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Research Article

Optimization of Mechanical Oil Expression from Sandbox (*Hura crepitans* Linn.) Seeds

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RETRACTION

ABSTRACT

Optimization of process variables has become very vital in oil extraction processes to obtain maximum oil yield from oilseeds and nuts. This work focussed on the optimization of process oil extraction process from sandbox seed by mechanical expression. Effects of moisture content, roasting temperature, roasting time, expression pressure and expression time on oil yield from sandbox seed was studied using a 5×5 Central Composite Rotatable Design of Response Surface Methodology experimental design. Results obtained were subjected to Analysis of Variance (ANOVA) and SPSS statistical tool at ($p = 0.05$). Optimum conditions predicted were validated by experiments. All the processing factors were significant at ($p = 0.05$) for the sandbox oil yield except roasting temperature. The experimental results and predicted values showed low deviation (0.01-0.62). Oil yields obtained from the sandbox seed at varying process conditions varied from 16.38-38.68%. The maximum oil yield of 38.68% was obtained when the sandbox seed was subjected to process conditions of 6% moisture content, 85°C roasting temperature, 15 min roasting time, expression pressure of 20 MPa and 8 min pressing time. Mathematical equations to predict sandbox seed oil yield at varying process conditions were developed with an R^2 (0.8908). The optimum extractable oil yield of 38.95% was predicted for sandbox seed at processing conditions of 7.03% moisture content, 97.72°C roasting temperature, 11.32 min roasting time, 15.11 MPa expression pressure and 8.57 min expression time. The study results provide data for designs of process and equipment for oil extraction from sandbox and other oilseeds.

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INTRODUCTION

The sandbox (*Hura crepitans* Linn.) tree is of the (Euphorbiaceae) family, indigenous to the humid zones of the American continents. The sandbox is referred to as the dynamite tree because of the shooting reverberations of the matured pods as they split before dropping. The sandbox seeds are flattened, about 2 cm, arranged as carpel of 14-16 seeds in fruit capsules of height 3-5 cm and diameter of 5-8 cm (Feldkamp, 2006; Okolie *et al.*, 2012). Consumption of sandbox seed has been reported to cause sicknesses such as burning throat, suffocation, headache, nausea, stomach pain, vomiting and diarrhea, while the plant sap coming in contact with the eye can cause blindness. Sandbox leaves have been recognized to be used as curatives, but the seed has not really been harnessed and used (Allen, 2000; Clarke, 2000). Sandbox seed has been noted to contain a number of important properties that can be useful for the production of feeds, paints, and cosmetics amongst others (Olatidoye *et al.*, 2010; Idowu *et al.*, 2012). Sandbox seed was noted amongst seeds with high oil content (Idowu *et al.*, 2012; Basumatary, 2013). Sandbox seed properties, proximate composition and its oil's chemical characterization have been studied (Fowomola and Akindahunsi, 2007; Idowu *et al.*, 2012; Okolie et al., 2012). However, sandbox has been classified amongst underutilized species of plants; in most parts of the world, the trees have been used as shade due to their large spreading branches (Idowu *et al.*, 2012). In Nigeria, the trees are grown as cover plants, while the seeds were thrown away as waste (Adewuyi *et al.*, 2012).

Oil extraction from sandbox seeds by earlier studies was focused mainly on solvent extraction (Okolie *et al.*, 2012; Muhammed *et al.*, 2013; Adewuyi *et al.*, 2014; Nwanorh, 2015; Ottih *et al.*, 2015; Shonekan and Ajayi, 2015). Oil extraction by solvent methods has increased oil recovery up to 98% and has made it economically attractive for some oilseeds (Matthäus, 2012). However, oil extraction by mechanical methods still remains a good option for oil extraction from seeds and nuts.

Mechanical oil expression from many agricultural products has been studied, viz: almond seed (Akubude *et al.*, 2017); groundnut (Pominski *et al.*, 1970; Adeeko and Ajibola, 1990; Olajide *et al.*, 2014); dika kernels (Abidakun *et al.*, 2012; Ogunsina *et al.*, 2014); African oil bean (Aremu and Ogunlade, 2016); various clones of rubber seed (Ebewele *et al.*, 2010); fine and coarse roselle seed (Bamgboye and Adejumo, 2011); sesame seeds (Tunde-Akintunde *et al.*, 2000; Akinoso *et al.*, 2006; Hashim *et al.*, 2014; Elkhaleefa and Shigidi, 2015); soybean seed (Mwithiga and Moriasi, 2007; Lawson *et al.*, 2010); bitter gourd (Umamaheshwari and Dinesh Sankar Reddy, 2016); neem seed (Awolu *et al.*, 2013; Orhevba *et al.*, 2013); avocado fruit (Southwell and Haris, 1990); rice bran respectively (Sivala *et al.*, 1991); coconut (Hammonds *et al.*, 1991); shea butter (Olaniyan and Oje, 2007); melon (Ajibola *et al.*, 1990); conophor nuts (Fasina and Ajibola, 1989); peanut (Badwaik *et al.*, 2012); sunflower kernels (Southwell and Harris, 1992); African star apple seed (Ajala and Adeleke, 2014); *Moringa* seed (Adejumo *et al.*, 2013; Fakayode and Ajav, 2016).

