

## PAPER 33 – EFFECTS OF PROCESS PARAMETERS ON OIL AND BIODIESEL YIELD FROM SANDBOX (*HURA CREPITANS*) SEED

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### ABSTRACT

Multiple applications of vegetable oil for food, industrial applications and biodiesel production have necessitated the need to boost product yield. Process factors that influence oil and biodiesel yield were investigated. Factors studied for oil extraction were, moisture content (%wb), roasting temperature (°C), roasting time (min), extraction temperature (°C) and time (min). Reaction time (min), reaction temperature (°C), catalyst concentration (%wt) and molar ratio were investigated for biodiesel yield. Central composite rotatable design of response surface methodology experimental design was used for the study. Results obtained were analysed at ( $p \leq 0.05$ ). The oil yield from the sandbox seed ranged from 20.9-53.6%. The maximum oil yield of 53.6% was obtained at the processing conditions of 10.0%wb moisture content, 95 °C roasting temperature, 15 min roasting time, 65 °C extraction temperature and 90 min extraction time. The biodiesel yield ranged from 80.00-96.12% and, maximum biodiesel yield of 96.12% was extracted at 72.0 min reaction time, 50.0 °C reaction temperature, 0.9%wt catalyst concentration and 1:6 molar ratio. Mathematical models to predict sandbox seed oil and biodiesel yields at varying process conditions were developed. Coefficient of determination ( $R^2$ ) relating the oil extraction and biodiesel production were 0.81 and 0.74, respectively. The results from the study provide data for equipment and process designs for oil extraction and biodiesel production from sandbox and other oilseeds.

**KEYWORDS:** *Hura crepitans*, Oil extraction, oil yield, biodiesel production, biodiesel yield.

### 1. INTRODUCTION

Sandbox (*Hura crepitans* Linn.) is a dicotyledon tree of the (spurge) family Euphorbiaceae. It is a native tree of the tropical zones of the Amazon rainforest of North and South America (Adewuyi *et al.*, 2014). Sandbox seed has been suggested to contain a high oil content in addition to a number of important properties that can be useful for food and feed production, paints, and cosmetics amongst others industrial application and pharmaceutical potentials (Olatidoye *et al.*, 2010; Onwe and Bamgboye, 2020; Basumatary, 2013). It is however grouped under underutilized species of plant (Adewuyi *et al.*, 2014). According to Idowu *et al.* (2012), sandbox is used as shade trees in many parts of the world because their wide spreading limb. In corroboration, Adewuyi *et al.* (2012) noted that sandbox is an underutilized plant in Nigeria and the seeds are unused. Solvent extraction has made it more profitable to recover most oil from seeds, nuts, and other materials with relatively low oil content, as up to 98% of oil can be recovered using solvent extraction (Matthäus, 2012). Oil is extracted from oil-bearing matters using crude liquids like acetone, ether, chloroform, petroleum, spirit, carbon tetrachloride, diethyl ether, and carbon tetra chloride. Various oilseeds have been studied to determine the best extraction conditions for the highest oil yield: sesame seed (Hashim *et al.*, 2014; Elkhaleefa and Shigidi, 2015); rubber seed (Awais *et al.*, 2015); soybean seed (Lawson *et al.*, 2010); dried Bitter Gourd seed (Umamaheshwari and Dinesh Sankar Reddy, 2016); canola seed (Blake, 1982); un-sieved rice bran and sieved rice bran respectively (Sivala *et al.*, 1991); sunflower kernels (Southwell and Harris, 1992) and grated coconut (Hammonds *et al.*, 1991); Neem (*Azadirachta indica*) seed (Awolu *et al.*, 2013); Sorrel (*Hibiscus sabdariffa*) seed (Betiku and Adepoju, 2013); almond seed (Akubude *et al.*, 2017); Dika nut (Abidakun *et al.*, 2012); groundnut (Olajide *et al.*, 2014); Shea kernel (Olaniyan and Oje, 2007); African star apple seed (Ajala and Adeleke, 2014); *Moringa* seed (Adejumo *et al.*, 2013). The global concern of the rapid depletion of the petroleum and its potential extinction, coupled to environmental pollution emissions from its combustion exhaust, has made biodiesel from organic lipids an available substitute to petroleum diesel (Reyes and Spulveda, 2006; Goering *et al.*, 1982). Organic lipids like vegetable oils, animal fats, waste oils, and recycled lubricants are combined with alcohol, primarily methanol or ethanol, in a displacement reaction known as transesterification to create fatty esters like methyl/ethyl ester (biodiesel). Factors that influence methyl ester yield from lipids have been studied (Zhang *et al.*, 2003; Ma and Hanna, 1999; Meher *et al.*, 2006; Van, 2005 and Schuchardt *et al.*, 1998). Oil extraction by solvent extraction method from sandbox seed have been reported (Okolie *et al.*, 2012; Muhammed *et al.*, 2013; Adewuyi *et al.*, 2014; Shonekan and Ajayi, 2015; Nwanorh, 2015; Ottih *et al.*, 2015). Biodiesel was produced from sandbox seed oil (Adewuyi *et al.*, 2012; Adepoju *et al.*, 2013; Igbum *et al.*, 2012). The present work is focused on investigating the effects of process parameters on sandbox seed oil and biodiesel yield respectively.

