Journal of Engineering Research and Reports

Volume 26, Issue 3, Page 113-124, 2024; Article no.JERR.113711
ISSN: 2582-2926

Effect of Thermally Extracted Carrot Oil Using Biomass Solvent to Boost Consumer Goods: Box-Behnken Design Approach

F. C. Ozioko [a*], Sunday Chukwuka Iweka [b], N. E. Nwanze [c] and T. F. Adepoju [a]

[a] Department of Chemical Engineering, Delta State University of Science and Technology, Ozoro, Nigeria.
[b] Department of Mechanical Engineering, Delta State University of Science and Technology, Ozoro, Nigeria.
[c] Department of Agricultural Engineering, Delta State University of Science and Technology, Ozoro, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2024/v26i31098

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/113711

Original Research Article

Received: 20/12/2023
Accepted: 27/02/2024
Published: 02/03/2024

ABSTRACT

Massive production of fast-moving consumer goods boosts the economy of any nation. Thus, the need to look into ways of accelerating and transforming carrot utilization into more commercialized usage in order to add value to the developmental strides of any nation where carrot is cultivated like Nigeria. This study concluded that the optimization of the carrot oil extracted from crushed carrot and coconut oil (biomass volume) via soxhlet equipment using Box-Behnken Design (BBD) of Response Surface Methodology (RSM) approach, generated an ideal optimal output of 18.58 wt% at SW of 60 g, BV of 200 ml and ET of 14mins. Although, three input elements which are sample

**Corresponding author: Email: oziokofabian@yahoo.com;*

weight (SW), biomass volume (BV), and extraction time (ET) were modelled to generate 17 setups by BBD, but standard order (Std) 8 from the 17 setups generated an ideal output of 18.58 wt%. Thus, the process optimization of the extraction process via BBD of RSM showed that both the coefficient of determination (R^2) which is 0.9886, and the difference between adjusted R^2 and predicted R^2 which is less than 0.2 fall within an ideal range. Also, the elements considered for modeling are mutually significant with the quadratic model equation and the interactive effects of the independent parameters on the carrot oil output showed that an increase in the sample weight and time led to a corresponding increase in the carrot oil output, and this is corroborated by the perturbation plot. Additionally, the physiochemical valuables of the carrot oil generated showed that the free fatty acid and the acid value were very low signifying that the carrot oil is edible and can be used in the manufacturing process using the saponification method in making soap and moisturizing cream for the benefit of mankind.

Keywords: Biomass volume; carrot; Soxhlet equipment; BBD; FMCG.

1. INTRODUCTION

The demand for a healthy nation requires concepts that can derive development and reduce pollution for the benefit of humans on earth [1-3]. Oil can be derived from renewable and non-renewable sources. Renewable sources are preferable because its eco-friendly, available, cheaper, and accessible [4-7]. And renewable sources leads to bio-oil production from biomaterials (biomass) [2,3,5,8].

From Inception, different animal and plant sources have been utilized for bio-oil production such as edible seeds like palm kernel seeds [3], carrot [9], pumkin seeds [8] etc. and inedible seeds like pawpaw seeds [2], neem seeds, castor seeds [10], yellow oleander-rubber seed [11] etc. Animal sources like goat fat-poultry waste fat [8]. Although, carrot is an edible seeds used for making varieties of food, perfumery, pharmaceutical, juices and blends [12], its utilization for bio-oil may attack food chain, but for a country to attain significant development especially struggling countries like Nigeria with worsening economic crisis, there is need to look into ways of accelerating and transforming carrot utilization into more commercialized usage in order to add value to the developmental strides of any nation where carrot is cultivated like Nigeria.

Carrots is one of the most commonly used vegetables for human nutrition and consumed daily due to its vitamin and fiber content. Carrot (*Daucus carota subsp. Satiyus*) is a root vegetable and very economical [13]. It has varieties of colours like orange, purple, red, white, and yellow depending on location [9]. Carrot are majorly grown in Asia, Europe, Iran, Afghanistan, Nigeria, Mexico, USA etc. [12,14]. And a steady increase in carrot juice consumption has also been reported from other countries like Japan, Afghanistan, Iran, Switzerland, Germany, Mexico, USA, China, Spain etc. [15]. It is regarded as a healthy food item because of its high vitamin and fiber content [16,17]. Carrot as depicted in Fig. 1 is a fast growing cultivars mature within three months (90 days) of sowing the seed, while slower- maturing cultivars are harvested four months later (120 days) and this illustrates why it`s considered an available and accessible vegetable. The United Nations Food and Agriculture Organization (FAO) stated that the global production of carrots for the year 2013 was 37.2 million tons; almost half less than 45% were grown in China. Iweka et al. [5] and Iweka et al. [2] noted that the location of a place affects the yield of a plant. Thus, the need to investigate the physiochemical qualities of carrot oil extracted with coconut milk from plants grown in Akwa Ibom State and compare with bio-oil of carrot from other locations globally with a view to establish a company in host communities that can boost consumer goods and local content of any country.