According to Mwithiga and Moriasi (2007), seed quality is the first determinant of the quantity and quality of producible oil from an oilseed, before the consideration of the process and machine to be used. Variations in seed and machine parameters including seed size, moisture level, preparation temperature and time, expression pressure and duration of extraction greatly influence oil yields from oilseeds and nuts during mechanical expression

(Khan and Hanna, 1984). It is therefore of optimum importance to control these parameters during oil extraction for optimal oil extraction. Improper management of these variables during mechanical expression may possibly lead to low oil yield and oil quality. Therefore, quality lipid feedstocks and effective handing before expression are vital to achieving quality and higher oil yield (Bamgboye and Adejumo, 2011).

Data for mechanical oil extraction from sandbox seed and process optimization of same is however scarce. To quantify and predict oil yield from sandbox seed by mechanical expression relatively to process factors, the Response Surface Methodology (RSM) was employed. According to Giwa *et al.* (2015), process optimization where other process factors are kept constant and varying one, does not correctly capture the inter-relationship existing amongst the factors. Hence, such procedure may not accurately predict the best combination of interaction of factors that gives the optimum outcome of the process. The (RSM) was developed as an appropriate statistical tool for optimization of processes. It employs the use of Central Composite Design (CCD), Box-Behnken design and D-optimal experimental designs (Triveni *et al.*, 2001). According to Hamzat and Clarke (1993), accurate knowledge of interactions between oil expression devices and processing variables improves the efficiency of oil extraction. RSM has shown to be a tool in effectively relate the inter-relationship occurring amongst process variables such as effect of moisture, heat application and heating time, pressing pressure and duration on oil yield. Superior to normal methods, the RSM uses minimal experimental investigations to predict the values of process factor combination for optimum result(s) and also generates model equation(s) connecting the factors and response(s) (Giwa *et al.*, 2015). RSM utilizes results from practical experiments to generate models that can predict response such as oil yield in relation to process factors. In this work, how process factors: moisture content, treating temperature and time, expression pressure and time influence oil expression and yield from sandbox seed was investigated and optimized using the RSM.

MATERIALS AND METHODS

Design of experimental

Among processing factors, seed moisture, treating temperature and time, expression pressure and time have been observed to significantly at ($p = 0.05$) increase oil yield by mechanical expression methods (Fakayode and Ajav, 2016). The process of oil extraction from sandbox seed by mechanical means was optimized by varying these factors. The design of experiment adopted was 5×5 factorial Central Composite Rotatable Design (CCRD) of Response Surface Methodology developed by Box *et al.* (1978). According to Fakayode and Ajav (2016), CCRD is combining factorial, (d_f), axial, (d_a) and central, (d_c) design points respectively. $t = 2^c\left(d_f\right) + 2c(d_a) + c(d_c)$, represents the total number of treatments, where 'c' is the number of process factors. The average experiment of the CCRD design was 32 combinations, representing $T = 2^{c-1} + 2c + (t_0)$ design points, consisting of 16 factorial CCD, 10 axial points and 6 replications of the center points.

The initial moisture content of the mature sandbox seed influenced the decision of the moisture content range selected for the experiment. There is a lack of information on mechanical extraction of oil from sandbox seed, its oil yield and optimization of the process. Thus, data from previous studies on oil extraction by mechanical methods from other oilseeds was used to carry out preliminary investigations on the sandbox seed. Results obtained informed the varying values of process factors selected for the experiment. Values used were; moisture content, mc (4, 6, 8, 10 and 12% wet-basis); roasting temperature, γ_{tp} (80, 85, 90, 95 and 100°C) and time, γ_{tm} (0, 5, 10, 15 and 20 min); expression pressure, ε_{Pr} (5, 10, 15, 20 and 25 MPa) and time, εx_{tm} (2, 4, 6, 8 and 10 min).

Development of laboratory screw press

A five-barrel pilot screw press (Figure 1) was developed and used for the experiment. Designed for 25MPa maximum capacity, the screw pitch diameter was calibrated by length to vary the applied pressure. Preliminary test was conducted by placing a piece of wire gauze into the base of the screw press barrel, and 500 gram sample of the ground sandbox was placed on the wire gauze and another piece of wire gauze was placed on the specimen. The 25 MPa mark was got with a spring gauge as a point where the press screw could not push the sample any further. Pitch lengths were used to mark the other pressure points; 20, 15, 10 and 5 MPa respectively. The multiple barrel press designed was adopted to easily cover the multiple experiments carried out.