## 2. MATERIALS AND METHODS

About 100 kg of mature sandbox fruits were collected from Uyo metropolis, Akwa Ibom State, Nigeria between (2016-2018). The fruits were cracked to remove the seeds and the seeds peeled to get the kernel (mesocarp) (Figure 2.1).



Figure 2.1 Sandbox seed processing

### 2.1. Solvent oil extraction from sandbox seed

Oil extraction was carried out according to the American Oil Chemists' Society (AOCS 5-04) standard procedure. A six-in-one Soxhlet apparatus was used for the extraction process. The experiments were carried out at varying processing conditions: moisture content, mc (4, 6, 8, 10 and 12% wet-basis), roasting temperature,  $r_{tp}$  (80, 85, 90, 95 and 100°C) and time,  $r_{tm}$  (0, 5, 10, 15 and 20 min), extraction temperature,  $e_{tp}$  (60, 65, 70, 75 and 80°C) and time,  $e_{tm}$  (60, 90, 120, 150 and 180 min). The sandbox seed oil (Figure 2.2) was weighed and taken as a fraction of the ground seed samples. The oil yield was calculated from Equation 2.1 as adopted by Bello and Daniel (2015) for determination of oil yield percentage.

$$\text{Oil Yield (\%)} = \frac{\text{Wiegth of oil extracted}}{\text{Wiegth of sandbox seed sample used in the extraction}} \times 100 \quad (2.1)$$



Figure 2.2 Biodiesel production

### 2.2. Biodiesel production from sandbox seed oil

The effects of process variables: reaction time (24, 48, 72, 96 and 120 min), reaction temperature (40, 45, 50, 55 and 60 °C), catalyst concentration (0.3, 0.6, 0.9, 1.2 and 1.5 %wt) and molar ratio (1:2, 1:4, 1:6, 1:8 and 1:10 methanol: oil ratio) on the methyl ester yield were investigated. Two hundred millilitres (200 ml) of sandbox seed oil, amounting to 184 g in weight was used in each of the experiment. Other parameters were calculated as percentage weight or volume of the oil. Methanol was used as the alcohol in the transesterification reaction, and potassium hydroxide was used as the catalyst for the reaction. The Central Composite Rotatable Design (CCRD) of Response Surface Methodology was used for both experiments. Experiments were replicated thrice.

## 3. RESULTS AND DISCUSSION

The results of the sandbox oil and biodiesel yields at various process conditions are presented in Tables 3.1 and 3.2 respectively. Charts showing the effects of process parameters on oil and biodiesel yield are shown in Figures 3.1-3.4.

Table 3.1 Oil Yield from Sandbox Seed at Various Processing Conditions

Run	Factor 1 A: mc (%)	Factor 2 B: $r_{tp}$ (%)	Factor 3 C: $r_{tm}$ (min)	Factor 4 D: $e_{tp}$ (°C)	Factor 5 E: $e_{tm}$ (h)	Response 1 Oil yield (%)
1	8	90	10	70	2.0	45.76
2	8	90	10	70	3.0	35.02

3	8	90	10	70	1.0	23.00
4	6	85	5	65	2.5	38.33
5	8	90	10	60	2.0	42.87
6	10	85	15	75	1.5	40.00
7	10	85	5	75	2.5	40.12
8	4	90	10	70	2.0	20.86
9	10	85	15	65	2.5	48.88
10	8	90	10	80	2.0	44.00
11	12	90	10	70	2.0	30.00
12	8	90	10	70	2.0	45.00
13	6	95	15	65	2.5	40.00
14	8	90	10	70	2.0	50.00
15	8	90	10	70	2.0	49.80
16	10	95	15	75	2.5	46.54
17	6	85	15	65	1.5	35.66
18	10	95	5	65	2.5	36.00
19	8	80	10	70	2.0	38.10
20	8	90	10	70	2.0	47.77
21	10	85	5	65	1.5	36.56
22	6	95	15	75	1.5	39.00
23	10	95	5	75	1.5	42.40
24	6	85	5	75	1.5	39.60
25	6	85	15	75	2.5	40.55
26	6	95	5	65	1.5	40.06
27	6	95	5	75	2.5	38.99
28	8	90	10	70	2.0	46.44
29	8	90	0	70	2.0	21.00
30	10	95	15	65	1.5	53.60
31	8	90	20	70	2.0	47.99
32	8	100	10	70	2.0	51.33