However, the extraction of the carrot oil from the seeds can be carried out in different dimensions with a view to increasing the quantity and the quality of the bio-oil output. Thus, the three different distinctive methods of carrot oil extraction from the seeds are mechanical method, enzymatic method and the solvent extraction method [2,3,18,19]. In mechanical method of extraction, the carrot roots which have undergone pretreatment such as drying in the oven at about 105^{o}Cor sun for about 3 weeks are fed into the mechanical expellers or either manual ram press or engine driven screw press for the oil extraction. And the extracted oil contains impurities and that leads to further purification process such as filtration and degumming while mechanical extractor is always designed specifically for a particular seed and consequently affects the yield of extracted bio-oil. And the process can only extract 60-80% of the available oil. Enzymatic carrot oil extraction method involves the use of micro-organisms to extract carrot oil from the crushed seeds. Although the process is environmentally friendly and does not produce volatile organic compounds, it takes long processing time. Additionally, a solvent extraction using chemical such as n-hexane, acetone, etc. has been tried but hexane produced higher oil yield but its drawback is its adverse environmental impacts due to waste water generation and higher emissions of volatile compounds. The previous researches on the carrot oil extraction have shown that the oil obtained are inedible owing to the fact that inedible solvent such n-hexane and other poisonous chemicals were used for the extraction. Thus, this research work is meant to curb this problem by making use of edible oil (coconut oil) as biomass solvent for the extraction.

Coconut oil is an edible oil derived from the kernels, meat, and milk of the coconut palm fruit. The broken coconut as depicted in Fig. 2 contains medium chain fatty acids including capric acid; caprylic acids, and lauric acid. About 52% to 85% of coconut oil is made up of specific saturated fats called medium chain fatty acids. It has a moisturizing effect when applied on the skin. People commonly use coconut oil as local pomade (cream), eczema treatment and growth treatment in premature infants. It is also used for psoriasis, obesity, breast cancer, heart disease and many other conditions. Based on the qualities of the coconut oil, it can be efficiently used in the solvent extraction of the carrot oil. And it`s grown in Jamaica, Sri Lanka, Indonesia, Nigeria, Philippines, Dominica Republic, Malaysia, India, South America, East and West Africa etc. [20,21].

Process optimization of the carrot oil extraction was carried out to ascertain the best operating conditions and parameters. Process optimizations taking into cognizance of factors have been adopted in the optimization of carrot oil extraction with a view to determining the maximum product yield [22]. The factors that impact every operation processes are time, solvent volume, weight, temperature, stirring rate etc. [2,3,23,24], but extraction time, solvent volume and weight were considered for this study via 3 Levels optimization approach. The process modeling and optimization of operational parameters such as extraction time, volume of the solvent and the weight of the dried and grinded carrot root were carried out using Box-Behnken Design (BBD), a package under Response Surface Method (RSM) [2]. The BBD was utilized ahead of other packages in RSM because it`s more economical and are available for 3 to 21 factors [2]. The essence of the this study is to produce a bio-oil safe for human consumption and the application of BBD is for the optimization of the carrot oil using coconut oil as biomass solvent during thermal extraction with a view to model and optimize the bio-oil in order to ascertain the best output and validate findings. The acid value from this bio-oil characterization will detect how corrosive the output is [2,3,24]. Additionally, the bio-oil produced from this study will revolutionize bio-oil industries business globally.

Fig. 1. Carrot

Fig. 2. Coconuts with Broken one

Thus, the need to investigate the Effect of Thermally Extracted Carrot Oil Using Biomass Solvent to Boost Consumer Goods: Box-Behnken Design Approach in order to revolutionize Fast-Moving Consumer Goods (FMCG) and optimization Industries for the benefit of humans on earth.

2. MATERIALS AND METHODS

2.1 Materials

Carrot (*Daucus carota*) seed fruits and freshly harvested coconut as biomass solvent were obtained from Marina junction, in Eket local Government Area in Akwa Ibom State, Nigeria. All reagents such as: NaOH pellets, HCl, H_2SO4, KOH, Ethanol, phenolphthalein, Diethyl ether, and cyclo- hexane used were obtained from Isolak Nig. Ltd and were of analytical standard.

2.2 Methods

2.2.1 Purification and pretreatment of carrot (*Daucus Carota*)

Raw carrot seed fruits were washed for about 4 to 5 times to remove the particles of dirt and other unwanted particles. They were sun dried for 10 days.

In order to ensure large surface area of contact enabling every oil bearing cell of the carrot seed fruit to be brought into contact with the organic solvent for optimal penetration and percolation, the thoroughly dried carrot seed fruits were manually grinded into powdered form using a manual grinder. The highly dried and grinded carrot seed fruit in powdered form were then treated with organic solvent coconut oil.

2.2.2 Purification and extraction of coconut oil

The biomass solvent used for the extraction of carrot oil from the Daucus Carota was coconut oil. The coconut was removed from the husks, followed by the removal of the shell. It was then washed and mixed with boiled warm water and thoroughly washed. The coconut shaft was separated from the milk and left for 24 hours with a view to separating the milk from the water. The separated milk was then used for the extraction of the carrot oil from the powdered carrot seed fruits.

2.2.3 Carrot oil extraction procedure

In the extraction method, the prepared specimen (powdered carrot seed fruits) was placed in the porous thimble of soxhlet equipment. The thimble was placed in an extraction chamber which was suspended above a flask containing a known volume of the solvent (coconut oil) and below a condenser. The containing coconut oil was placed on a mantle which supplied heat at a temperature slightly below the boiling point of the solvent. The heating led to the evaporation of the solvent and the vapour moved to the condenser connected to a liquid that trickles into the extraction chamber containing the sample and the process is allowed for few hours. After the extraction process, the flask containing the solvent and carrot oil was removed. The solvent in the flask was then evaporated and the mass of the remaining carrot oil was measured and weighed.

