International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:9, No:10, 2015

Comparative Study of the Effects of Process Parameters on the Yield of Oil from Melon Seed (*Cococynthis citrullus*) and Coconut Fruit (*Cocos nucifera*)

Ndidi F. Amulu, Patrick E. Amulu, Gordian O. Mbah, Callistus N. Ude

Abstract**—**Comparative analysis of the properties of melon seed, coconut fruit and their oil yield were evaluated in this work using standard analytical technique AOAC. The results of the analysis carried out revealed that the moisture contents of the samples studied are 11.15% (melon) and 7.59% (coconut). The crude lipid content are 46.10% (melon) and 55.15% (coconut).The treatment combinations used (leaching time, leaching temperature and solute: solvent ratio) showed significant difference ($p < 0.05$) in yield between the samples, with melon oil seed flour having a higher percentage range of oil yield (41.30 – 52.90%) and coconut (36.25 – 49.83%). The physical characterization of the extracted oil was also carried out. The values gotten for refractive index are 1.487 (melon seed oil) and 1.361 (coconut oil) and viscosities are 0.008 (melon seed oil) and 0.002 (coconut oil). The chemical analysis of the extracted oils shows acid value of 1.00mg NaOH/g oil (melon oil), 10.050mg NaOH/g oil (coconut oil) and saponification value of 187.00mg/KOH (melon oil) and 183.26mg/KOH (coconut oil). The iodine value of the melon oil gave 75.00mg I_2/g and 81.00mg I_2/g for coconut oil. A standard statistical package Minitab version 16.0 was used in the regression analysis and analysis of variance (ANOVA). The statistical software mentioned above was also used to optimize the leaching process. Both samples gave high oil yield at the same optimal conditions. The optimal conditions to obtain highest oil yield ≥ 52% (melon seed) and ≥ 48% (coconut seed) are solute - solvent ratio of 40g/ml, leaching time of 2hours and leaching temperature of 50^{o}C. The two samples studied have potential of yielding oil with melon seed giving the higher yield.

Keywords**—**Coconut, melon, optimization, processing.

I. Introduction

OILS from plant seeds called vegetable oil are mostly edible and used in food preparations. The nutritive and calorific values of seeds make them good sources of edible oils and fats diet [1], [2]. Seed oils have extensive demands both for human consumption and for industrial applications [3] and also have been rated as one of the most valuable commodity in the world trade today [4]. Many factors influence the yield of oil during leaching process and these factors include: solute-solvent ratio, leaching time and temperature, particle size and agitation of the fluid etc. [5].

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Melon (*Cococynthis citrullus*, family-*Cuclumbitaceae*) is a variety of melon seeds grown in India, Africa and part of Asia especially in the drier region. It is a creeping annual plant and an intercropping plant used in traditional farming practices, thrives well on rich light soil in the hot climate region of Africa [6]. It is popularly called “*egusi*” in West Africa. It however, has been noted to tolerate low rainfall [7]. In the South Eastern regions of Nigeria, *egusi* is best cultivated after the first rains of the year [8].

The seeds are obtained either in shelled or unshelled forms in West African markets and are used greatly in West African cookery. The melon seeds can be milled and used to prepare a popular “*egusi*” soup where it acts as a food thickener. It can also be fermented to produce “*Ogiri*” and used as condiments to season or flavour soup [9], [10].

Melon seeds may also be eaten as snacks, either as whole toasted seeds or as fried cake prepared from milled seeds [11], [12]. The seed has a protein content of about 32% and has a yield between 110-220 kg/ha [13].

Coconut (*Cocos nucifera* Linn.; Family *Palmae*) is a palm which grows within the tropics, generally on the littoral; an alluvial soil, with high temperature, high rainfall and sunshine being preferred. It is one of the most extensively grown and used nuts in the world and is rated as one of the most important of all palms [14], [15]. Coconut has been a traditional food practically in all the counties where it is grown and the quantity of fresh coconuts consumed locally varies from over 90% of the total production. Coconut enters into the diet of the people in many ways; in the form of tender nuts used for their water, mature nuts for cooking and the preparation of sweetmeats, and oil for home consumption [13]. Coconut can also be used to produce desired texture in cookies, candles, cakes, pies, salads and desserts. Coconut is commercially viable because of its rich values [1], [3].

Numerous research work have been carried out on a number of seeds primarily because of the extensive and increasing demands for human consumption and for numerous industrial applications [1], [3], [9], [16]. Only few literatures have reported the optimization of leaching of oils and comparative analysis of the process on coconut fruit and melon seed.

Therefore, the objective of this work is to extract, characterize, optimize and compare the effects of process variables on the yield of oil from coconut fruit and melon seed. The optimization was done using a standard statistical package Minitab version 16.0 program.