Where  $mc$  = moisture content of sandbox seed,  $\gamma_{tp}$  = Roasting temperature,  $\gamma_{tm}$  = Roasting time,  $\varepsilon_{tp}$  = Extraction temperature and  $\varepsilon_{tm}$  = Extraction time

The oil yield from the sandbox seed ranged from 20.86-53.60%. The highest oil yield of 53.60% obtained was similar to 53.61 and 53.81% obtained by Okolie *et al.*, (2012) and Muhammed *et al.* (2013), and higher than 37.75, 36.70 and 42.70% obtained by Adewuyi *et al.* (2014), Shonekan and Ajayi, (2015) and Nwanorh, (2015). The value was however lower than the 57.26% obtained by Ottih *et al.* (2015). According to Anwar *et al.* (2006); Orhevba *et al.* (2013), differences in oil yield during extraction are a function of extraction methods employed, and also biological and environmental conditions.

Increase in oil yield was observed as the moisture content increased from 4-10%wb, after which the yield declined (Fig. 3.1). The highest oil yield was obtained at 10% seed moisture; the decline in oil yield at moisture contents above 10%wb could be attributed to the observation that the ground sandbox seed forms a slurry paste at moisture contents above 10%, making further oil removal difficult. The trend is in agreement with reports on soybeans, and un-sieved and sieved rice bran (Lawson *et al.*, 2010; Sivala *et al.*, 1991) among others.

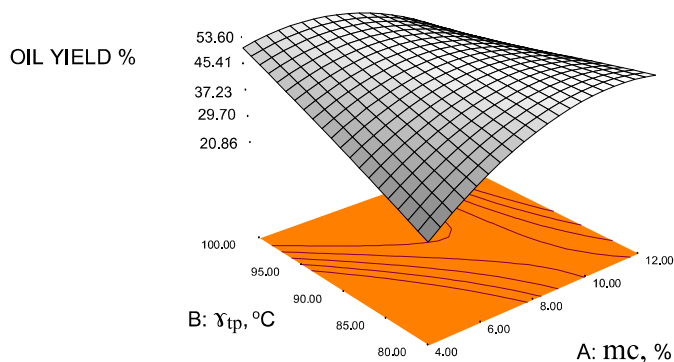


Figure 3.1. Oil yield against roasting time and moisture content

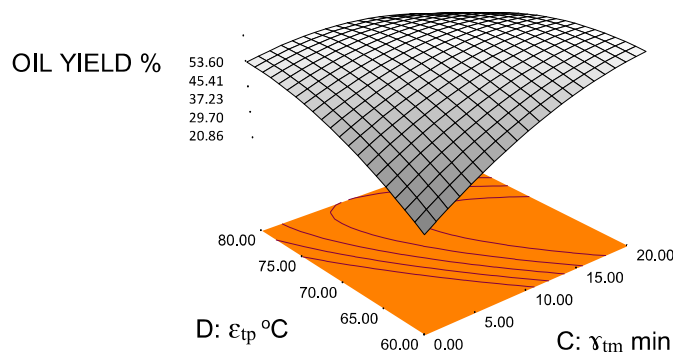


Figure 3.2. Extraction time and roasting temperature against oil yield

The sandbox oil yield increased as roasting temperature increased. The highest oil yield occurred at the roasting temperature region of 95-100°C (Figure 3.1). Due to the sandbox seed's softness, a seed similar to melon seed, roasting temperature around 100 °C was sufficient to penetrate the seed and release its oil. Similar roasting temperature of 100°C was obtained for maximum oil yield from *Moringa oleifera* (Adejumo *et al.* (2013). The unroasted samples at 0 min roasting time produced the lowest oil yield from the sandbox, and then the oil yield increased with an increase in roasting time up to 15 min beyond which the yield became constant (Figure 3.2). The sandbox oil yield increased with an increase in extraction temperature up to 75 °C, after which the oil yield decreased (Figure 3.2). Extraction temperature range of 60-90 °C has been reported to be suitable for maximum oil yield from seeds and nuts by solvent extraction. Solvent extraction temperature of 60 °C was reported by Asoiro and Akubuo (2012) as suitable for maximum oil extraction from *Jatropha curcas* L. Umamaheshwari and Dinesh Sankar Reddy (2016) obtaining maximum oil yield from bitter gourd at 98 °C extraction temperature and Elkhaleefa and Shigidi (2015) reported a lower extraction temperature of 40 °C for maximum oil yield from sesame seed. The sandbox oil yield increased with increase in extraction time up to 120 min, beyond which a decrease in oil yield was observed. It was observed that 2 hours reaction time was enough for complete oil removal from sandbox seed by solvent extraction. Lawson *et al.* (2010) obtained maximum oil yield from soybeans at an extraction time of 2½ hours.

