Modeling and optimisation of oil recovery and throughput capacity in mechanically expressing oil from African oil bean (*Pentaclethra macrophylla* Benth) kernels

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Abstract The relationship existing between operating parameters like speed of operation, applied pressure, feed rate and dependent variables like oil recovery and throughput capacity was investigated while mechanically expressing oil from kernels of *Pentaclethra macrophylla*. A 3-factor, 5-levels central composite design of response surface methodology was used for modeling and optimization of the process. The speed was varied over 15, 30, 45, 60 and 75 rpm using pulley arrangement, applied pressure was varied over 5, 10, 15, 20 and 25 MPa by adjusting the wormshaft distance of the oil expeller and the feed rate was varied over 100, 200, 300, 400 and 500 g/min by regulating the quantity of kernels fed into the expeller. Developed models were validated by comparing predicted values with experimental values. In optimizing the process, the oil recovery and throughput capacity were maximized while the independent variables were set at ranges. Optimum oil recovery of 73.2% and throughput capacity of 4.18 kg/h was obtained at 45 rpm speed of operation, 20 MPa applied pressure and 300 g/min feed rate. A quadratic polynomial model was developed for the oil recovery while a two-factorial-interaction model was developed for the throughput capacity. The results showed that speed of operation, applied pressure and feed rate had significant influence on the oil recovery and throughput capacity. The models developed were valid as they showed a good

agreement between the variable due to low variations between calculated and predicted values.

Keywords Operating parameters · Applied pressure · Speed · Feed rate · Oil recovery · Throughput capacity

Introduction

Vegetable oil has become a very important component of food and non food industries (Ogunlade and Aremu 2019), there is presently an increasing universal demand for good quality vegetable oil because of their nutritional, pharmaceutical and industrial applications thus, studies on vegetable oil to meet its demand in the human society are essential. The present production rate of vegetable oil in Nigeria is inadequate to meet the demand of her citizenry (Obi 2013), this has led to the supply of oils of varying qualities to the Nigerian market with some posing various health risks. It is essential to investigate the quality and quantity of oil from some unexploited and underutilized oilseeds to make more oils available for human nutrition, bio-power, enhance food security and reduce the wide gap between the demand and supply of oil.

Pentaclethra macrophylla Benth is a leguminous tree that belongs to Leguminosae and Mimosoideae family and sub-family respectively. The kernels is oleaginous with the potential of meeting growing demand of vegetable oil for industrial and nutritional applications (Aremu et al. 2014; Aremu and Ogunlade 2016a, b; Ogunlade and Aremu 2019). The seed contains adequate proportion of essential nutrient for human development including sodium, potassium, magnesium, calcium, phosphorus, and lower concentrations of iron, zinc, copper; it is also rich in protein, oil, energy. The consumption of the seed reduces the risk of

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life diseases like cancer and some tobacco-related diseases (Bonnie 2010). The kernels embedded inside the seed contains high quantity of oil in its cotyledon which can be increased through proper processing from around 52 to over 60.1% (Enujiugha and Akanbi 2005; Aremu and Ogunlade 2016a).

Oil can be extracted from biomaterials chemically through the use of solvents, or mechanically through the use of screw or hydraulic press. Solvent oil extraction method from African oil bean kernels have been investigated (Akindahunsi 2004; Odoemelam 2005; Enujiugha and Akanbi 2005; Akubugwo et al. 2008; Sodi 2012), it has proven to be highly efficient with over 98% oil recovery (Bargale 1997; Ibrahim and Onwualu 2005) but requires high technical expertise also, the oil and cake obtained from this method will contain some traces of the solvent. The mechanical extraction method on the other hand has demonstrated low costs of investment, the oil and cake otherwise obtained from this method is neither contaminated nor prone to fire hazard and the method ensures high working capacity and easy manipulation of many variables and parameters (Aremu and Ogunlade 2016a, b; Ogunlade and Aremu 2019).