The oil yield was calculated using equation (1) below

$$\text{CLOY}\left(\%\frac{\text{w}}{\text{w}}\right) = \frac{\text{Weight of extracted oil (g)}}{\text{Weight of the sample (g)}} \dots \quad (1)$$

2.2.4 Quality Characteristics of the oil

Quality characterization of the carrot oil extracted was carried out in order to determine the qualities of the oil such as the moisture content, specific gravity, iodine value, peroxide value, pH, refractive index, acid value as well as the free fatty acid (FFA), heating value, cetane number, diesel index, API gravity using a standard method of Association of Official Analytical Chemists [25].

The acid value was calculated using equation 2

$$\text{Acid value (mgKOH/goil)} = \frac{\text{V x N x 28.2}}{\text{W}} \text{ X } 100 \quad (2)$$

Where V= volume of KOH used during titration, N= Normality of KOH, and W = Weight of the oil sample. And other qualities characterized were also recorded using recommended equations.

2.2.5 Design and process optimization of carrot oil extraction

2.2.5.1 Box-Behnken Design Optimization Method

Box-Behnken Design (BBD) a subset of RSM of Design-Expert Version 13, were used to design Akwa Ibom Carrot Oil format as depicted in Table 1. The design input parameters which are sample weight (SW), biomass volume (BV) and extraction time (ET) gave 3 levels.

Table 1. Input parameters of BBD

	Name	Units	Low	High
A [Numeric]	SW	G	40	60
B [Numeric]	BV	mL	150	250
C [Numeric]	ET	Min	10	14

Thus, a design pattern incorporating the three input elements of SW, BV, ET, were designed as depicted in Table 1 to check their impacts on the output (response) known as bio-oil yield leading to seventeen (17) experimental setups, and after a Soxhlet extraction process, the results of each setup were fixed accordingly as in Table 2 with its corresponding input parameters.

3. RESULTS AND DISCUSSION

3.1 Modelling Results of Carrot Oil

Bio-oil from Carrot was extracted using Soxhlet equipment with standard reagents. BBD was used to design Carrot Oil from Akwa Ibom. The three modeled input parameters of SW, BV and ET were designed to determine their impacts on the response (carrot oil parameters of bio-oil output). The BBD designed generated seventeen (17) experimental setups, and after thermal treatment via soxhlet unit, the results of each setup were displayed in Table 2 in the BBD carrot oil yield (response) column. At standard order (Std) 8, the SW of 60 g, the SV of 200 ml and the ET of 14 mins produced the highest carrot oil output (18.58 wt%). Additionally, Std 5, Carrot oil output generated the lowest output of 11.02 wt.% at SW of 40 g, SV of 200 ml and ET of 10 min. This Soxhlet extraction approach appears to be basically powered by the impacts of the ET and SW, which is confirmed by the 3D plot depicted in Fig. 4b, Perturbation plot of Fig. 5 as well as Std 8 in Table 2. Thus, time is the fundamental factor in Carrot-oil synthesis, followed by the quantity of carrot weight and biomass volume as depicted in Fig. 4a, Fig. 4b, Fig. 4c and Fig. 5.

Analysis of Variance (ANOVA) was used to determine the significance of the function parameters in this study and their rate of influence on carrot oil output within the region considered. The outcome of the ANOVA via Soxhlet extraction approach. The BBD model is significant as depicted in Table 3 because the F-value of 67.31 and p-value of 0.0001. According to [1, 5, 6] a term is judged to be significant if its p-value is < 0.05. However, because their values are > 0.05, the interacting terms, such as AB (weight and time) and BC (biomass volume and time), and with quadratic term C^2 (excessive time) are unimportant. The model's lack of fit is insignificant as against the pure error, with F-value of 0.4481, which suggests that 73.22% noise could occur.

Table 2. Carrot-oil output from BBD modeling via Soxhlet extraction approach

Std	Run	A:SW (g)	B:BV (mL)	C:ET (min)	Carrot Oil Output (wt. %) BBD
4	1	60	250	12	15.89
17	2	50	200	12	15.58
2	3	60	150	12	13.72
11	4	50	150	14	14.5
13	5	50	200	12	14.97
3	6	40	250	12	13.21
14	7	50	200	12	15.68
1	8	40	150	12	10.23
6	9	60	200	10	13.02
12	10	50	250	14	17.85
10	11	50	250	10	13.3
7	12	40	200	14	14.46
15	13	50	200	12	14.89
16	14	50	200	12	15.76
5	15	40	200	10	11.02
8	16	60	200	14	18.58
9	17	50	150	10	11.4

Table 3. BBD ANOVA outcome of carrot oil output

Source	Sum of Squares	Df	Mean Square	F-value	p-value	Remarks
Model	78.92	9	8.77	67.31	< 0.0001	Significant
A-SW	18.88	1	18.88	144.93	< 0.0001	Significant
B-SV	13.52	1	13.52	103.78	< 0.0001	Significant
C-ET	34.65	1	34.65	266.01	< 0.0001	Significant
AB	0.1640	1	0.1640	1.26	0.2988	not significant
AC	1.12	1	1.12	8.63	0.0218	Significant
BC	0.5256	1	0.5256	4.03	0.0845	not significant
A^2	4.67	1	4.67	35.84	0.0005	Significant
B^2	4.74	1	4.74	36.35	0.0005	Significant
C^2	0.0118	1	0.0118	0.0908	0.7719	not significant
Residual	0.9119	7	0.1303			
Lack of Fit	0.2294	3	0.0765	0.4481	0.7322	not significant
Pure Error	0.6825	4	0.1706			
Cor Total	79.83	16				