Table 3.2. Biodiesel Yield from the Transesterification of Solvent Extracted Sandbox Seed Oil

S/N	Factor 1 A:τ <sub>tm</sub> (min)	Factor 2 B:ε <sub>tp</sub> (°C)	Factor 3 C:ç <sub>cc</sub> (% of oil wt)	Factor 4 D:η <sub>ra</sub> (% vol. of oil)	Response Fuel yield (%)
1	48	45	0.60	8	86.20
2	96	45	0.60	4	86.12
3	48	55	0.60	4	88.65
4	48	55	1.20	4	81.02
5	48	45	1.20	8	83.79
6	48	45	0.60	4	86.25
7	96	45	0.60	8	87.16
8	72	50	0.90	6	94.55
9	72	50	0.90	6	94.89
10	72	50	0.30	6	89.48
11	72	50	0.90	2	80.11
12	72	50	0.90	6	91.99
13	96	55	0.60	4	88.01

14	96	55	1.20	4	82.36
15	96	45	1.20	4	83.88
16	72	50	0.90	10	87.98
17	72	40	0.90	6	88.42
18	120	50	0.90	6	92.68
19	48	55	0.60	8	91.23
20	72	60	0.90	6	96.12
21	48	55	1.20	8	83.33
22	24	50	0.90	6	81.65
23	72	50	0.90	6	86.99
24	96	55	1.20	8	81.22
25	72	50	0.90	6	87.98
26	96	45	1.20	8	82.63
27	48	45	1.20	4	80.11
28	72	50	0.90	6	92.65
29	96	55	0.60	8	85.00
30	72	50	1.50	6	80.00

Where  $t_{\text{im}}$  = reaction time,  $t_{\text{ip}}$  = reaction temperature,  $c_{\text{cc}}$  = catalyst concentration (KOH) and  $m_{\text{ra}}$  = molar ratio

The biodiesel yield ranged from 80.00-96.12%. The maximum biodiesel of 96.12% was extracted at 72.0 min reaction time, 50.0 °C reaction temperature, 0.9%wt catalyst concentration and 1:6 molar ratio.

The biodiesel yield increased with increase in reaction time from 24 min to about 90 min before a decline in biodiesel yield was observed (Figure 3.3). This was an indication that transesterification reaction for sandbox seed oil requires about 1.5 hour to be completed. Similarly, Math *et al.* (2010) reported 90 min reaction time as optimum for maximum biodiesel yield from lipids with FFA. A lower reaction time of 40 min was obtained by Nakpong and Wootthikanokkhan (2010) for maximum biodiesel yield from crude *Jatropha curcas* oil. Reports have shown that transesterification process is spontaneous at the beginning of the reaction, converting approximately 80% of the reactants into ester fuels in the first 5 min and gaining approximately 93-98% conversion after 1 h of reaction period (Encinar *et al.*, 2005; Srivastava and Prasad, 2000; Alcantra, 2000; Shailendra *et al.*, 2008).

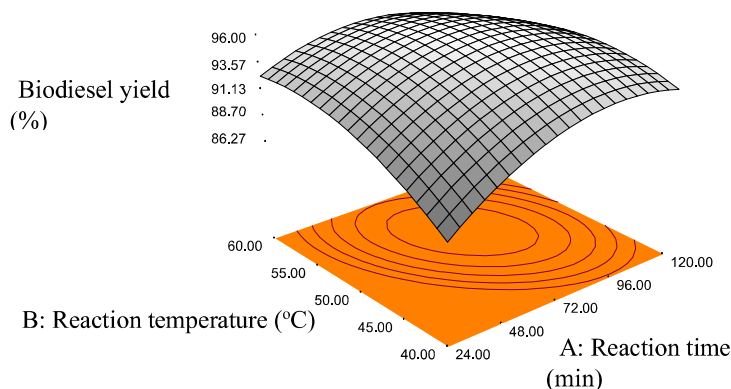


Figure 3.3. Reaction temperature and reaction time against fuel yield

The sandbox biodiesel yield increased with increase in reaction temperature from 40 °C to 50 °C after which the yield became steady (Figure 3.3). This indicates that 50-60 °C reaction temperature range is adequate for the

