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Optimization of Some Selected Processing Parameters on Oil Yield from Developed Oil Expeller for Groundnut (*Arachishypogaea*) Seeds

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Abstract: The use of mechanical pressing is thought to be a suitable method for small and medium-sized farmers in developing nations, due to its reduced initial and ongoing expenses when compared to the use of a screw press and a solvent expression procedure. A combined roaster-expelling machine was used in the study to examine the effects of applied pressure, moisture content, and roasting temperature on the oil output of groundnut seeds. A 3^3 box – benken design was used for the experiment. Moisture content, roasting temperature, and pressure applied were experimental variables that affected oil yield. Using the response surface analysis method, the experiment's parameters were optimized. Data analysis shows that all the variables significantly affected the oil yield at 95% confidence level. The optimum conditions of the independent variables for the oil yield were determined at, moisture content 6%, roasting temperature 110°C and applied pressure 25 Mpa at corresponding oil yield of 24.5%. Also, the R^2 and R^2 adj. value of 0.9561 and 0.3432 respectively indicated that the regression model was a good one and verification experiment confirmed the validity of the predicted model. The experimental values were not significantly distinct from the expected values at p0.05, although they were extremely close to them. The developed regression model has served as a foundation for choosing the best process variables for the recovery of oil while using a combination roaster and melon seed expression machine.

Keywords: Groundnut Seed, Expression, Box Benken Design, Response Surface Methodology, Optimization, Oil Yield

1. Introduction

Groundnut (*Arachishypogaea*) popularly known as the peanut or earthnut, is botanically the largest and most significant member of the leguminosae family, belonging to the papilionaceae family. [3] Due to its commercial and nutritional benefits, it is a crucial food and oil seed crop all over the world. [14] Groundnuts, which are mostly a native of warmer climes, typically serve as a source of food for people or livestock, and in the absence of meat, they serve as a source of vegetable protein. [3]. The manufacturing of groundnut cake, which is used as an element in animal and poultry feed, as well as groundnut oil for human use, is a rich source of plant protein. There are two primary types of groundnuts, and they grow well in semi-arid regions. The America groundnut (*Arachishypogeal*) and the Africa groundnut the Bambaranut (*Voandzeiasubterranean*). [3] Both are grown in Western Africa. In most developing countries, including those in South Asia and Africa, the production of groundnut oil is typically done manually. Like all manual tasks, it is laborious and time-consuming. Mechanical expression has been used to express groundnut oil [16, 17]. The most widely used technique for expressing oil is mechanical pressing, which uses a variety of presses, including rolling, screw, and hydraulic presses. [5] solvent extraction is also another method which can be used to extract over 98% oil [9]. However, this method has drawbacks as well, including expensive equipment requirements, a significant risk of fire or explosion during the process, and the need for particular processing before moving on to the next procedure due to the solvent utilized. [4]. According to [10, 19] said that the mechanical screw press has improved safety features; less pollution and greater efficiency depending on type of expeller.

Although mechanical pressing has lower initial and ongoing expenses than using a screw press or a solvent extraction processes, it is thought to be a suitable method for small and medium-sized farmers in developing nations to express oil from oil-bearing seeds. [4] The majority of the food produced in these nations is grown by small- and medium-sized farmers. Size reduction of the oil seeds is necessary before heat treatment, pressure application, and oil expression from oil seeds using the expeller. The particle size, seed moisture content, roasting temperature, expeller time, applied pressure, and pressing time all affect how much oil is expressed [4]. In order to increase the oil recovery using the important process conditions, this study evaluated the processing parameters (Moisture content, roasting temperature, and roasting duration) that maximize the oil yield from groundnut oil expellers.

2. Materials and Method

2.1. Test Materials and Sample Preparation

The shelling, cleaning, and sun-drying of groundnut seed was carried as preliminary preparation of the sample, while the groundnut sample's initial moisture content was determined by oven drying at 103°C. [2]. The samples were split into three equal parts and treated by adding a calculated amount of water necessary to achieve the chosen desired moisture contents. The condition seeds were placed in a refrigerator for at least 48 hours to let the added moisture to equilibrate, and then the moisture content was determined using a moisture analyzer. Calculated quantity of water using equation 1 [1]. Plate 1a and 1b present unshelled groundnut seeds and shelled groundnut seed.