II. Materials and Method

Collection and processing of samples: Healthy coconut fruits and melon seeds were obtained from Ogbete Main Market Enugu, Enugu State. The samples were taken to Food Science and Technology Laboratory of the Institute of Management and Technology (I.M.T.) Enugu.

A. Preparation of the Sample

Standard methods for sample processing, preparation and analytical procedures were used.

The coconuts were husked manually with knife and the inner hard shells removed. It was then carefully broken and the fruit collected and sun-dried after cutting to small sizes to reduce the moisture content; thereafter it was milled manually using milling machine, wrapped in polythene bag and kept in a desiccator until needed.

The melon seeds were hand peeled to remove the husks. The peeled seeds were then sundried and milled using machine, wrapped in a polythene bag and kept in a desiccator until needed.

B. Proximate and Lipid Indices Analysis

Proximate analysis tells the food value and nutritional composition of the food. Proximate analysis was carried out on the coconut flour to determine the percentage moisture, crude fat, ash, protein and carbohydrate contents using standard method of analysis. The moisture content of the processed sample was determined by the gravimetric method of AOAC. The crude fat content of the minced sample was extracted by Soxhlet apparatus method as described by [17], [18]. The crude protein was determined by the Kjedahl method, the protein was calculated using the general factor 6.25 [19]. The percentage ash content of the sample was determined gravimetrically by the method of AOAC, while the percentage carbohydrate content was estimated as the nitrogen free extract (NFE) as outlined in [19]. The results of the proximate analyses are presented in Table III.

C. Oil Extraction

The extraction of oil from the processed flour was done using solid-liquid extraction otherwise known as leaching. The treatment combination variables are: leaching time (x_1), leaching temperature (x_2) and concentration(x_3). A known weight each of the flour sample was dispersed in a given volume of solvent and subjected to a desired temperature and at a specific time in a water bath. At the end of the process, the supernatant (oil-solvent mixture) was decanted and centrifuged at 900rpm for 5 minutes. The clear transparent liquid obtained after centrifuging was then evaporated completely in a hot oven and the oil was cooled, weighed and the yield calculated. The % oil yield was calculated thus:

$$\%\text{ oil yield} = \frac{weight\ of\ Extracted\ oil}{weight\ of\ sample} x \frac{100}{1} \quad (1)$$

D. Physicochemical Analyses of Oil

A standard procedure of American oil chemist society was used for the lipid indices values, acid and peroxide values were determined as outlined by [19]. The indicator method was used in determining the saponification value as outlined by [20]. The iodine value was determined by Wij's method as described by [17], [18]. The refractive index of the oil sample was determined using a refractometer according to [3]. The specific gravity of the castor oil sample was described using pycometric method as described by [21], while the viscosity was determined using a viscometer according to the method outlined by [19]. The results are shown in Table IV.

III. Experimental Design

The experiment was designed using Minitab software version 16.0 to determine the influence of leaching time, leaching temperature and solute/solvent ratio as parameters in extraction of oil from the flour samples. The three parameters were investigated at two levels (low and high). Eight experiments each were obtained and the detailed experimental design is presented in Tables I and II.

TABLE I
EXPERIMENTAL DESIGN SHOWING TREATMENTS GIVEN TO MELON SEED FLOUR

S/NO	Code	Leaching Time (hr) (X_1)	Leaching Temp. (^{0}C) (X_2)	Solute; Solvent ratio (g /ml) (X_3)
1	MEF_1	1	40	2:40
2	MEF_2	2	50	2:40
3	MEF_3	2	40	2:30
4	MEF_4	2	40	2:40
5	MEF_5	1	50	2:30
6	MEF_6	2	50	2:30
7	MEF_7	1	50	2:40
8	MEF_8	1	40	2:30

TABLE II
EXPERIMENTAL DESIGN SHOWING TREATMENTS GIVEN TO COCONUT FLOUR

S/NO	Code	Leaching Time (hr) (X_1)	Leaching Temp. (^{0}C) (X_2)	Solute; Solvent ratio (g/ml) (X_3)
1	COF_1	1	40	2:40
2	COF_2	2	50	2:40
3	COF_3	2	40	2:30
4	COF_4	2	40	2:40
5	COF_5	1	50	2:30
6	COF_6	2	50	2:30
7	COF_7	1	50	2:40
8	COF_8	1	40	2:30

MOF = Melon Flour, COF = Coconut Flour

A. Statistical Analysis of Factors Affecting Oil Yield

All extraction and analysis were performed in duplicate. Results were expressed as mean± standard deviation (SD). The design of experiment selected for this study is two level-three factor factorial design and the response measured is the yield of oil from the flours samples. The three parameters studied were leaching time, leaching temperature and solute/solvent concentration. Fisher's least significant difference (LSD) was used to identify significant differences among treatment means at $P \leq 0.05$ using a statistical package