transesterification of sandbox seed oil. The reaction temperature was same with 60 °C obtained by Adepoju *et al.* (2013) for sandbox seed oil biodiesel and lower than 70 °C obtained by Adewuyi *et al.* (2014) for maximum biodiesel yield from transesterification of (H<sub>2</sub>SO<sub>4</sub>) acid pre-treated sandbox seed oil and but the. This difference in reaction temperature might be due to reaction process used. Similar reaction temperatures were reported by (Alhassan *et al.*, 2014 for *Gossypium Arboreum* seed oil; Anguebes-Franseschi *et al.*, 2016 for crude palm oil of African origin; Nakpong and Wootthikanokkhan, 2010 for *Jatropha* seed; Singh *et al.*, 2006 for canola oil; Mansourpoor and Shariati, 2012 for sunflower oil).

The biodiesel yield increased as the catalyst concentration increased from 0.3% to 0.9% after which the yield dropped sharply. The value 0.9% g wt/wt of oil represents 0.5% weight of volume of oil used in the reaction (Figure 3.4). The result is average to 0.4% and 0.55% obtained by Adewuyi *et al.*, 2014 and Adepoju *et al.*, 2013 for sandbox seed. Similar result was obtained by Alhassan *et al.*, 2014 for *Gossypium Arboreum* seed oil, Anguebes-Franseschi *et al.*, 2016 African palm oil and Mansourpoor and Shariati, 2012 for sunflower seed.

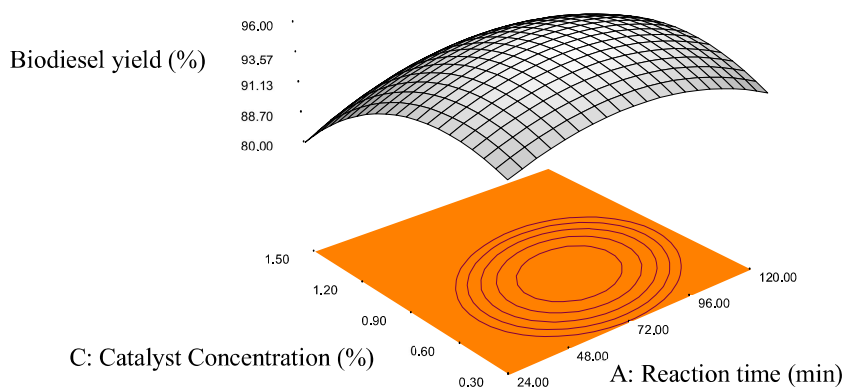


Figure 3.4. Catalyst concentration and reaction time against fuel yield

The sandbox biodiesel increased with increase in molar ratio from 1:2 up to 1:6 after which a decrease in yield was observed (Figure 3.4). Adewuyi *et al.* (2014) and Adepoju *et al.* (2013), obtained ratios of 1:6 and 1:5 respectively for maximum biodiesel yield from sandbox seed oil. Similar molar ratio was reported by Anastopoulos *et al.*, 2009; Alhassan *et al.*, 2014; and Nakpong and Wootthikanokkhan, 2010 as optimum for maximum biodiesel yield from four different vegetable oils, *Gossypium Arboreum* seed oil and *Jatropha curcas* seed oil respectively. The optimum molar ratio of 1:6 or less for other edible oils has been found to give the highest fuel yield (Encinar *et al.*, 2005; Vicente *et al.*, 2004; Dorodo, 2002).

#### a. Processes model equations

Mathematical relationship for predicting oil yield from sandbox relatively to the process factors is given in Equation 3.1. The coefficient of determination (R<sup>2</sup>) relating the oil extraction process and oil yield was 0.81.

$$\begin{aligned} \bullet \quad OY = & 45.89 + 2.09mc + 1.81\chi_{tp} + 3.59\chi_{tm} + 0.013\varepsilon_{tp} + 1.10\varepsilon_{tm} - 1.91mc^2 - 0.88\chi_{tp}^2 - 1.67\chi_{tm}^2 + 0.56\varepsilon_{tp}^2 \\ & - 3.05\varepsilon_{tm}^2 + 0.57mc\chi_{tp} + 2.23mc\chi_{tm} - 0.63mc\varepsilon_{tp} - 0.29mc\varepsilon_{tm} + 0.70\chi_{tp}\chi_{tm} - 0.23\chi_{tp}\varepsilon_{tp} - 1.85\chi_{tp}\varepsilon_{tm} - \\ & 1.39\chi_{tm}\varepsilon_{tp} + 0.80\chi_{tm}\varepsilon_{tm} + 0.50\varepsilon_{tp}\varepsilon_{tm} \end{aligned} \quad (3.1)$$