In the application of mechanical oil extraction method, various factors influencing the efficiency include crop, operating or processing parameters like applied pressure, particle size, moisture content, handling and storage, speed of operation, feed rate, seed dimension, heat applications (Akinoso 2006; Akinoso et al. 2006; Fakayode and Ajav 2016a, b). The effect of heating duration, heating temperature and moisture content on the mechanically expressed African oil bean kernels have been investigated (Aremu and Ogunlade 2016a, b; Ogunlade and Aremu 2019) while literature is very scarce on the influence of operating parameters like applied pressure, speed of operation and feed rate thus, this study aimed at investigating the degree of influence of speed, applied pressure and feed rate on mechanically expressed African oil bean kernels; modeling and optimization of mechanical oil expression process.

Materials and methods

Seed procurement and preparation

Freshly harvested seeds were obtained from Nri market, Imo State, Nigeria. They were cleaned, manually sorted and dehulled to obtain the kernels while defective ones were discarded and good kernels were packed in airtight polythene bags. The kernel moisture level at harvest was determined using ASAE (1998) method by drying the kernels in an electric oven at 105 °C until there is no

change in weight. Equation (1) was used to obtain the moisture content of the kernels:

$$m = \frac{I - F}{F} \times 100 \quad (1)$$

where m is the moisture content (% db), I is the weight of kernels before drying (g), and F is the weight after drying (g).

Oil expeller

a multipurpose oil expeller ranging from 5 to 20 kg/h, powered by a 2.5 hp, 3-phase electric motor with a reduction gear motor was used for expression of oil (Fakayode and Ajav 2016a, b; Aremu and Ogunlade 2016a, b; Ogunlade and Aremu 2019).

Oil content of the African oil bean kernels

AOAC (2005) direct gravimetric method for extraction of vegetable oil was employed for the oil content determination of the kernels using n-hexane of boiling point 80 °C. 400 g of samples was weighed into the thimble of a Soxhlet Extractor. Reflux condenser was attached and extraction was carried out for an approximate of 8 h after which the solvent was distilled off by removing the traces of solvent through heating of the flask containing oil using air-oven method. Extracted oil was weighed and the oil content was calculated using Eq. (2):

$$\% \text{ oil} = \frac{A - B}{W} \times 100 \quad (2)$$

where A is the weight of the flask + oil, B is the weight of the flask only and W is the weight of kernel samples taken.

Experimental design

The effects of operating parameters (speed of operation, applied pressure and product feed rate) were studied on the oil recovery and throughput capacity (mass flow rate) while mechanically expressing oil from *Pentaclethra macrophylla* kernels. 3-factors, 5-levels Central Composite Design using Design Expert Software Package (Stat-Ease, Version 10.0.1, Newcastle, England) was adopted in design of experiments. The levels, codes and intervals of all independent variables is presented in Table 1.

Independent variables

The independent variables considered include speed of operation, applied pressure and product feed rate. The speed of operation was varied over five levels; 15, 30, 45, 60 and 75 rpm using the pulley arrangement; the speed was

Table 1 Levels, codes and intervals of independent variables

Independent variable	Intervals ($\alpha = 2$)					
	Codes	$-\alpha$	-1	0	$+1$	$+\alpha$
Screw speed (rpm)	X_1	15	30	45	60	75
Applied pressure (MPa)	X_3	5	10	15	20	25
Feed rate (g/min)	X_2	100	200	300	400	500

measured with a Contact/Surface Digital Tachometer (DT-2235B, S805217). The applied pressure was varied over five levels 5, 10, 15, 20, 25 MPa using the method of Orheva et al. (2013) and Fakayode and Ajav (2016a, b) by adjusting the wormshaft distance of the oil expeller and using Eqs. (3)–(4).

$$W = \frac{2\pi N}{60} \quad (3)$$

$$\text{Power} = \text{Torque} \times \text{Angular Speed} \quad (4)$$

W is the angular speed of shaft (rad/s), N is the speed of the shaft.