Table 4. Model fitness parameters of previous and current study

Parameters	PSO	Carrot oil Values
Standard Deviation	0.3754	0.3609
Mean	21.54	14.36
C.V. %	1.74	2.51
R^2	0.9786	0.9886
Adjusted R^2	0.9510	0.9739
Predicted R^2	0.8455	0.9407
Adeq Precision	22.4039	29.5995

Note: PSO as referenced by [2] and this study = Carrot Oil

The fitness of the model was examined using the statistical elements depicted in Table 4. The data's standard deviation is very close to zero, which means that experimental outcomes are in order. Additionally, as evidenced by the close proximity of the coefficient of determinant (R^2), Adjusted R^2, and Predicted R^2, the experimental outcomes were consistent. The R^2 of this study was 0.9886, which quite close to one, which is ideal according to [2]. Thus, corroborating the validity of the closing remark. Additionally, there is a significant correlation between the forecasted values and the true values as shown by the Adjusted R^2 and Predicted R^2, with the difference of < 0.2 between these elements. A number higher than 4 is preferable, and a precision of 29.5995 shows that the model has enough signals to manipulate the design region. And when compared with previous findings from Iweka et al. [2] on pawpaw seeds oil, it shows that the Carrot oil fitness elements are of R^2, standard deviation and Adeq precision are better than pawpaw seeds oil (PSO) fitness elements as displayed in Table 4. Thus, the model can effectively be used to optimize the carrot oil via Soxhlet extraction process.

Equation (3) uses coded elements to explain the actual quadratic regression equation that describes the statistical link between the model output and the three independent elements.

$$Carrot\ Oil - Y\ (wt.\%) = -34.64375 + 0.969625A + 0.172430B - 0.691375C - 0.000405AB + 0.026500AC + 0.003625BC - 0.010530A^2 - 0.000424B^2 - 0.013250C^2 \quad (3)$$

where the response is Carrot oil output. The linear terms are A, B and C, and the coefficients of the linear terms are 0.969625, 0.172430, and 0.691375 respectively, and the intercept term is -34.64375. The interacting terms are AB, AC and BC, and the coefficients of the interacting terms are 0.000405, 0.026500, and 0.003625. Additionally, the quadratic terms are A^2, B^2 and C^2, and the coefficients of the quadratic terms are 0.010530, 0.000424 and 0.013250 respectively. Sample weight as A, biomass volume as B and extraction time as C. From the Fig. 4a, 4b, 4c, and Fig. 5, it is clear that C and A, has better deviation.