Where, OY = Oil Yield (%), mc = moisture content of sandbox seed,  $\chi_{tp}$  = Roasting temperature,  $\chi_{tm}$  = Roasting time,  $\varepsilon_{tp}$  = Extraction temperature and  $\varepsilon_{tm}$  = Extraction time

Mathematical relationship for predicting biodiesel yield from sandbox relatively to the process factors is given in Equation 3.2. The coefficient of determination (R<sup>2</sup>) relating the transesterification process and biodiesel yield was 0.74.

$$\begin{aligned} \bullet \quad \text{Fuel Yield} = & 91.51 + 0.74r_{tm} + 0.84r_{tp} - 2.47\dot{c}_{cc} + 0.83m_{ra} - 1.46r_{tm}^2 - 0.18r_{tp}^2 - 2.07\dot{c}_{cc}^2 - 2.24m_{ra}^2 - \\ & 0.69r_{tm}r_{tp} + 0.49r_{tm}\dot{c}_{cc} - 0.81r_{tm}m_{ra} - 0.60r_{tp}\dot{c}_{cc} - 0.17r_{tp}m_{ra} + 0.19\dot{c}_{cc}m_{ra} \end{aligned} \quad (3.2)$$

Where  $r_{tm}$  = reaction time,  $r_{tp}$  = reaction temperature,  $\dot{c}_{cc}$  = catalyst concentration (KOH) and  $m_{ra}$  = molar ratio

## 4. CONCLUSION

Effects of process factors on oil and biodiesel yield from sandbox seed were investigated. Among the process factors studied, the oil yield from the sandbox seed ranged from 20.9-53.6%. The maximum oil yield of 53.6%

was obtained at the processing conditions of 10.0%wb moisture content, 95 °C roasting temperature, 15 min roasting time, 65 °C extraction temperature and 90 min extraction time. The biodiesel yield ranged from 80.00-96.12%. The maximum biodiesel of 96.12% was extracted at 72.0 min reaction time, 50.0 °C reaction temperature, 0.9%wt catalyst concentration and 1:6 molar ratio. Mathematical models to predict sand box seed oil and biodiesel yields at varying process conditions were developed with 0.81 and 0.74 coefficient of determination ( $R^2$ ).