Preparation of sample

About 100 kg of mature sandbox fruits were collected from under the trees in Uyo metropolis, Akwa Ibom State, Nigeria between 2106-2018. The fruits (Figure 2) were cracked to remove the seeds (Figure 3) and the seeds peeled to get the kernel (mesocarp) (Figure 4).

Figure 1. Screw press.

Figure 2. Sandbox fruits.

Figure 3. Sandbox seeds.

Figure 4. Sandbox kernels.

Moisture content determination

Initial moisture content of the sandbox seeds was determined using ASABE standard for oven drying method as adopted by Olaoye (2000), Ozguven and Vursavus (2005), Fakayode and Ajav (2016) and Onwe *et al.* (2020) for castor nut, pine nuts, African star apple and

Moringa seeds respectively. Three 50 g ground samples of the sandbox box seed designated A, B, C were used for the experiment. The three different samples were placed and dried in the oven at 105°C and weighed after 6 hours and subsequently at intervals until a constant weight was attained. Equation 1 below was used to calculate the mc (wet-basis).

$$MC\ (\%\ w.b.) = \frac{W_i - W_f}{W_i} \times 100 \quad (1)$$

W_i = initial sample weight and W_f = final sample weight

1 kg each of the samples were subjected to 4, 6, 8, 10 and 12% wet basis moisture content respectively using Equation 2 as adopted by Olajide (2000); Fakayode and Ajav (2016).

$$Q = \left(\frac{100 - S_i}{100 - S_d} - 1\right) \times W_s \quad (2)$$

Q = quantity of required moisture to be absorbed (ml); S_i = initial sample moisture (%wb); S_d = required sample moisture (%wb); W_s = weight of sample (g)
The conditioned samples were wrapped in fabrics and placed in polyethylene bags and stored in a refrigerator at 5°C for two days for the required moisture content to even up.

After that, the samples were stored in a desiccator to retain them at the conditioned moisture content for the experiment.

Experimental procedures

From the already conditioned samples of the sandbox seed at 4, 6. 8, 10, 12% wb moisture content, the various experiments were conducted using 500 g weight. A hotplate was used for roasting the sandbox seed samples. The various roasting temperature levels of 80, 85, 90, 95 and 100°C were achieved by regulating the hotplate temperature. A frying pot was placed on top of the hotplate, and a digital thermometer probe was used to check the pot temperature until the required temperatures were obtained before pouring the sandbox seed samples for frying. A stopwatch was used to time the roasting periods for 0, 5, 10, 15 and 20 min respectively. Afterwards, the samples were fed into the extraction chamber (barrel); wire gauze was placed at the base of the barrel and on top of the samples before pressing. The samples were subjected to 5, 10, 15, 20 and 25 MPa extraction pressure, at 2, 4, 6, 8 and 10 min extraction duration. The experiments were replicated three times. Pressed samples were left to drain into containers for three days before the weight of the oil was determined (Weiss, 2000). Oil yields were determined by Equation 3, used by Bello and Daniel, (2015) for groundnut oil yield determination.

$$Oil\ Yield\ (\%) = \frac{Wieght\ of\ oil\ expressed}{Wieght\ of\ sandbox\ seed\ sample\ before\ pressing} \times 100 \quad (3)$$

Response Surface Methodology (RSM)

The experiment was designed using a software package of RSM Design Expert (6.0.6). The software generated sets of combinations of experimental factors when their ranges were keyed in. These combinations of factors were used for the experiments. The oil expressions were carried out using these combinations. The percentage of expressed oil for each experiment was keyed in as the response of the particular combination. The Design Expert contains four different models, which include the linear, the two factorial interactions (2FI), the quadratic and the cubic models respectively. These four models analyses the outcome of the experiments in terms of the probability of error value (p-value) and coefficient of determination (R^2), which are statistical parameters indicating the degree of relationship between process factors and oil yield. The decision on the best model for the oil expression process was based on their p and R^2 values. The chosen model was subjected to Analysis Of Variance (ANOVA) to further prove the model's level of significance and fitness in explaining the relationship between the process factors and oil yield. Then the tests of between-subjects of effects of processing conditions on oil yield were analyzed using Windows 20.0 SPSS statistical software package. Combination conditions suggested to be optimal for oil expression by the model were used to conduct fresh experiments for validation. Then, the results from real experimental and model predicted values were also compared to test for similarities.