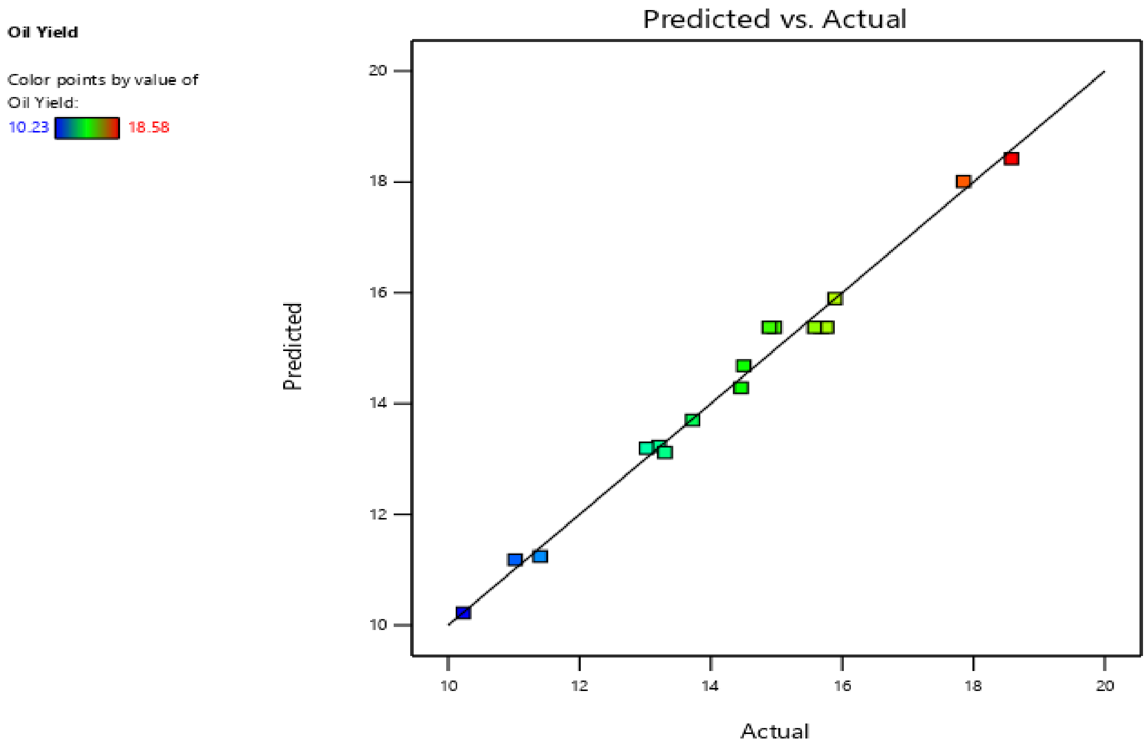

Fig. 3. Predicted vs actual plot of carrot oil output

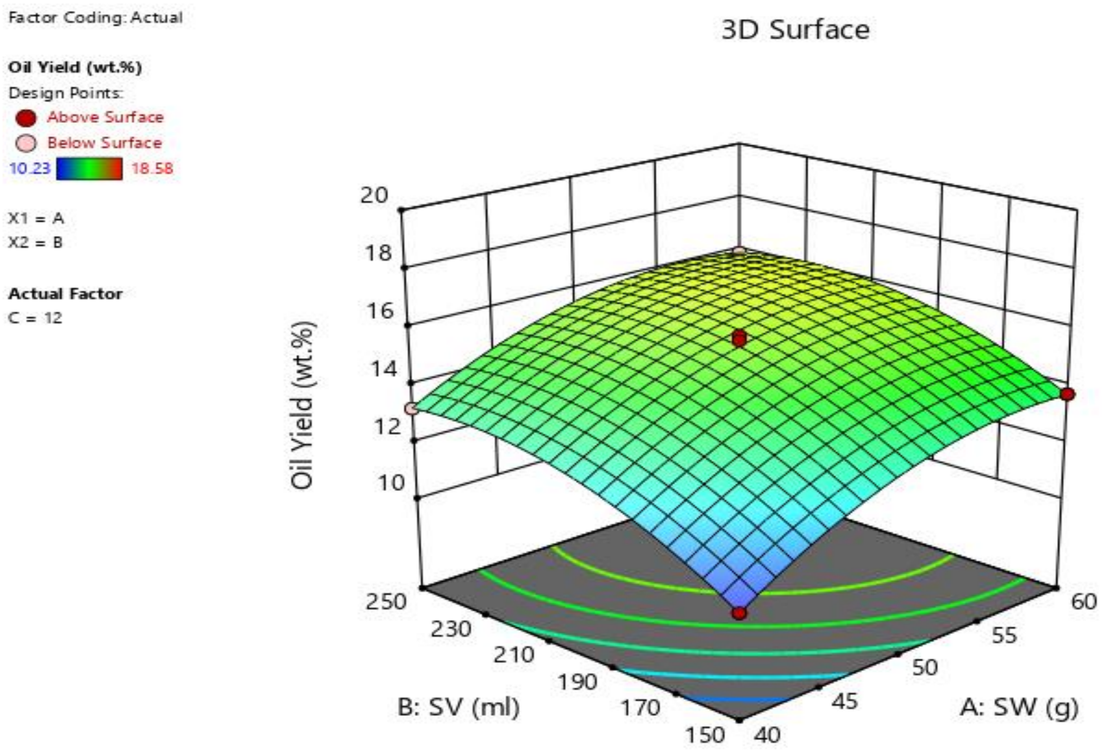

Fig. 4a. 3D of SW vs SV

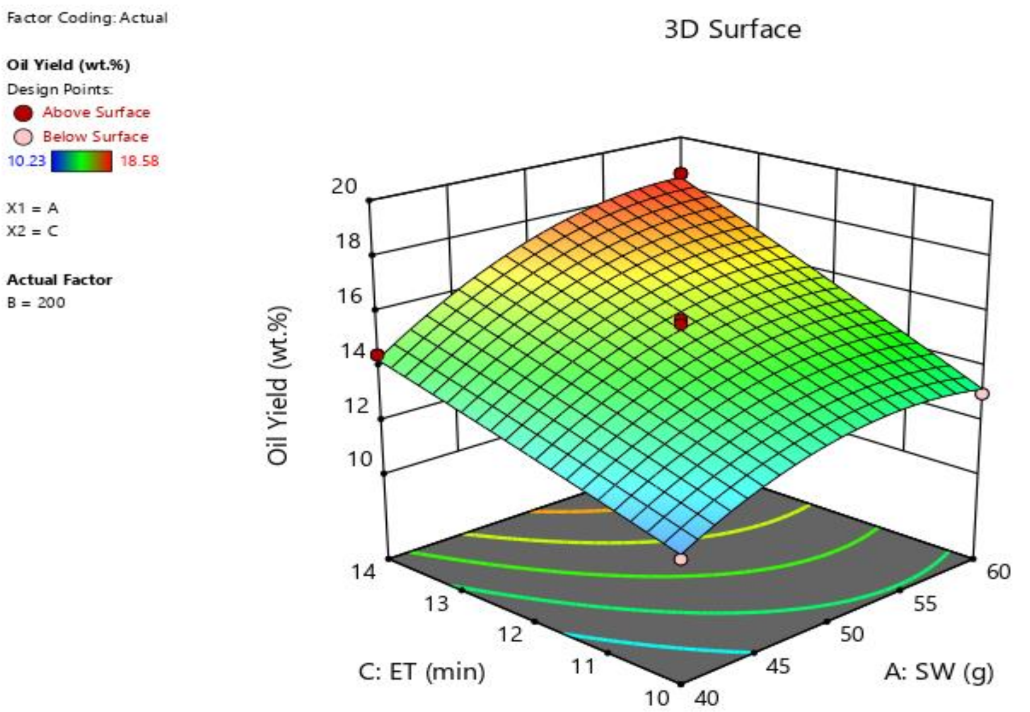

Fig. 4b. 3D of SW vs ET

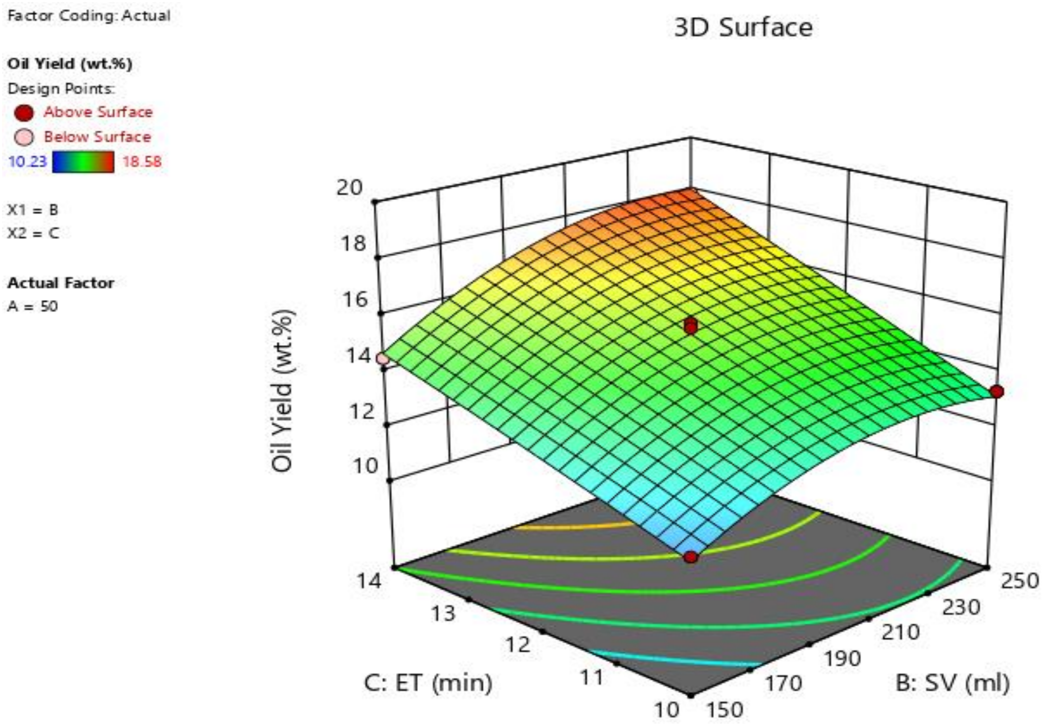

Fig. 4c. 3D of SV vs ET

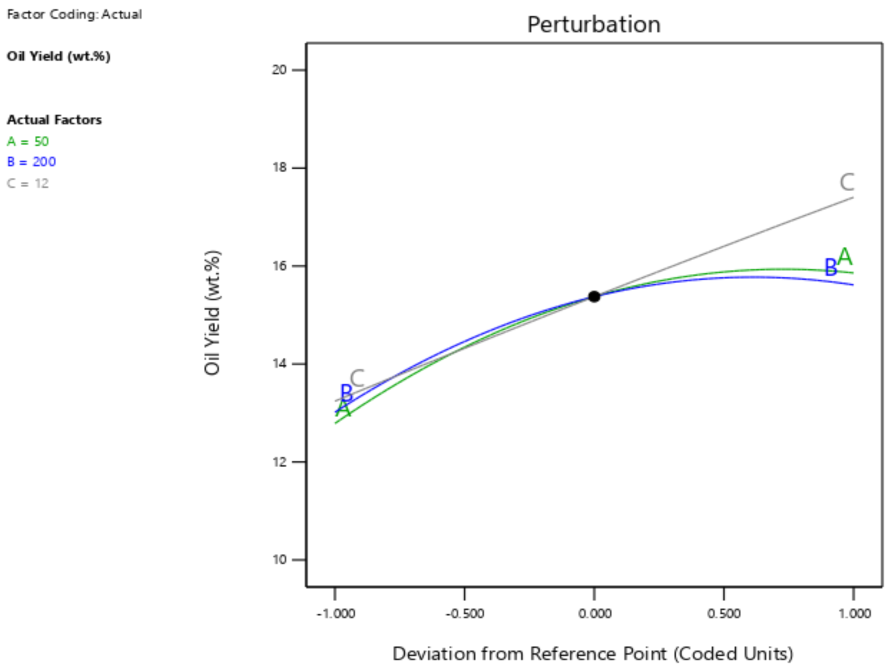

Fig. 5. The perturbation plot of carrot oil

The plot of predicted carrot oil output vs actual in Fig. 3 also helps in understanding the validity of the data modeled and the chosen model. The data points are all on the line of fitness or quite close to it, demonstrating a good approximation of the model. This further supports the model's strong coefficient of correlation, which was seen in the ANOVA's statistical variables.

The most ideal carrot oil output is situated in the color red area of the plots in Fig. 4(a-c). The carrot oil from the extraction operation is shown using the colour ranging from blue to red which depicts minimum and maximum output. Blue indicates low yield, whereas green defines an average output.