(SPSS version 17.0). Minitab version 16.0 program was also used in the regression analysis of variance (ANOVA). The statistical softwares mentioned above were used to generate single effect plots, interaction plots, contour plots and 3D surface plots. The response or yield of oil extracted from the two flour samples was used to develop a mathematical model that correlates the yield of oils (melon and coconut oil) to the process variables studied. Equation (2) is the generalized mathematical model equation of the two flour samples:

$$Y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{23} x_2 x_3 + b_{123} x_1 x_2 x_3 \quad (2)$$

where Y is the predicted response, a is the value of the fixed response or intercept ; b_1, b_2 and b_3 are the linear coefficients for the input factors x_1, x_2 and x_3 ; b_{12}, b_{23} and b_{123} are the interaction effects coefficients regression terms, respectively; x_1, x_2, x_3 are the levels of independent variables.

IV. Result and Discussion

A. Proximate Analysis

TABLE III
PROXIMATE COMPOSITION OF THE TWO SAMPLES

Components	Coconut (%)*	Melon (%)*
Moisture	7.590±0.014	11.150±1.630
Fat	55.150±1.202	46.100±1.560
Protein	5.650±0.212	5.650±0.354
Ash	7.350±0.354	15.200±1.131
Carbohydrate	19.510±1.146	20.050±1.910

*Data are means of duplicate determination ±SD

Table III shows the proximate composition of the coconut fruit and melon seed, results from the present investigation show that they are of high nutritional values. The proximate composition, being the nutrient composition show reasonable values in fat, protein, carbohydrate and ash. The values of the moisture content of the coconut and the melon seed differed significantly. The moisture content of the coconut (7.59%) conformed to that reported for coconut (7.57%) by [22]. The fat content of the melon and the coconut (46.10% and 55.15%) respectively are higher compared to reported value range of 3.15–34% for most tropical plant seeds in Africa [3], [6], [23], [24]. The samples studied are rich in lipid which suggests them as good source of edible oil that gives energy and other fat soluble vitamins when ingested. The good source of energy is also confirmed by the relatively high carbohydrate content of the samples. The samples studied were found to have the same value in their protein content (5.65%) which is slightly lower than the value (7.0%) reported for *Telfera occidentallis* by [25]. These values do not meet up with the value (12%) reported by [20] as the minimum value of protein for plant food.

B. Physicochemical Analysis

Table IV shows the physicochemical composition of the 2 oil sample (melon and coconut oils). The viscosity of melon seed oil and coconut oil differed significantly with coconut exhibiting a lower value (0.002) and thus can be used as a penetration fluid in lubrication. The acid value of coconut oil is by far above that of melon and can therefore be recommended for biofuel where high acidity is needed. The peroxide value of melon and coconut oils have no significant difference, the values compared favourably with the range (0.39 – 7.4ml/g of oil) reported for non-conventional seed oils in Nigeria and Congo Brazzaville [9]. Peroxide values are used as indication of deterioration of oil. Fresh oils have peroxide values less than 10meq/kg while values above 20 meq/kg exhibit a rancid taste and disagreeable odour [20]. The saponification values of melon seed oil and coconut oil do not differ significant. The range (183.20 - 187.00mgKOHg^{-1}) are however higher than those reported for *Deuterium microcarpum* (123.3 mgKOHg^{-1}) by [3]. The oil samples studied have low level of hydrolytic activities in them which suggests them as good source of raw materials for industries.

TABLE IV
PHYSICOCHEMICAL COMPOSITION OF THE OIL SAMPLES

Parameters	Coconut oil*	Melon oil*
V (cp)	0.002±0.000	0.008±0.000
RI (30-40°C)	1.361±0.170	1.487±0.008
AV (mgNaoHg^{-1} of oil)	10.050±0.71	1.000±0.283
SG	0.900±0.004	0.924±0.000
PV (ml$g^{-1}$of oil)	5.000±0.000	7.250±1.340
IV (I_2g^{-1} of oil)	81.000±1.414	95.000±4.243
SV (mg koHg^{-1} of oil)	183.260±0.085	187.00±4.243
FFA (%)	5.050±0.071	0.500±0.141

Data are means of duplicate determination ±SD.*
Key V = viscosity, RI = Refractive index, AV = Acid value, SG = Specific gravity.
PV = peroxide value, SV = saponification value, FFA = free fatty acid.