The product feed rate was varied over levels: 100, 200, 300, 400 and 500 g/min by regulating the quantity of kernel fed into the machine per time. It was obtained by methods described by Akinoso et al. (2009); the mass of kernels fed into the machine with time was measured using a Digital Electronic Weighing Scale (± 0.001 , Yongkang Yongzhou Weighing Apparatus, Model, SF 400A, China).

Dependent variables

this includes oil recovery and throughput capacity. They were determined in accordance to standard evaluation methods. The kernels were subjected to similar conditions of moisture and temperature applications for each experimental run (Ogunlade and Aremu 2019).

Percent oil recovery Oil expeller specification (PAES 230: 2005) standard for evaluating oil expellers was used for determination of the oil recovery. Known mass of kernels was fed into the expeller and the mass of oil expressed from each experimental run were obtained, the oil recovery rate was obtained using Eq. (5) (PAES 230: 2005; Aremu and Ogunlade 2016a, b).

$$O_r = \frac{M}{X \cdot K} \times 100\% \quad (5)$$

where O_r is the oil recovery (%), M is the mass of oil collected (g), K is the weight of kernels fed into the hopper of the expeller (g), X is the oil content of African oil bean kernels (obtained from Soxhlet extraction method).

Throughput capacity (T_p) this is the mass flow rate and the quantity of kernels processed per time by the oil

expeller, it was obtained as the ratio of kernel fed into the expeller to the retention time taken to express oil from the last drop of the kernels fed into the machine (Karaj and Muller 2011), Eq. (6) was used for obtaining the throughput capacity:

$$T_p = \frac{S}{Rt} \quad (6)$$

where S is the mass of kernels processed by the expeller (kg) and Rt is the retention time taken to process the known mass of kernels (h).

Modeling, optimization and data analysis

Simultaneous testing of the effects between and within parameters was carried out using factorial experiment. In order to correlate the findings from this study, mathematical models predicting relationship between independent variables (speed, applied pressure and product feed rate) and dependent variables (oil recovery rate and throughput capacity) were developed. The optimization process was carried out on each response separately by maximizing the oil recovery and throughput capacity while the independent variables were set at the range of values used. Multiple linear regression at 95% level of confidence was used by testing four different models. The authenticity of the models was obtained using the R^2 and probability of prediction F ratio test. The appropriate model was chosen based on selection of the highest order polynomial where the additional terms are significant and the model is not aliased, insignificant lack of fit and the maximization of the 'Adjusted R^2 value' and the 'Predicted R^2 value'. The global predictive equation from which specific solution may be derived is presented in Eq. (7):

$$Y = \beta_o + \sum_{i=1}^k \beta_i X_i + \sum_{i < j=3}^k \beta_{ij} X_i X_j X_k + \sum_{i=1}^k \sum_{j=1}^k \delta_{ij} X_i X_j X_k + \varepsilon \quad (7)$$

where Y is the response (dependent variables), β_o is the model intercept, $\sum_{i=1}^k \beta_i X_i$ characterises the main linear effects of individual process variables, $\sum_{i < j=2}^k \beta_{ij} X_i X_j$ incorporates the interaction effects between variables and $\sum_{i=1}^k \sum_{j=1}^k \delta_{ij} X_i X_j$ represents the main quadratic effects of the variables, ε is the random error of experimentation, X_{ijk} represents the matrix of the uncoded process variables.

The determination of the unknown coefficients of β_o , β_i , β_{ij} and δ_{ij} was accomplished via regression analysis implemented on the statistical analysis software Design Expert Version 10.0.1 using the empirical data. The models were validated by comparing experimental results with

calculated results using the models, analysis of variance (ANOVA) was used to determine significance and fitness of each equation and interactions of responses and variables. To achieve the optimization, the independent variables were set at a range while the oil recovery rate and throughput capacity were maximized. Optimal parameters were validated by conducting experiments and comparing experimental values with predicted values, chi square goodness of fit test was used for the validation of the models (Mooney and Swift 1999; Subroto et al. 2015).