## REFERENCES

- Abidakun O. A., Koya O. A., and Ajayi, O. O. (2012). *Effect of extraction conditions on the yield of Dika Nut (Irvingia gabonensis) oil under uniaxial compression*. Proc. ICCM, 315-320.
- Adejumo B. A., Alakowe A. T., and Obi D. E. (2013). *Effect of heat treatment on the characteristics and oil yield of Moringa oleifera seeds*. The International Journal of Engineering and Science (IJES), 2(1), 232-239.
- Adepoju T. F., Abiodun A., Okunola A.A., and Dahunsi O. S. (2013). Experimental investigation of sand box biodiesel performance in an internal combustion engine. International Journal of Engineering Research & Technology (IJERT), 2(11), 3833-3855.
- Adeyuyi A., Paul O., Awolade, P. O., and Oderinde R. A. (2014). *Hura crepitans seed oil: an alternative feedstock for biodiesel production*. Journal of Fuels, 464590 (8).
- Adeyuyi A., Gopfert A., Wolff T. Rao B. V. S. K., and Prasad R. B. N. (2012). *Synthesis of azidohydrin from Hura crepitans seed oil: a renewable resource for oleochemical industry and sustainable development*. ISRN Organic Chemistry, 2012/ID 873046.
- Ajala A. S., Adeleke S. A. (2014). *Effect of drying temperatures on physicochemical properties and oil yield of african star apple (Chrysophyllum albidum) seeds*. Global Journal of Engineering Design and Technology (G.J. E.D.T.), 3(3), 12-16.
- Akubude V. C., Maduako J. N., Egwuonwu C. C., Olaniyan A. M., Ozumba I. C., Nwosu C., and Ajala O. E. (2017). *Effect of process parameters on oil yield mechanically expressed from almond seed (Using Response Surface Methodology)*. American Journal of Food Science and Nutrition Research, 4(1), 1-8.
- Alcantra, R., et al. 2000. *Catalytic production of biodiesel from soy-bean oil used frying oil and tallow*. Biomass Bioenergy, 18, 515-527.
- Alhassan, Y., Kumar, N., Bugaje, I. M., and Mishra, C. (2014). *Optimization of (Gossypium arboretum) seed oil biodiesel production by Central Composite Rotatable Model of Response Surface Methodology and evaluation of its fuel properties*. Journal of Petroleum Technology and Alternative Fuels, 5(1), 1-12.
- Anguebes-Franseschi, F., et al. (2016). *Optimization of biodiesel production from African crude palm oil (Elaeis guineensis Jacq) with high concentration of free fatty acids by a two-step transesterification process*. Open Journal of Ecology, 6, 13-21.
- Anwar F., Zafar S. N., Rashid U. (2006). *Characterization of Moringa oleifera seed oil from drought and irrigated regions of Punjab*. Pakistan Grasas Aceites, 57(2), pp. 60-168.
- Asoiro F. U., Akubuo C. O. (2012). *Effect of temperature on oil extraction of Jatropha curcas L. kernel*. The Pacific Journal of Science and Technology, (2), 456-463.
- Awais B., Suzana Y., and Murni M. A. (2015). *Optimization of the Parameters that Affects the Solvent Extraction of Crude Rubber Seed Oil Using Response Surface Methodology (RSM)*. Recent Advances in Engineering, 28-33.
- Awolu O. O., Obafaye R. O., Ayodele B. S. (2013). *Optimization of solvent extraction of oil from neem (Azadirachta indica) and its characterizations*. Journal of Scientific Research and Reports, 2(1), 304-314.
- Basumatary S. (2013). *Non-conventional seed oils as potential feedstocks for future biodiesel industries: A Brief Review*. Research Journal of Chemical Sciences, 3(5), 99-103.
- Betiku, E., and Adepoju, T. F. (2013). *Sorrel (Hibiscus sabdariffa) seed oil extraction optimization and quality characterization*. American Chemical Science Journal, 3(4), 449-458.
- Blake J. A. (1982). *Evaluation of an On-farm Press*. In: *Vegetable oil fuels*. ASAE Publication, No. 482, MI 49055, 247-251.
- Bello E. I., and Daniel F. (2015). *Optimization of groundnut oil biodiesel production and characterization*. Applied Science Report, 9(3), 172-180.
- Dorodo, W., Ballesteros, E., De Almeida, J., Schellert, C., Lohrlein, H., and Krause, R. 2002. *An alkali-catalyzed transesterification process for high free fatty acid waste oils*. Trans ASAE, 45(3), 525-9.
- Elkhaleefa A., Shigidi, Ihab I. (2015). *Optimization of sesame oil extraction process conditions*. Advances in Chemical Engineering and Science, 5, 305-310.
- Encinar, J. M., Gonzalez, J. F., and Reinares, A. R. (2005). *Biodiesel from used frying oil: variables affecting the yields and characteristics of the biodiesel*. Ind. Eng. Chem. Res., 44, 5491-9.
- Goering C. E., Schwab A. W., Daugherty M. J., Pryde E. H., and Heakin A. J. (1982). *Fuel properties of eleven oils*. Transactions ASAE, 25, 1472-1483.
- Hammonds T. W., Harris R.V., and Head S. W. (1991). *The influence of moisture content on the extraction of oil from fresh grated Coconut*. Tropical Science, 31, 73-81.