Fig. 4(a-c) shows the 3D surface plots generated using the quadratic regression equation. Using three-dimensional surfaces, the relationship between the region's elemente and the most ideal carrot oil output is graphically documented. It is clear from Figures 4a, 4b, and 4c that SW and ET are very important in generating optimal output. Going by the ANOVA results, 3-D and perturbation plots of the carrot oil, ET demonstrated to be the most influential element in bumper bio-oil output.

3.2 Properties of Extracted Carrot Oil

The aim of analyzing the physiochemical properties of this oil, was to check if the extracted carrot oil is safe for consumption and for making soap and moisturizing cream. Thus, the physiochemical properties of the carrot oil extracted using biomass volume were evaluated as shown in Table 5. It was discovered that the carrot oil obtained was yellow in colour with a moisture content of 0.262 %, viscosity of 3.4740 kg/m.s, specific gravity of 0.9516, acid value and the percentage free fatty acid (%FFA) were 0.00841mg KOH/gmol and 0.42 respectively. The peroxide value of 46megO_2/kg while the iodine value was 59.04g I_2/ 100g. The carrot oil saponification value was less than 200 mg KOH/g, an indication that there is little tendency that the carrot oil will form soap during the transesterification process. The moderate iodine value of 59.04 I_2/ 100g of the Carrot oil shows that the oil is a good.

Furthermore, Table 5 clearly shows that the carrot oil produced is good for the skin, it`s edible and it`s good for making moisturizing cream and soap because its acid value and free fatty acid is very low compared to previous studies from CSO, PSO. Thus, will boost FMCG industries in Nigeria and globally.

3.3 Drawback Detected

There was difficult in breaking the coconut and removing the flesh/meat part from the shell. Although, this was done manually, there need is to develop a machine that can do the dehusking effectively, thereby, saving time and energy.

Table 5. Physiochemical properties of carrot oil

Properties	This Study	PSO Value	CSO
Yield (wt.%)	18.58	23.93	20.56
Moisture content (%)	0.262	0.004092	NA
Density (kg/m^3)	880	955	450
Specific gravity	0.952	0.9235	0.879
Viscosity (N.s/m^2) @30^{o}C	3.474	622.1	NA
Acid value (mg KOH/g)	0.0084	27.974	2.52
Free fatty acid (mg KOH/g)	0.420	13.99	1.29
Peroxide value (mg O_2/kg)	46.0	56.00	NA
Iodine value (g I_2/100g oil)	59.04	93.71	70.90
Saponification value (mg KOH/g)	307.75	140.25	187.30

Note: CSO known as Carica papaya referenced as [26], PSO known as Pawpaw seed oil referenced as [2] and NA = Not available

3.4 Future Scope

Future work on bio-oil can incorporate stirring tool using modern day equipment other than soxhlet extractor and compare with findings.

4. CONCLUSION

Massive production of fast-moving consumer goods boosts the economy of any nation. Thus, the need to look into ways of accelerating and transforming carrot utilization into more commercialized usage in order to add value to the developmental strides of any nation where carrot is cultivated like Nigeria. This study concluded that the optimization of the carrot oil extracted from crushed carrot and coconut oil (biomass volume) via soxhlet equipment using Box-Behnken Design (BBD) of Response Surface Methodology (RSM) approach, generated an ideal optimal output of 18.58 wt% at SW of 60 g, BV of 200 ml and ET of 14mins. Although, three input elements which are sample weight (SW), biomass volume (BV), and extraction time (ET) were modelled to generate 17 setups by BBD, but standard order (Std) 8 from the 17 setups generated an ideal output of 18.58 wt%. Thus, the process optimization of the extraction process via BBD of RSM showed that both the coefficient of determination (R^2) which is 0.9886, and the difference between adjusted R^2 and predicted R^2 which is less than 0.2 fall within an ideal range. Also, the elements considered for modeling are mutually significant with the quadratic model equation and the interactive effects of the independent parameters on the carrot oil output showed that an increase in the sample weight and time led to a corresponding increase in the carrot oil output, and this is corroborated by the perturbation plot. Additionally, the physiochemical valuables of the carrot oil generated showed that the free fatty acid and the acid value were very low signifying that the carrot oil is edible and can be used in the manufacturing process using the saponification method in making soap and moisturizing cream for the benefit of mankind.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Iweka SC, Owuama KC. Biogas yielding potential of maize chaff inoculated with cow rumen and its characterization. Journal of Energy Research and Reviews. 2020;34–50.
2. Iweka SC, Ozioko FC, Edafiadhe ED, Adepoju TF. Bio-oil production from ripe pawpaw seeds and its optimal output: Box-Behnken Design and Machine Learning approach. Scientific African. 2023;e01826.
3. Iweka SC, Akpomedaye O, Emu AO, Adepoju TF. Impact of optimization parameters on green sustainable oil from ripe palm kernel seeds for energy utilities: A machine learning approach. Scientific African. 2024;23:e02097.
DOI: 10.1016/j.sciaf.2024.e02097
4. Iweka SC, Owuama KC, Chukwuneke JL, Falowo OA. Optimization of biogas yield from anaerobic co-digestion of corn-chaff and cow dung digestate: RSM and python approach. Heliyon. 2021;7(11):e08255.
5. Iweka SC, Falowo OA, Amosun AA, Betiku E. Optimization of microwave-assisted biodiesel production from watermelon seeds oil using thermally modified kwale anthill mud as base catalyst. Heliyon. 2023;9(7):e17762.