Results and discussions

The oil content of the kernels obtained from solvent extraction ranged within 54.1–60.2%, with an average value of 55.6% (± 2.17), this was obtained at a moisture content of 8% dry basis. The experimental values obtained from the study are presented in Table 2. Optimum responses were obtained at 45 rpm speed of operation, 20 MPa applied pressure and 300 g/min machine feed rate which gave an optimum oil recovery of 73.2% and throughput capacity of 4.18 kg/h at a desirability of 0.81.

Effect of Speed, applied pressure and feed rate on oil recovery

The oil recovery obtained varied from 43.1 to 78.6% with an average value of 63.9 (± 12.3). A quadratic polynomial model was chosen to represent relationship between oil recovery, speed of operation, applied pressure and feed rate based on highest order polynomial where additional terms are significant and the model is not aliased, maximization of adjusted and predicted R^2 , and low standard deviation over other models (linear, factorial interaction, and cubic). The 2nd order quadratic polynomial model used to express the oil recovery (O_r) as a function of speed, applied pressure and feed rate in terms of coded and actual factors is presented in Eqs. (8) and (9) respectively while the Analysis of Variance of the model is presented in Table 3.

Final equation in terms of coded factors

$$O_r = 69.79 - 1.27A + 8.52B - 0.23C - 6.77AB - 1.24AC - 3.46BC - 5.30A^2 - 5.10B^2 + 0.30C^2 \quad (8)$$

Final equation in terms of actual factors

Table 2 Experimental values

Runs	Speed of operation (rpm)	Applied pressure (MPa)	Feed rate (g/min)	Percent oil recovery (%)	Throughput capacity (kg/h)
1	45	15	300	75.5	3.222
2	60	20	400	52.3	2.29
3	45	20	300	75.4	5.411
4	60	10	400	57.7	3.66
5	30	10	200	43.1	6.79
6	30	20	300	76	4.267
7	45	15	300	73.6	2.94
8	45	20	300	77.6	5.54
9	75	15	300	48.9	4.67
10	45	15	300	48.1	3.89
11	60	20	200	63.3	5.423
12	45	15	300	76.1	4
13	45	25	300	65.8	3.264
14	45	15	300	77.5	3.66
15	60	10	200	53.6	6.79
16	30	20	200	78.6	4.267
17	30	10	400	50.9	2.94
18	15	15	300	49.3	5.54
19	45	15	300	64	4.67
20	45	15	500	71.6	3.89

Table 3 ANOVA response for quadratic model predicting oil recovery

Source	Df	Mean square	F value	P value Prob > F
Model	9	241.23	3.42	0.0344 ^a
X-speed of operation	1	24.94	0.35	0.5654
Y-applied pressure	1	658.91	9.34	0.0121 ^a
Z-Feed rate	1	0.4	5.691E-003	0.9414
XY	1	340.7	4.83	0.0527
XZ	1	9.54	0.14	0.7208
YZ	1	74.88	1.06	0.3272
X ²	1	717.11	10.16	0.0097 ^a
Y ²	1	309.06	4.38	0.0628
Z ²	1	1.13	0.016	0.9017
Residual	10	70.56		
Lack of fit	4	13.85	0.13	0.9668
Pure error	6	108.37		–
Correlation total	19	–	–	–

^aSignificant

$$O_r = -145.38643 + 3.63683A + 13.96443B + 0.12057C - 0.09025AB - 8.2418Exp - 0.04AC - 6.92746Exp - 003BC - 0.023562A^2 - 0.20406B^2 + 3.029Exp - 005C^2$$

(9)

(Std. Dev. = 8.4, $R^2 = 0.8747$, Mean = 63.94, Adj. $R^2 = 0.6339$, Pred. $R^2 = 0.5421$).

where O_r is the oil recovery (%), A is the speed of operation (rpm), B is the applied pressure (MPa) and C is the feed rate (g/min).