RESULTS AND DISCUSSION

The moisture content of 6.12% wb was obtained as the initial moisture content of the sandbox seed. The oil yields from the combination of varying process conditions are as shown in Table 1. Plots relating the process factors and the oil yield are presented in Figures. 5-9. The sandbox oil yield varied from 16.38-38.68%. The optimum oil yield of 38.68% was obtained when the sandbox seed was subjected to process conditions of 6% moisture content, 85^oC roasting temperature, 15 min roasting time, expression pressure of 20 MPa and 8 min pressing time. Relatively to sandbox seed oil extraction by solvent methods; Ottih *et al.* (2015) and Okolie *et al.* (2012) obtained 57.26% and 53.61% oil yield respectively using n-hexane. Nwanorh (2015) obtained 42.70% oil yield using petroleum ether. According to Bockisch (1998), the reason why solvent extraction produces better oil yield when compared to other extraction methods could be as a result of solvents permeation ability to solubilize lipids in the cell structures to extract as much oil as possible. However, Adewuyi *et al.* (2014) and Shonekan and Ajayi (2015) obtained 37.75 and 36.70% oil yield respectively using n-hexane. Difference in oil yield during extraction is a function of extraction methods employed, and also biological and environmental conditions (Anwar *et al.*, 2006; Orhevba *et al.*, 2013).

Table 1. Oil yield from sandbox seed at various processing conditions.

Run	Factor 1 A: mc (%)	Factor 2 B: $ɤ_{tp}$ (%)	Factor 3 C: $ɤ_{tm}$ (min)	Factor 4 D: ε_{Pr} (MPa)	Factor 5 E: εx_{tm} (min)	Response Oil yield (%)
1	8	90	10	15	6	36.14
2	6	85	5	10	8	32.77
3	6	95	15	10	8	35.09
4	10	95	15	10	4	23.66
5	8	90	10	15	2	16.38
6	8	90	10	15	6	35.00
7	10	85	15	20	4	24.43
8	8	90	10	15	10	37.02
9	8	80	10	15	6	32.66
10	4	90	10	15	6	32.22
11	8	90	10	15	6	36.22
12	6	85	15	10	4	24.68
13	8	90	10	15	6	35.00
14	10	95	5	20	4	19.44
15	10	85	5	20	8	25.00
16	8	100	10	15	6	36.00
17	6	95	15	20	4	25.00
18	6	95	5	10	4	21.66
19	8	90	20	15	6	34.33
20	8	90	10	15	6	36.77
21	10	95	15	20	8	32.88
22	8	90	10	5	6	18.66
23	8	90	10	25	6	30.00
24	12	90	10	15	6	20.49
25	6	95	5	20	8	30.66
26	10	85	5	10	4	24.99
27	8	90	10	15	6	35.66
28	8	90	0	15	6	18.62
29	10	95	5	10	8	32.54
30	10	85	15	10	8	34.65
31	6	85	15	20	8	38.68
32	6	85	5	20	4	23.11

Where mc = moisture content of sandbox seed, $ɤ_{tp}$ = Roasting temperature, $ɤ_{tm}$ = Roasting time, ε_{Pr} = Expression pressure and εx_{tm} = Extraction time

The oil recovery from the sandbox seed increased substantially at the moisture content range of 4-8% wb, but declined when the moisture level exceeded 8% wb (Figures 5-6). This could be attributed to the observation by Sivala *et al.* (1992), that moisture addition pushes particles faster to saturation points during oil expression. Nevertheless, in the presence of excess moisture, the particle's liquid phase absorbs the expression pressure and debar it from reaching the oil capillaries, thereby, decreasing oil yield.

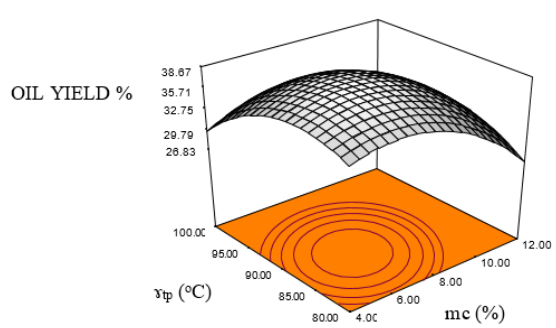

Figure 5. Extraction time and moisture content against oil yield.

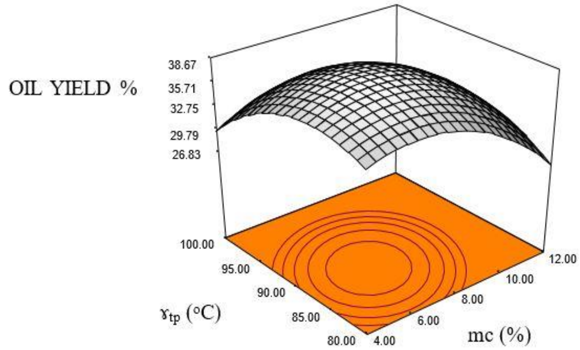

Figure 6. Roasting temperature and moisture content against oil yield.