6. Nwanze NE, Iweka SC, Madu KE, Edafiadhe ED. Solar radiation forecasting models and their thermodynamic analysis in asaba: Least square regression and machine learning approach. Journal of Energy Research and Reviews. 2024; 16(2):9–21.
DOI: 10.9734/jenrr/2024/v16i2333
7. Siddique M, Babar Munir HM, Qaisrani ZN, Sultan SH, Khan K, Khan LA, et al. Extraction and characterization of lignocellulosic agricultural biomass pretreatment method for biofuel. Sigma Journal of Engineering and Natural Sciences – Sigma Mühendislik ve Fen Bilimleri Dergisi. 2023;41(6):1221–30.
8. Akhabue ER, Eyibio UP, Ukanwa KS, Adepoju TF, Amabogha B, Balogun TA. Osamilite (K–Na–Ca–Mg–Fe–Al–S): A derived base catalyst for the synthesis of biodiesel from blends of pumpkin seed oil-goat fat-poultry waste fat. Case Studies in Chemical and Environmental Engineering. 2023;7:100347.
9. de Andrade Lima M, Charalampopoulos D, Chatzifragkou A. Optimisation and modelling of supercritical CO2 extraction process of carotenoids from carrot peels. The Journal of Supercritical Fluids. 2018;133:94–102.
10. Falowo OA, Oloko-Oba MI, Betiku E. Biodiesel production intensification via microwave irradiation-assisted transesterification of oil blend using nanoparticles from elephant-ear tree pod husk as a base heterogeneous catalyst. Chemical Engineering and Processing-Process Intensification. 2019;140:157-170.
11. Falowo OA, Betiku E. A novel heterogeneous catalyst synthesis from agrowastes mixture and application in transesterification of yellow oleander-rubber oil: Optimization by Taguchi approach. Fuel. 2022;312:122999.
Available:https://doi.org/10.1016/j.fuel.2021.122999
12. Kadluczka D, Grzebelus E. Comparative fruit morphology and anatomy of wild relatives of carrot (daucus, apiaceae). Agriculture. 2022;12(12):2104.
13. Irshad M, Ali Subhani M, Ali S, Hussain A. Biological importance of essential oils. In: Essential Oils - Oils of Nature [Internet]. IntechOpen; 2020.
[cited 2024 Feb 14].
Available:http://dx.doi.org/10.5772/intechopen.87198
14. Iorizzo M, Douglas A, Shelby L, Dariusz G, Pablo F. Genetic structure and domestication of carrot (*Daucus carota* subsp.Satirus (Apiaceae). American Journal of Botany. 2013;100(5):930-938.
15. Lee SW, Kim BK, Han JA. Physical and functional properties of carrots differently cooked within the same hardness-range. LWT. 2018;93:346–53.
16. Stanojević J, Ilić ZS, Stanojević L, Milenković L, Kovač R, Lalević D, et al. Essential oil yield, composition, and antioxidant activity in two umbel maturity stages of wild carrot (*Daucus carota* L. ssp. carota) from Montenegro. Horticulturae. 2023;9(3):328.
17. Bahrami R, Ghobadi A, Behnouud N, Akhtami E. Medicinal properties of *Daucus carota* in traditional Persian medicine and modern phytotherapy. J. Biochem. Tech special issue. 2018;2:107-114.
18. Tawil M, Bekdash A, Mirouch M, Daher CF, Abi-Habib RJ. Wild Carrot oil extract is selectively cytotoxic to human acute myeloid leukemia cells. Asian pac. J. cancer prev. 2015;16:761-767
19. Saha S, Walia S, Kundu A, Sharma K, Paul R. Optimal extraction and finger printing of carotenoids by accelerated solvent extraction and liquid chromatography with tandem mass spectrometry food chem. 2015;177:369-375.
20. Nieto G, Lorenzo JM. Plant source: Vegetable oils. In: Food Lipids [Internet]. Elsevier. 2022;69–85.
[Cited 2024 Feb 14].
Available:http://dx.doi.org/10.1016/b978-0-12-823371-9.00011-3
21. Hernandez EM, Sanders TAB. Specialty oils. Functional and nutraceutical properties. In: functional dietary lipids [Internet]. Elsevier. 2024;69–97.
[Cited 2024 Feb 14].
Available:http://dx.doi.org/10.1016/b978-0-443-15327-3.00002-1
22. Sylvie NK, Doriane TD, Pierre-Michael JD. Effect of solid state fermentation on the Essential oil yield of curcuma longo Residues. Waste and Biomass valorization. 2022;13:4565-4573.
23. Orugba HO, Iweka SC. Determining the thermodynamic parameters of iron oxide leaching from a Nigerian clay. Advances in Multidisciplinary & Scientific Research Journal Publication. 2019;5(1):83–96.

24. Onwudili AE, Iweka SC. Full-annealing and its effect on the mechanical properties of alloy 304H stainless steel. Journal of Engineering Research and Reports. 2021; 20(7):28–44.
25. AOAC. Official methods of analysis of the association of official analytical chemists; AOAC: Washington, DC, USA; 1990.
26. Senrayan J, Venkatachalam S. Solvent-assisted extraction of oil from papaya (*Carica papaya* L.) seeds: Evaluation of its physiochemical properties and fatty-acid composition. Separation Science and Technology. 2018;53(17): 2852–9.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/113711