The relationship between the predicted and actual values (Fig. 2a) shows a high correlation ($R^2 = 0.87$), this means that the values are in close agreement and the data fitted the model perfectly and thus represents the relationship between oil recovery rate and the independent variables appropriately. In the range of speed of operation of 15–75 rpm, applied pressure of 5–25 MPa, and feed rate of 100–500 g/min; an optimum oil recovery of 73.2% was obtained at an experimental value of 45 rpm speed, 20 MPa applied pressure and 300 g/min. The positive terms in the equation suggests a direct interaction between operating parameters and oil recovery rate while the negative terms shows an inverse relationship. The model F-value of 3.42 implies that the model is significant and values of Prob > F less than 0.0500 indicate model terms are significant thus; Y and X² are significant model terms. It was obtained that the model is significant with a very low probability value (< 0.0001) and a satisfactory coefficient of determination which shows that the model can explain 87% of the total variability in the responses.

Figure 2b–d shows that the oil recovery rate increases as the applied pressure increases and speed of operation

increases from 15 to 45 rpm after which a decrease was observed till 75 rpm, it also increases slightly as the feed rate of the machine increases from 100 to 500 g/min (as presented in Figs. 1b, 2d).

Effect of speed, applied pressure and feed rate on throughput capacity

The throughput capacity of the oil expeller varied from 2.29 to 6.79 kg/h with an average value of (± 1.24). an optimum throughput capacity value of 4.18 kg/h was obtained at a combination of speed, applied pressure and feed rate of 45 rpm, 20 MPa and 300 g/min respectively. A quadratic polynomial model was chosen to depict relationship between oil recovery rate and the speed of operation, applied pressure and feed rate based on highest order polynomial where additional terms are significant and the model is not aliased, maximization of adjusted and predicted R^2 , and low standard deviation over other models (linear, two Factorial interaction, quadratic and cubic). The two factorial interaction (2FI) model suggested to express the throughput capacity (T_c) as a function of operating speed, applied pressure and feed rate in terms of coded and actual factors is presented in Eqs. (10) and (11). The throughput capacity can also be referred to as mass flow rate is the quantity of African oil bean kernels processed with time. Higher throughput gives lower oil recovery per kg of seeds, due to shorter residence/retention time in the press. Throughput can also be affected by changing the rotational speed of the screw and feed rate of the machine. The effect of speed of operation, applied pressure and feed rate on throughput capacity is presented in Fig. 2b–d while

Fig. 1 Oil recovery rate as affected by: **b** speed and feed rate, **c** applied pressure and speed **d** applied pressure and feed rate

the predicted and actual throughput as influenced by speed and feed rate is presented in Fig. 2a.

The model F value of 2.18 implies that the model is not significant and values of Prob > F less than 0.0500 indicate model terms are significant thus; Z is a significant model term (Table 4).

Final equation in terms of coded factors

$$T_c = 4.51 - 0.11A - 0.33B - 0.94C - 0.17AB - 0.31AC + 0.49BC \quad (10)$$

Final equation in terms of actual factors

$$T_c = 8.69706 + 0.08906A - 0.25352B - 0.014804C - 2.31828Exp - 0.03AB - 2.0444Exp - 0.04AC + 9.71819Exp - 0.04BC \quad (11)$$

(Std. Dev. = 1.01, $R^2 = 0.8366$, Mean = 4.36, Adj. $R^2 = 0.7329$, Pred. $R^2 = 0.649$).

where Or is the oil recovery (%), A is the speed of operation (rpm), B is the applied pressure (MPa) and C is the feed rate (g/min).