The highest oil yield was obtained for sandbox seed at the moisture level of 8% wb (Figures 5-6). The trend agrees to earlier results from groundnut, neem, avocado, roselle, dika and locust beans (Southwell *et al*., 1990; Owolarafe *et al*., 2003; Ogunsina *et al*., 2008; Bamgboye and Adejumo, 2011; Orhevba *et al*., 2013; Olajide *et al*., 2014) and many other authors as the most suitable moisture level for mechanical oil extraction.

Increase in the sandbox box oil yield was observed as the roasting temperature increased from 80-90°C. The oil yield decreases as the roasting temperature increased from 90-100°C (Figs. 6-7). Roasting temperature has been recognized as one of the factors that greatly enhance oil yield (Costa *et al*., 2014; Terigar *et al*., 2011; Martinez *et al*., 2013). According to Fakayode and Ajav, (2016), expected oil yield cannot be got from oil samples at lower heating temperatures. At the same time, roasting at high temperatures hardens oil samples, causing them to resist applied pressure during extraction, and thus, leading to lower oil yield. In comparison, the roasting temperature value for maximum oil recovery from sandbox seed was similar to 81.93°C heating temperature reported by Olajide, (2000) for groundnut kernel (*Arachis hypogeae*), 90°C reported by Aremu and Ogunlade, (2016) for African oil bean seed. The sandbox seed grain is very soft and roasting at 90°C was suitable heat treatment to release optimum oil yield from it.

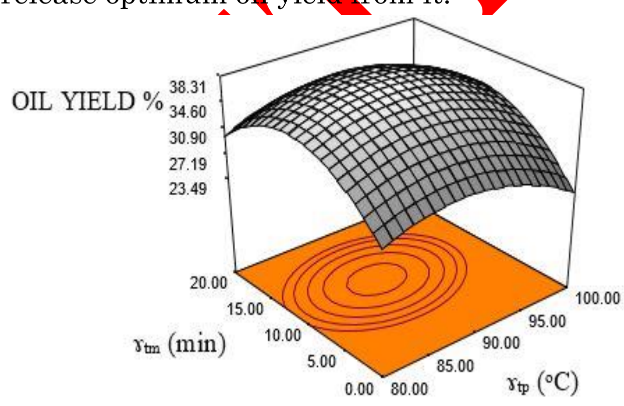

Figure 7. Roasting time and roasting temperature against oil yield.

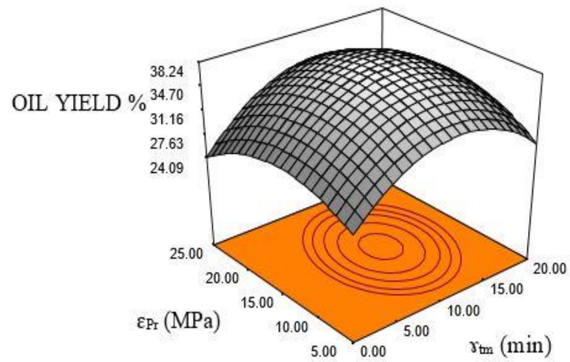

Figure 8. Expression pressure and roasting time against oil yield.

Findings from Ajibola *et al.* (1993); Alonge *et al.* (2003); Bamgboye and Adejumo (2011) are all in agreement with this heat treatment observed for sandbox seed, which was attributed to the phenomenon of oilseeds undergoing concurrent decrease in moisture content, oil viscosity and protein coalescence by heat injection, which enhances oil expression. However, at higher temperatures, excessive moisture loss can occur, causing seed hardening, thereby reducing the oil yield. This observation conforms to findings on dika nut, groundnut, and shea kernel respectively (Olaniyan and Oje, 2007; Abidakun *et al.*, 2012; Olajide *et al.*, 2014;).

Roasting the sandbox samples up to 15 min increased the oil yield (Figures 7-8). It was observed that the oil yield was least for the un-roasted sample which represents the 0-minute roasting time. The unroasted samples yielding the lowest oil is an indication of the importance of heat-treating oil samples before extraction. Sandbox oil yield decreased at roasting time above 15 min. Kagwacie and Anozie (1995) observed that the flow of oil is inversely proportional to the kinematic viscosity. Thus, as heat treatment progresses, kinematic viscosity of samples is lowered for oil to flow. According to Fakayode and Ajav (2016), heating oilseed samples at lowered temperatures requires more time to allow for the adjustment of moisture content to the optimum level that would lead to the folding of oil vessels, congealing of protein and allow flowability, but heating at higher temperature would take shorter time to reach these conditions, that additional heat would cause a reduction in oil yield. Movement of moisture during heat treatment creates a vacuum which becomes an accommodating capacity for the rupturing oil capillaries as heating continue. Oil yield is higher and faster and proportional to the rate of protein coalescence and decline in kinematic viscosity (Ajibola *et al.*, 2000; Akintunde *et al.*, 2001). This phenomenon enables the emergence of oil from the oil tubes into the inter-grain vacuum (Adeeko and Ajibola, 1990). This occurrence could be obtained at higher roasting temperatures and short time respectively, while extended roasting time at higher temperatures causes drastic drop in moisture content, leading to hardening of oilseeds which results in decrease in oil yield. The sandbox oil yield was highest when seed samples were roasted at 85^oC for 15 min (Figures 7-8). Similar conditions were reported for groundnut and sheanut (Adeeko and Ajibola, 1990; Olajide, 2000; Ajav and Olatunde, 2011).