Figure 1. *a: Unshelled groundnut seeds; b: Shelled groundnut seeds.*

$$Q = A\,(b-a)/(100-b) \quad (1)$$

Where A = Initial mass of the sample (Kg)
a = Initial moisture content of the sample, (%)
wet basis (wb)
b = final (desired) moisture content of sample (%)
Q = mass of water to be added (kg)

To be able to know the optimal level of moisture content required for the optimal expression operation because previous studies shows that moisture content in seed results in plasticity effect during mechanical expression. Hence, the moisture content selected for this study ranged from 6 to 10% w.b. Heat treatment is also essential since it reduces viscosity of oil in the oil capillaries, coagulate the protein to increase void which allows easier expression the roasting temperature ranged from 70 to 110°C. It also brings the moisture content to the optimum for expression roasting time of more than 20-30 mins is not advisable since these do not increase yield significant.

2.2. Experimental Procedure

1 kg of the sample prepare was measured and transferred into the expeller hopper. The sample was heated at 3 levels 70, 90 and 110°C of heating temperature for 20 minutes and expressed at pressure range of 15, 25, and 35 Mpa respectively, throughout the experiment. The duration of the expression was determined by the time the last drop of oil was noticed at the oil outlet.

2.3. Description of the Oil Expression Machine

The pieces of the oil expeller employed for this study are as follows. Worm shaft, toaster, thermocouple, pressure transducer, main frame, oil outlet, barrel, barrel outlet, and feeding hopper. The shaft of the expeller is tapered and has an equal pitch. In order to increase the pressure on the materials as they are transported through the barrel, the pitch of the oil flights gradually lowers as they approach the outlet. The barrel's last section was pierced to let expressed oil escape. The barrel outlet was used to discharge press cake, and the discharge port's diameter was adjusted to control the pressure inside the barrel. For heating purposes, a 605 W electric band heater was fitted around the barrel. It also included a temperature controller for simple temperature control during the expression process. A set of thermocouples connected to a temperature controller makes up the temperature monitoring and control unit.

2.4. Experimental Design

Response Surface Methodology (RSM) is a mathematical and statistical techniques tools useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize this response. The main advantage of software is the capability to minimize the number of experimental runs and reduce cost. For the study, a Central Composite Design (CCD) of RSM was employed. The experimental design adopted three factors, at five levels. The number of design layout was given using (N) is $N = 2^k + 2k + 6$. The three variables, gave eight factorial points, six axial points and six replications at the center points. A second-order polynomial equation was used to express the responses, Y as a function of the independent variables as given in equation.

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=1+1}^{n} \beta_{ij} x_i x_j \quad (2)$$

Where; Y = response, β_0 = constant coefficient, β_i = linear coefficient, β_{ii} = the quadratic coefficient, β_{ij} = interaction coefficient, x_i and x_j = coded values of the independent variables.

For each independent variable, the levels were chosen with respect to the preliminary experiments and previous work by various researchers on various oilseeds. The processing parameters selected were moisture content at 3 levels (6, 8 and 10%), roasting temperature at 3 levels (70, 90 and 110°C) and roasting time at 3 levels (15, 25 and 35 Mpa) while the dependent variables were oil yield, expression efficiency and expression loss. while the response is the oil yield. Table 1 shows the experimental design for melon oil expression. while Table 2 shows response surface modified quadratic model of melon oil yield, expression efficiency and expression loss. The center points were used to determine the experimental error and the reproducibility of the data. The independent variables are coded to the (−1, 1) interval where the low and high levels are coded as −1 and +1, respectively. The axial points are located at (±α, 0, 0), (0, ±α, 0) and (0, 0, ±α) where α is the distance of the axial point from center and makes the design rotatable. In this study, the (α) value was fixed at 0.5 (others). The oil yield was determined using Equation 3.

Oil yield OY (%)

$$OY = \frac{M_{Oil}}{M_{Seed}} \times 100 \quad (3)$$

where,

OY is oil yield (%);

M_{oil} is the mass of oil expressed (g); and

M_{Seed} is the mass of see(g).

3. Results and Discussion

Result obtained from the study was presented in Table 1.

Table 1. *Result of the data obtained from the experiment.*

Run	A:Applied Pressure MPa	B:Moisture Content %	C:Temperature Celsius	Oil Yield %	Extraction Efficiency %	Extraction Loss %
1	15	10	90	23.6	56.11	22.7
2	25	10	110	23.8	56.15	22.71
3	15	8	110	23.4	56.9	22.72
4	15	8	70	23.6	56.9	22.53
5	25	10	70	23.6	56.21	22.72
6	25	8	90	23.4	56.3	22.11
7	25	8	90	23.42	56.28	22.12
8	25	6	70	23.3	56.65	22.16
9	25	8	90	23.5	56.32	22.13
10	35	10	90	23.1	56.21	22.73
11	25	8	90	23.51	56.29	22.11
12	25	8	90	23.52	56.32	22.12
13	25	6	110	24.5	56.89	22.73
14	25	8	90	23.49	56.3	22.13
15	35	8	110	23.4	56.8	22.71
16	25	8	90	23.48	56.31	22.12
17	35	6	90	23.5	56.05	22.72
18	35	8	70	22.2	56.1	22.71
19	15	6	90	24.3	56.97	22.16
20	25	8	90	23.51	56.29	22.11