Discussion

The oil content obtained from the use of soxhlet extractor using n-hexane as solvent was 55.6% (± 2.17) of the total

Fig. 2 Throughput capacity as affected by speed of operation, feed rate and applied pressure: **b** effect of speed and feed rate, **c** applied pressure and speed (**d**) applied pressure and feed rate

Table 4 ANOVA response for surface quadratic model for throughput capacity

Source	Df	Mean square	F value	P value Prob > F
Model	6	2.46	2.18	0.1122
X-speed of operation	1	0.17	0.15	0.7019
Y-applied pressure	1	1.4	1.24	0.2851
Z-feed rate	1	8.99	7.98	0.0144 ^a
XY	1	0.23	0.2	0.6619
XZ	1	0.59	0.52	0.4823
YZ	1	1.48	1.31	0.2724
Residual	13	1.13		
Lack of fit	7	1.82	5.83	0.0236 ^a
Pure error	6	0.31		
Cor total	19			

^aSignificant

weight of the kernel. The mechanical screw press yielded a maximum oil recovery of 78.6% and minimum oil recovery of 43.1% within the speed of operation range of 15–75 rpm, applied pressure range of 5–25 MPa and feed rate of 100–500 g/min (35.03%). The oil recovery increases as the speed increased from 15 to 45 rpm and decreased as the speed increased further to 60 and 75 rpm. The oil recovery rate gives an average of half to two-third of the residual oil in oleaginous crops in comparison with the solvent extraction method; this value is in similar trend with literatures for the use of mechanical screw press for oil expression (Bargale et al. 1999). The oil content is far above values reported for similar oil bearing seeds and kernels; Olaniyan et al. (2011) reported 13.48% oil yield for palm kernel and 9.47% for soybean; Moses (2014) reported mean oil yield and expelling efficiency of 6.61–14.22% and 32.26–68.13% respectively for soybean using an oil expeller, the findings from this study are in tandem to reports by Bamgboye and Adejumo (2007), Olaniyan et al. (2010b), Olaniyan et al. (2011), Hassan (2011), and Bamgboye and Adejumo (2015) and Fakayode and Ajav (2016a, b) in the use of oil expellers.

A similar optimum speed of operation of 45 rpm was reported by Davies and Davies (2011); who reported that greater efficiency, higher mass of cake production and greater oil recovery can only be achieved using the pressing method to extract oil if the speed of operation is low and a further increase in the machine speed results in the decline of the machine parameters like reduced mass of cake produced, lower efficiency and lower oil recovery. Also, Olayanju (2003) in the study of effects of speed of shaft screw press (30–75 rpm) on sesame oil quality obtained highest oil yield at 45 rpm screw speed; Olayanju et al. (2006) obtained maximum oil recovery from expelled beniseed at 45 rpm speed of operation. Conversely, Akinoso et al. (2009) obtained maximum percent oil recovery at a screw speed of 110 rpm for palm kernel oil, Deli et al. (2011) reported highest oil yields for *Nigella sativa* L. seed oils at a rotational speed of 21 rpm; Onwuka (2013) and Olatunde et al. (2014) in different application of oil expeller to remove oil from groundnut reported the best performance of expellers at a speed of 60 rpm; the variations in screw speed for different expellers can be attributable to nature (physical and mechanical properties) of the oleaginous crop being processed, power rating of the electric motor and speed of the electric motor used in the design of the oil expeller. The use of oil expellers is cost-effective and does not pose any threat to the immediate environment; the machine is simple to operate (Olaniyan 2010a, 2010b; Ojomo et al. 2011). Less harmful oil free from solvent and cakes which can be used in functional foods, fertilizers and pharmaceutical formulations are also produced from mechanical expression (Al-Obaidi 2013)

even **though solvent extracted oil is higher than mechanical in quantity.