- Hashim, A. B., Giwa, S. O., Ibrahim, M., and Giwa, A. (2014). *Finding the optimum parameters for oil extraction from sesame seed using Response Surface Methodology*. International Journal of Scientific Research and Management Studies (IJSRMS), 2(1), 1-13.
- Idowu D. O., Abegunrin T. P., Ola F. A., Adediran A. A., Olaniran J. A. (2012). *Measurement of some engineering properties of sandbox seeds (Hura crepitans)*. Agriculture and Biology Journal of North America, 8, 318-325.
- Igbum O. G., Eloka-Eboka A. C and Nwadinigwe C. A. (2012). *Effects of transesterification variables on yields and properties of biodiesel fuels produced from four virgin tropical seeds oils*. International Journal of Environmental Bioenergy, 1 (1), 119-130.
- Lawson O. S, Oyewumi A., Ologunagba F. O., Ojomo A. O. (2010). *Evaluation of the parameters affecting the solvent extraction of soybean oil*. ARPN Journal of Engineering and Applied Sciences, 5(10), 51-55
- Ma F., and Hanna M. (1999). *Biodiesel production: A review*. Bioresource Technology, 70(1), 1-15.
- Mansourpoor, M., and Shariati, A. (2012). *Optimization of biodiesel production from sunflower oil using response surface methodology*. J. Chem Eng Process Technol, 3(4), 5.
- Math, M. C., Sudheer, P. K., and Soma V. C. 2010. *Optimization of biodiesel production from oils and fats with high free fatty acids*. Indian Journal of Science and Technology, 3:3, 318-321.
- Matthäus B. *Oil technology*. S.K. Gupta (ed.), *Technological Innovations in Major World Oil Crops*, pp. 2.
- Meher L. C., Sagar D. V., and Naik S. N. (2006). *Technical aspects of biodiesel production by Transesterification: A review*. Renewable Sustainable Energy Reviews, 10(3), 248-268.
- Muhammed N. A., Isiaka A. A., and Adeniyi O. A. (2013). *Chemical composition of Hura crepitans seeds and antimicrobial activities of its oil*. International Journal of Science and Research (IJSR), 2(3), 440-445.
- Nakpong, P., and Wootthikanokkhan, S. (2010). *Optimization of biodiesel production from Jatropha curcas L. oil via alkali-catalyzed methanolysis*. Journal of Sustainable Energy and Environment, 1, 105-109.
- Nwanorh K. O. (2015). *Extraction and characterization of oil from Hura crepitans (sandbox tree)*. International Research Journal of Education and Innovation, 1-2(17), 60-62
- Okolie P. N., Uaboi-Egbenni P. O., and Ajekwene A. E. (2012). *Extraction and quality evaluation of sandbox tree seed (Hura crepitans)*. Oil World Journal of Agricultural Sciences, 8(4), 359-365.
- Olajide J. O., Afolabi J. O., and Adeniran J. A. (2014). *Optimization of oil yield from groundnut kernel (Arachis hypogaeae) in an hydraulic press Using Response Surface Methodology*. Journal of Scientific Research and Reports, 3(14), 1916-1926.
- Olaniyan A. M., Oje K. (2007). *Development of mechanical extraction rig for dry extraction of Shea butter from Shea kernel*. Journal of Food Science and Technology, 44(5), 465-470.
- Olatidoye O. P., Adeleke A. E., Adegbite S. A., and Sobowale S. A. (2010). *Chemical composition and nutritional evaluation of sandbox (Hura crepitans) seed flour for domestic consumption and industrial*. Journal of Medical and Applied Biosciences, 2, 72-83.
- Onwe, D. N., and Bamgboye A. I. 2020. *Effect of process conditions on sandbox seed oil yield by mechanical expression: A response surface approach*. Sci. J. Agric. Eng. 3, 70-81
- Orhevba B. A., Chukwu O., Osunde Z. D., Ogwuagwu V. (2013). *Influence of moisture content on the yield of mechanically expressed neem seed kernel oil*. Academic Research International, 4(5), 252-257
- Reyes J. F., and Sepulveda M. A. (2006). *PM-10 Emissions and power of a diesel engine fuelled with crude and refined biodiesel from salmon oil*. Fuel, 85, 1714-9.
- Umamaheshwari P., Dinesh Sankar Reddy, P. (2016). *Effect of operating parameters on extraction of oil from bitter gourd seeds: a kinetic and thermodynamic study*. International Journal of Science and Research (IJSR), 5(2), 1243-1246.
- Vicente, G., Martinez, M., and Aracil, J. (2004). *Integrated biodiesel production: a comparison of different homogeneous catalysts systems*. Biores Technol, 92, 297-305.
- Shailendra S., Avinash, K. A., and Sanjeev, G. (2008). *Biodiesel development from rice bran oil: Transesterification process optimization and fuel characterization*. Elsevier; Energy Conversion and Management, 49, 1248-1257.
- Shonekan F. O., and Ajayi J. O. (2015). *The biochemical analysis of Hura crepitans (Sandbox Tree) seed oil and meal*. Globalacademicgroup.com, Retrieved January 15, 2016.
- Sivala K., Bhole N. G., and Mukherjee R. K. (1991). *Effect of moisture on rice bran oil extraction*. Journal of Agricultural Engineering Research, 1(50), 81-91.
- Southwell K. H., and Harris, R. V. (1992). *Extraction of oil from oilseeds using the hot water flotation method*. Tropical Science, 2(82), 251-256.
- Srivastava A., and Prasad R. (2000). *Triglycerides-based diesel fuels*. Renewable Sustainable Energy Rev, 4, 111-33.
- Van Gerpen J. (2005). *Biodiesel processing and production*. Fuel Processing Technology, 86(10), 1097-1107.
- Zhang Y., Dubé M. A., McLean D. D., and Kates M. (2003). *Biodiesel production from waste cooking oil: process design and technological assessment*. Bioresource Technology, 89, 1-16.