The sandbox oil yield was observed to increase with increase in expression pressure of 5-20 MPa, which decreased as the pressure increased to 25 MPa (Figures 8-9). It was observed that the pressed sandbox mash slurried and clogged the screw press oil holes and overflowing the pressing plate at pressure above 20 MPa. This may be that at pressing pressure beyond 20 MPa, the sandbox oil bearing capillaries were crushed, hence blocking the flow of oil. Bamgboye and Adejumo (2011) observed that seed cells rupture during oil expression due to pressure on seed cell walls, which causes them to release their lipid contents. Conversely, as the applied pressure increases, oil capillaries are repeatedly compressed, disrupted and could eventually become blocked (Ward, 1976). This finding on sandbox seed is similar to reports on other oilseeds and nuts: groundnut, rice bran, melon, roselle, dika, soybean, conophor (Fasina and Ajibola, 1989; Adeeko and Ajibola, 1990; Ajibola *et al.*, 1990; Sivala *et al.*, 1992; Akintunde *et al.*, 2001; Bamgboye and Adejumo, 2011; Ogunsina *et al.*, 2014).

The sandbox oil yield increased with increase in expression time from 2-8 min and dropped as the pressing time exceeded 8 min (Figure 9). The result is similar to those reported by Olajide *et al.* (2014) on groundnut kernel and Mwithiga and Moriasi (2007) on soybeans.

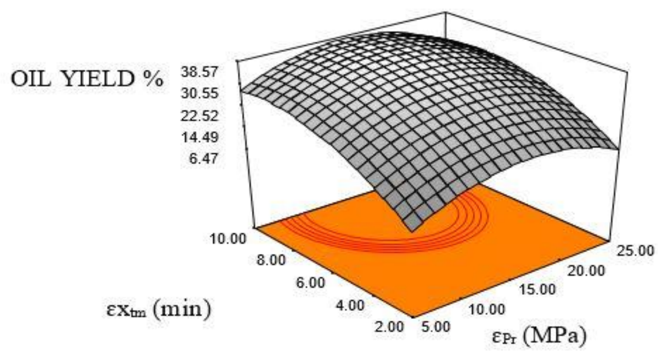

Figure 9. Roasting temperature and moisture content against oil yield.

Response surface optimization of oil extraction from sandbox seed

Out of the four models of the RSM software, the one chosen for the prediction of oil yield from sandbox seed by mechanical means was based on the model with the best statistics as regards the polynomial order with the largest number non- aliasing significant additional terms, insignificant lack-of-fit and high Adjusted and Predicted *(R^2)*. The quadratic model with the highest R^2 and lower standard deviation values (Table 2) was selected.

Table 2. Model comparison.

	Models			
Statistics	**Linear**	**2Factorial Interaction**	**Quadratic**	**Cubic**
Standard Deviation, SD	4.84	5.86	3.72	2.21
R^2	0.5623	0.6053	0.8907	0.9789
Mean	29.39	29.39	29.39	29.39
Adjusted R^2	0.4781	0.2353	0.6921	0.8909
Coefficient of Variation, C.V.	16.47	19.93	12.65	7.53
Predicted R^2	0.3910	-2.1284	-1.8079	-19.9477
PRESS	847.71	4352.06	3906.19	29140.84
Adequate Precision	9.272	5.449	7.280	10.349

PRESS = Predicted Sum of Square.

Mathematical relationship for predicting oil yield from sandbox relatively to the process factors is given in Equation 5.

$$OY = 35.35 - 1.5mc - 0.03\gamma_{tp} + 2.5\gamma_{tm} + 0.49\varepsilon_{Pr} + 4.8\varepsilon x_{tm} - 1.91mc^2 + 0.086\gamma_{tp}^2 - 2.41\varepsilon_{Pr}^2 - 1.83\varepsilon x_{tm}^2 + 0.39mc\gamma_{tp} - 0.098mc\gamma_{tm} - 1.09mc\varepsilon_{Pr} - 0.64mc\varepsilon x_{tm} - 0.27\gamma_{tp}\gamma_{tm} + 0.058\gamma_{tp}\varepsilon_{P} + 0.47\gamma_{tp}\varepsilon x_{tm} + 1.04\gamma_{tm}\varepsilon_{Pr} + 0.74\gamma_{tm}\varepsilon x_{tm} - 0.30\varepsilon_{Pr}\varepsilon x_{tm} \quad (5)$$