Analysis of Variance of the Oil Yield

The experimental result of the study was as presented in Table 1, and the corresponding ANOVA of the oil yield has been presented in Table 2. A, B, BC, A^2, and C^2 have negative coefficients, indicating an indirect proportionality with the oil yield, according to the regression equation constructed for oil yield with single components, quadratic factors, and interaction factors. C, AB, AC, and B^2 are directly proportional to the oil yield. The degree to which operating parameters have an impact on oil yield is clear. The obtained R^2, and *Adj.* R^2, are 0.9506 and 0.9062, respectively. The fitness of a model was determined by the R^2 (coefficient of determination) and the value should not be less than 0.80 as reported by [2]. Also, since the R^2 and the *Adj.* R^2 are close to 1 which implies that the model fits the data well.

Table 2. *Response surface quadratic model of ground nut oil yield (ANOVA).*

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	4.28	9	0.4752	24.20	< 0.0001	Significant
A-Applied Pressure	1.20	1	1.20	61.17	< 0.0001	
B-Moisture Content	0.4512	1	0.4512	22.98	0.0007	
C-Temperature	0.7200	1	0.7200	36.66	0.0001	
AB	0.1225	1	0.1225	6.24	0.0316	
AC	0.4900	1	0.4900	24.95	0.0005	
BC	0.2500	1	0.2500	12.73	0.0051	
A^2	0.1863	1	0.1863	9.49	0.0116	
B^2	0.9180	1	0.9180	46.75	< 0.0001	
C^2	0.0736	1	0.0736	3.75	0.0817	
Residual	0.1964	10	0.0196			
Lack of Fit	0.1825	3	0.0608	30.66	0.0002	Significant
Pure Error	0.0139	7	0.0020			
Cor Total	4.47	19				

Std. Dev. 1.29, R^2 0.9506, Mean 20.79, Adjusted R^2 0.9062, C.V. % 6.21, Predicted R^2 0.2835, Adeq Precision 14.1530
$P \leq 0.05$

The Effect of Roasting Temperature and Applied Pressure on the Oil Yield

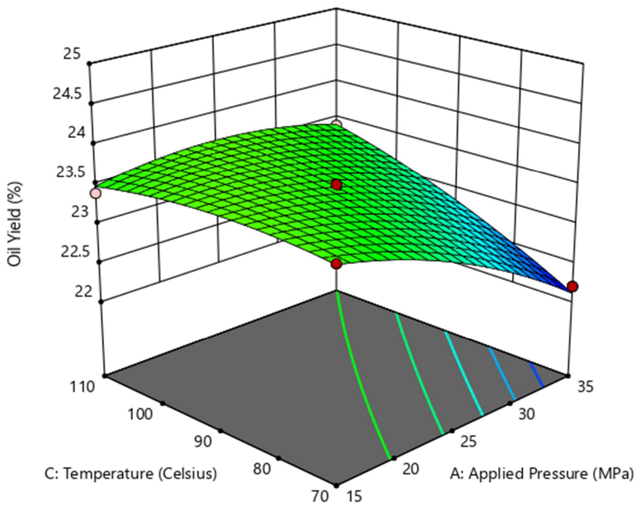

Figure 2. *Response surface plot showing the Effect of Roasting Temperature and applied pressure on the oil yield.*

According to the response chart in Figure 2 that compared the effects of moisture content and applied pressure, there was a modest improvement in oil recovery for all treatment combinations when the applied pressure was raised from 15 to 35 MPa. The oil recovery does, however, decrease at high roasting temperatures. The effect may be explained by the rapid evaporation of water at higher temperatures, which results in significant moisture loss; the compacted cake also becomes hard and dry, which reduces oil flow. When an oilseed is heated, moisture loss creates a void that acts as a migratory space for the contents of the oil-bearing cells, making oil-bearing cells more likely to rupture as the heating process continues [2]. Additionally, this causes the protein to clump together and reduces the oil's viscosity, allowing oil to leak out of the oil-bearing cells and onto the surface. A similar finding was made by [13] while pressing groundnuts, a stronger connection between temperature and pressure was seen at greater levels of these parameters. This relationship can be understood by noting that as temperature rises, the viscosity of the flowing oil drops, improving its capacity to flow through compressed media, whereas as applied pressure rises, the viscosity increases and the flow ability diminishes.