Optimum applied pressure of 20 MPa is in tandem with other oil bearing seeds like roselle (Bamgboye and Adejumo 2011), moringa (Fakayode and Ajav 2016a). It was observed that oil recovery increased as pressure increased from 5 to 20 MPa after which a decline in the oil recovery was noticed. The variations in oil recovery and throughput capacity with the applied pressure may be due to sealing up of inter kernel voids as pressure increases, an increase in pressure is likely to narrow, seal and shear the capillaries through which oil is expressed. The higher the pressure applied, the higher the cost of operation thus, processors of this oilseed should not apply a pressure than the optimum value of 20 MPa reported.

Moreover, the optimum feed rate of 300 g/min is in tandem with findings of Evon et al. (2013) in the extraction of oil from jatropha; Karaj and Muller (2011) in optimising mechanical oil expression of jatropha seeds with respect to press capacity, oil recovery and energy efficiency. However, the optimum feed rate obtained in this study is lower than the value reported by Akinoso et al. (2009) in their study on the effects of compressive stress, feeding rate and speed of operation with an optimum feed rate of 50 kg/h and speed of 110 rpm; this fluctuation may be due to the capacity of the expeller used. However, in-appropriate feeding of an expeller may affect the thermal properties of the constructional material and resultant malfunctioning of the machine; non proportional variation noticed with the feeding rate may be associated with this reason (Akinoso and Igbeka 2006; Akinoso et al. 2009).

Model validation

Adequacy of models was tested using experimental conditions to predict the optimum response values, the Chi-square (χ^2) goodness-of-fit test result examining the validity of the models (Mooney and Swift 1999; Subroto et al. 2015) is presented in Table 5. The deviations between the experimental and calculated values shows that there is no significant difference between the experimental and calculated data for all the dependent variables since the χ^2 value is much smaller than the cut-off value of χ^2 for 95% confidence level for 3 degrees of freedom. This indicates that the generated model is valid at 95% confidence level and there exist a close agreement between calculated values obtained with the model equations and experimental values of the response variables at the point of interest. A good agreement existing between calculated and predicted values showed that the findings fitted the models well and gave a convincingly good estimate of response for the mechanically expressed *Pentaclethra macrophylla* kernels.

Table 5 Validation of models using chi square

Run	Independent variable			Oil recovery (%)				Throughput capacity (kg/h)			
	Speed (rpm)	Applied pressure (MPa)	Feed rate (g/min)	Exp	Calc	Diff	χ^2	Exp	Calc	Diff	χ^2
1	45	20	300	72.7	73.2	0.5	0.00342	4.23	4.18	0.05	0.000598
2	45	20	200	78.2	77.8	0.4	0.00206	4.65	4.63	0.02	8.6Exp-5
3	30	25	300	76.3	75.9	0.4	0.00211	4.28	4.30	0.02	9.3Exp-5
4	60	15	400	62.6	62.1	0.5	0.00403	3.22	3.15	0.07	0.00156
5	30	10	500	55.8	55.5	0.3	0.00162	2.52	2.53	0.01	3.2Exp-5
				$\sum \chi^2$			0.010	$\sum \chi^2$			0.0024

Exp experimental data obtained, Calc the calculated data, Diff difference between Exp and Calc. values, χ^2 Chi Square, $\chi^2 = \sum \frac{(Exp - Calc)^2}{Calc}$

Conclusion

The effect of operating parameters including speed of operation, applied pressure and feed rate on oil recovery and throughput capacity of mechanically expressed *Pentaclethra macrophylla* kernels was investigated. Models predicting the relationship between the variables were developed. Optimum oil recovery and throughput capacity was obtained at 45 rpm, 20 MPa and 300 g/min. The models were validated and they showed an excellent agreement between the operating parameters and respective responses and the result showed that the speed of operation, applied pressure and feed rate had a significant effect on the oil recovery and throughput capacity of an expeller when used to express oil from *Pentaclethra macrophylla*.

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Compliance with ethical standards

Conflict of interest The authors do solemnly declare that there are no conflicts of interest on financial and or commercial application of this study.

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