[SD = 3.72, R^2 = 0.8908, Mean = 29.39, Adjusted R^2 = 0.6922, C.V. = 12.66, Predicted R^2 = –1.8061, PRESS = 3910.93, Adequate Precision = 7.301 and F-value of 4.49 (Tables 2 and 3)]

OY = Oil Yield (%), *mc* = moisture content of sandbox seed, γ_{tp} = Roasting temperature, γ_{tm} = Roasting time, ε_{Pr} = Expression pressure and εx_{tm} = Extraction time

From the equation, the oil yield varies directly with factors with positive sign and inversely with factors with negative sign. The values of "Prob > F" in Figure 3, lower than 0.05, such as γ_{tm}, εx_{tm}, mc^2, γ_{tm}^2, ε_{Pr}^2, and εx_{tm}^2, represents significant model parameters for sand box oil extraction.

Table 3. ANOVA for Response Surface Quadratic Model of the Oil Extraction

Source	Sum of squares	DF	Mean square	F value	Prob > F
Model	1241.52	20	62.08	4.49	0.0069^s
mc	58.56	1	58.56	4.23	0.0642
γ_{tp}	0.022	1	0.022	0.0016	0.9688
γ_{tm}	151.76	1	151.76	10.97	0.0069^s
ε_{pr}	5.82	1	5.82	0.42	0.5299
ε_{tm}	568.13	1	568.13	41.06	0.0001^s
mc^2	106.76	1	106.76	7.47	0.0180^s
γ_{tp}^2	0.22	1	0.22	0.016	0.9026
γ_{tm}^2	103.43	1	103.43	7.47	0.0194^s
ε_{pr}^2	171.01	1	171.01	12.36	0.0048^s
ε_{tm}^2	98.39	1	98.39	7.11	0.0219^s
$mc\gamma_{tp}$	2.44	1	2.44	0.18	0.6825
$mc\gamma_{tm}$	0.15	1	0.15	0.011	0.9179
$mc\varepsilon_{pr}$	18.86	1	18.86	1.36	0.2677
$mc\varepsilon_{tm}$	6.46	1	6.46	0.47	0.5084
$\gamma_{tp}\gamma_{tm}$	1.14	1	1.14	0.082	0.7795
$\gamma_{tp}\varepsilon_{pr}$	0.054	1	0.054	0.004	0.9513
$\gamma_{tp}\varepsilon_{tm}$	3.51	1	3.51	0.25	0.6246
$\gamma_{tm}\varepsilon_{pr}$	17.28	1	17.28	1.25	0.2875
$\gamma_{tm}\varepsilon_{tm}$	8.69	1	8.69	0.63	0.4449
$\varepsilon_{tp}\varepsilon_{tm}$	1.47	1	1.47	0.11	0.7506
Residue	152.21	11	13.84		
Lack of fit	149.68	6	24.95	49.25	0.0003^s
Pure Error	2.53	5	0.51		
Cor Total	1393.74	31			

The quadratic model had a high R^2 of 0.8908 and very low p-value of less than 0.0001 and thus was concluded to be significant (Table 4). The R^2 of 0.89 is an indication of a direct relationship between the oil yield and the process factors, showing 89.08% confidence that the model explained 89.08% of every irregularity as regards the process factors and oil yield.

Table 4. Test of between-subjects effect of process conditions on oil yield from sandbox seed

Source	df	Mean Square	F	Significance
Corrected Model	27	51.439	86.003	0.0001^{s}
Intercept	1	10656.051	17816.504	0.0001^{s}
mc	3	67.567	112.970	0.0001^{s}
$ϒ_{tp}$	2	4.189	7.004	0.049
$ϒ_{tm}$	2	122.883	205.456	0.0001^{s}
$ε_{Pr}$	2	124.977	208.957	0.0001^{s}
$εx_{tm}$	2	164.746	275.449	0.0001^{s}
Error	4	0.598		
Total	32			
Corrected Total	31			

The 4.49 model F-value (Table 3) indicated that the model effectively explained the inter-relationships between process factors and oil yield. The quadratic curve relationship is one of optimum and minimum. That means that there are process parameters values in which oil yield would be optimum or minimum. The sandbox seed grain is very soft, similar to melon seed, thus a mild roasting temperature of 85°C for 15 min was enough heat treatment to release optimum oil yield from it. The sandbox mash slurried and clogged the screw press oil holes and overflowing the pressing plate at pressure above 20 MPa and pressing time above 8 min and moisture content above 6% wb. The optimum oil yield for sandbox seed was obtained at the process variable ranges. From the findings, process parameter values for optimal sandbox oil yield were determined. Findings from Ebewele *et al.* (2010); Bamgboye and Adejumo (2011); Olajide *et al.* (2014); Yusuf *et al.* (2014); Aremu and Ogunlade (2016); Akubude *et al.* (2017) agrees with this finding as regards mechanical oil expression.