Also, according to [7] Increased pressure during the screw pressing process on oil seeds causes shears to get narrower and may finally cause the capillaries through which oil is pushed to become sealed. Because higher pressures do not always increase yield and expression efficiency and instead raise costs, it is advisable to determine the best expression pressures for oilseeds.

The Effect of Moisture Content and Roasting Temperature on the Oil Yield

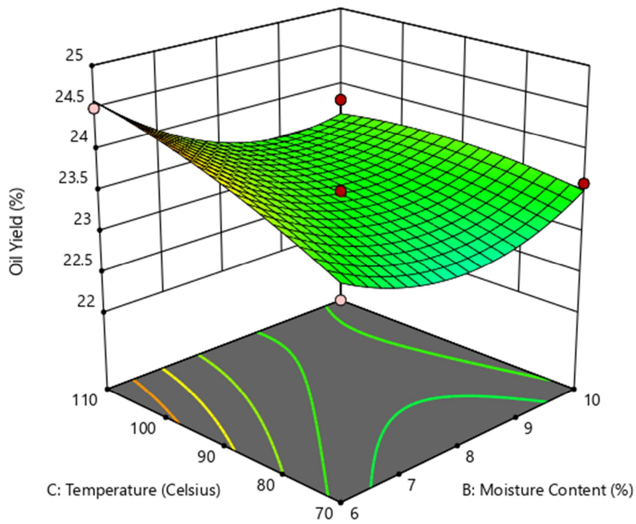

Figure 3. *Response surface plot showing the Roasting Temperature and Moisture Content on Oil Yield.*

Figure 3 shows maintaining all other variables fixed, the impact of the interaction between moisture content (B) and roasting temperature (C) on groundnut oil yield. At a roasting temperature of 110°C, the oil yield was at its highest, while at a temperature of 70°C, it was at its lowest. It has been discovered that the roasting temperature significantly affects oil output as reported by [8, 13]. Long-term roasting temperatures above 110°C will not boost the oil yield since there will be vaporization and volatilization of the oil; a similar finding was reported by [15]. Since roasting temperature increases, oil yield also improves until the roasting temperature reaches 110°C and then drops. Higher roasting temperatures result in faster protein coagulation and viscosity reduction, which increases oil yield. However, higher roasting temperatures also result in significant moisture loss, which causes samples to harden and, as a result, reduces oil yield. Oil flow is inversely correlated to kinematic viscosity, which falls as roasting temperature rises, increasing the oil's ability to flow [12]. Additionally, the oil output decreases from 6 to 10% moisture content. This shows that higher oil yield was achieved at 6% moisture level. The interaction between temperature and moisture content was discovered to be more significant than other interacting variables, this is in agreement with the findings of [6].

Oil recovery up to 6% wet basis significantly improved with a decrease in moisture content. The oil output, however, decreased as the moisture content increased more, reaching 10%. This may be explained by the fact that moisture addition speeds up the process of oil expression by helping the particles reach saturation sooner. However, when there is too much moisture, the liquid phase carries the entire load and the oil output decreases because the liquid phase is incompressible and puts no pressure on the castor oil particles. [18].

Therefore, the optimum moisture content for castor oil was found to be 6% wet basis for which an increase in moisture content causes a decline in oil yield.

4. Process Optimization and Validation

The optimum conditions of the oil yield were determined at, moisture content 6%, roasting temperature 110°C and applied pressure 15 Mpa at corresponding oil yield of 24.5% (Table 1).

To confirm the accuracy of the model, and oil expression was carried out with the optimum conditions. Experimental oil yield was found to be 24.50% while predicted oil yield was 25.70%. The percentage error was calculated to be 4.898 which confirmed the validity of the model equation. Table 3 also presents the percentage error, experimental and predicted value while the graph of predicted against the actual experimental runs of oil recovery is depicted in figure 3.

