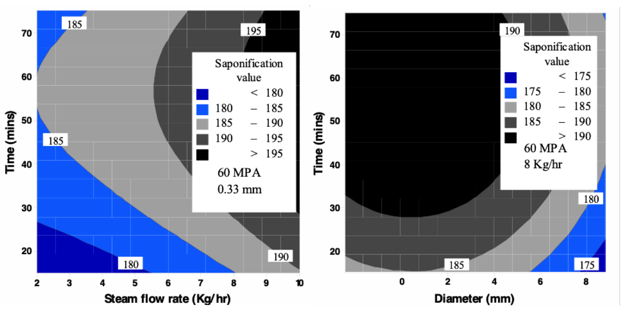


Fig. 8. Interaction between the Saponification and the factors that influence the oil extraction capacity.

Table 5. Optimum values of the responses

Response	Pressure (Mpa)	Size of groundnut (mm)	Steam flow rate (kg/h)	Time (min)	Predicted efficiency (%)	Actual efficiency (%)	Error (%)	Std div (%)
Efficiency	80	<0.33	10	75	55.69	55	1.23	±1.23
Iodine value	80	3	10	10	97.2	97	0.2	±0.2
Saponification value	80	0.3	10	60	198.45	198	0.23	±0.23

4. Conclusion

The efficiency of oil extraction is explored in this study utilizing a press type machine, and the process parameters were improved using the Response Surface technique. The agreement between the forecasts of response functions derived using statistical models and the actual data was excellent, showing the validity of the technique. The ideal oil extraction efficiency, iodine, and saponification values were determined using CCD. The highest oil extraction efficiency, iodine, and saponification value were 55%, 98, and 198, respectively, utilizing optimum pressure (MPa): groundnut size (mm): steam flow rate (kg/h): time (min) ratios of 80:0.33:10:75, 80:3:10:75, and 80:0.3:10:60. The ideal variables produced experimental results that were quite near to the model predictions. Our findings suggest that using the response surface methodology (RSM) in conjunction with a CCD can assist in identifying the most critical operational parameters for oil extraction using a press type extraction equipment.

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