Model validation

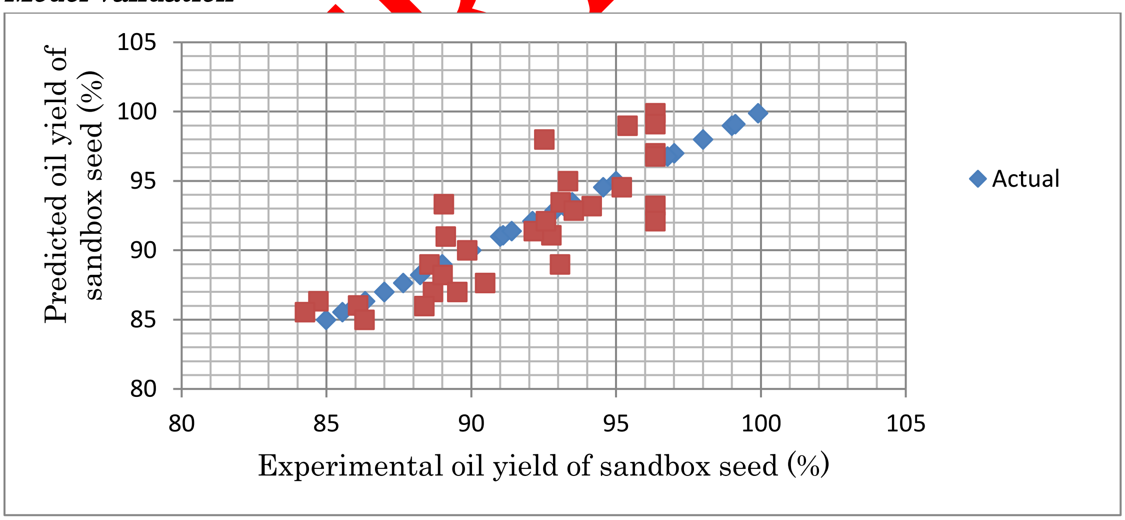

Figure 10. Predicted oil yield against actual oil yield

A similarity plot of correlation relationship of the laboratory results and predicted results of oil yield from the sandbox seed is shown in Figure 10. The R^2 of 0.8908 of the relationships is an indication of high correlation between the predicted oil yield values and the values gotten from the actual experiment. This is an indication that without distortions that accompany practical experiments, the model represents a reliable equivalent for the estimation of extractable oil from sandbox seed by mechanical means within the range of process variables studied. At the range of process factors: 8-12% wb moisture content, 80-100°C roasting temperature, 0-20 min roasting time, 5-25 MPa expression pressure and 2-10 min expression time, the maximum oil yield of 38.68% was obtained at 6% wb moisture content, 85°C roasting temperature, 15 min roasting time, expression pressure of 20 MPa and 8 min pressing time, while the predicted optimum oil yield was 38.95% at processing conditions of 7.03% moisture content, 97.72°C roasting temperature, 11.32 min roasting time, 15.11 MPa expression pressure and 8.57 min extraction time. Experiments carried out under the predicted optimum conditions produced an oil yield of 38.90%, validating the predicted oil yield and the processing conditions. The variations between the experimental and predicted results were low at the ranged 0.01-0.62. This is an indication that model used reasonably predicted the oil yield from sandbox seed by mechanical screw press.

CONCLUSION

Oil extraction process from sandbox seed using screw press was optimized. From the variations of process factors studied, the extracted oil from sandbox seed varied from 16.38-38.68%. The 38.68% oil yield, which was the highest, was attained at the process factor combination of 6% wb moisture content, 85°C roasting temperature, 15 min roasting time, 20 MPa expression pressure and 8 min pressing time. The model maximum predicted oil yield was 38.95% at 7.03% moisture content, 97.72°C roasting temperature, 11.32 min roasting time, 15.11 MPa expression pressure and 8.57 min extraction. Experiments carried out under the predicted optimum conditions produced an oil yield of 38.90%, validating the predicted oil yield and the processing conditions. The variations between the experimental and predicted results were low at the range of 0.01-0.62. All process factors considered seem to have greatly influenced the oil yield, with roasting temperature been insignificant. The model developed for the sandbox oil expression, with R^2 of 0.8908 indicates a high correlation between the process factors. The similarity between the values oil yield from actual experiment and predicted values, indicates that the model adequately predicted the oil yield from sandbox seed by mechanical expression.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

David Nwabueze ONWE: Conceptualization, Sample collection, Methodology, Investigation, Data collection, Analysis, Validation, Writing of Report.
Adeleke Isaac BAMGBOYE: Supervision, Visualization, Review, Correction and Editing of Report.

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