The final equation in term of coded factors for the Central Composite Design response surface second-order model is expressed in Eq. (4).

$$\text{Oil Yield} = 23.48 - 0.3875A - 0.2375B + 0.3000\,C + 0.1750\,AB + 0.3500\,AC - 0.2500\,BC - 0.2019\,A^2 + 0.4481B^2 - 0.1269C^2 \quad (4)$$

Table 3. *Optimum condition for oil expression and percentage error.*

Optimum condition for oil expression					
Moisture Content (%)	**Roasting Temperature (°C)**	**Applied pressure (Mpa)**	**Experimental value (%)**	**Predicted value (%)**	**Percentage error (%)**
6	110	25	24.50	25.70	4.898

5. Conclusion

The study showed that box-Benken experimental design an allied of response surface methodology were used to study the interaction of expression process variables and optimize oil yield in the study experiment. The result of optimization shows that expression conditions influenced the expression of oil groundnut seed. All process parameters considered were found to have significant effect on the oil yield. The coefficient of determination (R^2) of the model analysis was found to be 0.90. The optimum process parameters obtained were moisture content, roasting temperature and Applied pressure 6%, 110°C and 25 Mpa, respectively. The regression model obtained has provided a basis for selecting and predicting the oil yield using combined roaster- expeller.

References

[1] Akinoso, R. (2006). Effects of moisture content, roasting duration andtemperature on yield and quality of palm kernel (*Elaeisguineensis*) and sesame (*sesamumindicum*) oils; Ph.D. thesis, University of Ibadan. Nigeria.

[2] Akintunde, A. M., Ajala, S. O., and Betiku, E. (2015). Optimization of Bauhinia monandra seed oil extraction via artificial neural network and Response Surface Methodology; A potential biofuel candidate. Industrial crops and Products; 67: 387394.

[3] Ajao, K. R, Ajimofokan, H. A, and Olaomi, J (2009). Development and Performance Evaluation of a Groundnut oil Expelling Machine New York Science Journal 2(6), 76-77.

[4] Ajibola, O. O., Olowolarafe, O. K., Fasnina, O. O and Adeeko, K. A. (2002). Expression of oil from sesame seeds; *Jan. Agric. Eng*. 35: 83-88.

[5] Bamgboye A. L and Adejumo, A O. D (2007). Development of a sun Flower oil Expeller Agricultural Engineering International the E. Journal 9: 16.

[6] Bargale, P. C. (1997). Mechanical oil Expression from Selected Oil seeds Under Uniaxial Compression. University of Saskatchewan, Saskatoon, Canada.

[7] Baryeh, E. A. (2011). Effects of palm oil processing parameters on yield; *Journal of Food Engineering*. 48: 1- 6.

[8] Costa SS, Gariepy Y, Rocha SCS and Raghavan V. (2014). Microwave extraction of mint essential oil – Temperature calibration for the oven. Journal of Food Engineering. 2014; 126: 1-6.

[9] Deli, S., Farah, M. M., Tajul, A. Y. and Wan Nadiah, W. A. (2011). The Effect of Physical Parameters of the Screw Oil Expeller on Oil Yield from *Nigella sativa* L Seeds. *International food research journal* Vol 18(4): 1367-1373..

[10] Fitch-Haumann. B. (1997) mechanical expression capitalizing on solvent – free processing in form 8: 165-174.

[11] Hamzat, K. O and Clarke, B. (1993). Prediction of oil yield from groundnut using the concept of quasi-equilibrium of oil yield. *Journal of Agricultural Engineering Research*. 55: 79-87.

[12] Kagwacie, O. C and Anozie, N. A. (1995). Effect of processing conditions on solvent extraction of oil from rubber seeds. *Journal of Agricultural Technology*. 3(1), 31–40.

[13] Martínez ML, Penci MC, Marin MA, Ribota PD andMaestri DM. (2013). Screw press extraction of almond (Prunusdulcis (Miller) D. A. Webb): Oil recovery and oxidative stability. Journal of Food Engineering.; 119: 40–45.

[14] Olaomi J (2008) Design and Construction of a Motorized Groundnut oil Expelling Machine B. Eng Thesis Department of Mechanical Engineering University of Ilorin, Nigeria.

[15] Olaoye J. O. and Busari, R. A. (2017). Optimization of Mechanical Expression of Castor Seeds Oil (*Ricinuscommunis*) Using Response Surface Methodology. *AZOJETE*, 13(6): 878-887.

[16] Owolarafe O. K Adegunloye. A. Y Ajibola O. O (2003). The effect of some Processing condition on Oil point Pressure of Locust bean Journal of food Process Engineering 26. 489-497.

[17] Oyinlola A. and Adekoya L. O (2004). Development of a Laboratory Model Screw Process.

[18] Sivala, K., Bhole, N. G. and Mukherjee, R. K. (1992). Effect of moisture on rice bran oil expression. *Journal of Agricultural Engineering Resources*. 50, 81–91.

[19] Wiensen Born, D, Doddapaneni R. To Stenson K, and Kangas N. (2001). Cooking indices to Predict Screw Press Performance for Cramber seed Journal American Oil Chemist Society 78(5): 467-471.