C. Oil Yield

Table V shows the result of percentage oil yield from the two raw materials (melon and coconut). From the table, the treatments given to sample 1, 5, 6 and 7 for melon oil flour have no significant difference in their oil yield. The percentage oil yield for melon ranged from 41.30 – 52.99% with sample 2 exhibiting the highest percentage oil yield (52.99%) and samples 8 the least (41.30%) as shown in Table V.

TABLE V
YIELD OF OIL FROM THE TWO SAMPLES

S/NO	Sample treatment			Melon*	Coconut*
	(x_1)	(x_2)	(x_3)	%	%
1	1	40	40	46.03±0.18	44.12±0.19
2	2	50	40	52.99±0.01	49.50±0.71
3	2	40	30	47.98 ±0.11	48.30±0.28
4	2	40	40	52.43±0.04	49.83±0.39
5	1	50	30	46.42± 0.09	36.25±0.35
6	2	50	30	46.53±0.04	46.03±0.11
7	1	50	40	46.48±0.04	47.5±0.07
8	1	40	30	41.30±0.42	45.96±0.23

*Data are means of duplicate determination ±SD

The treatments given to samples 2 and 4 for coconut have no significant difference in their oil yields likewise the treatments given to samples 6 and 8. The treatments given to samples 3, 5 and 7 differed significantly. The percentage oil yields for coconut ranged between 36.25 – 49.83% and the highest percentage oil yield range was seen in sample 4 (49.83%).

D. Effect of Process Parameters on the Oil Yield

Single Factor Effect

The single effect of treatment combination x_1, x_2 and x_3 on the percentage oil yield is shown in Figs. 1 (a) and (b). The single (one) factor effect shows the interaction of the three process variables studied independently on the yield of oil from the two flour samples. Fig. 1 (a) (single effect plot of melon) reveals that there was a general increase in the percentage oil yield as the leaching time, leaching temperature and concentration increased. Higher oil yield was observed with leaching time and least with leaching temperature. This could be attributed to the fact that the increment in temperature caused the protein to coagulate at a very faster rate thus reducing the viscosity significantly thereby leading to the release of the oil band to them. Oil flow was found to be inversely proportional to the kinematic viscosity which decreases with increase in leaching temperature, thus increase in the ability of the oil to flow.

Fig. 1 (b) shows the single effect of the process variables on the yield oil from coconut. The effect of leaching time and concentration influenced the yield of oil from coconut fruit positively while leaching temperature showed a decline in the yield as temperature increased from low to high.

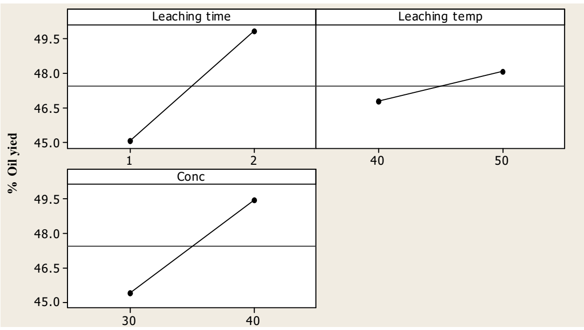

Fig. 1 (a) Single effect plot of melon

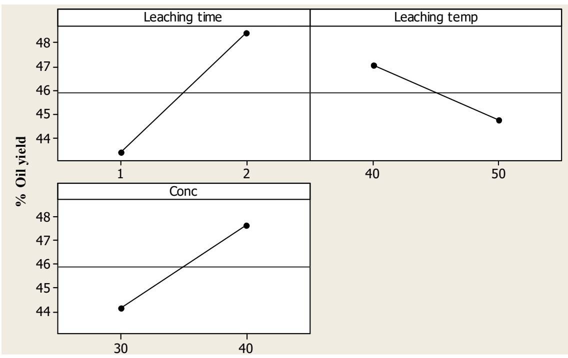

Fig. 1 (b) Single effect plot of Coconut

Effect of Interaction between Process Variable

The process variables were found to have significant interaction effects. Figs. 2 (a) and (b) show the various interactions of the process variables such as leaching time, leaching temperature and solute/solvent concentrations and their corresponding yields of oil from the samples. The parameters were operated at two levels; (high and low).The black line denotes low i.e. initial condition, while the red line denotes final condition.

Fig. 2 (a) indicates interaction effect of the three process variables on the yield of melon oil from its seed. The interaction of leaching time versus concentration, and also leaching temperature versus concentration showed that as all the parameters increased from low to high, the yield of oil from melon seed was significantly favored. The interaction between leaching time and leaching temperature showed that increasing the leaching time does not necessarily have much impact on the oil yield. Fig. 2 (b) is the interaction effect of the three process variables on the yield of oil from coconut fruit. The interaction of leaching time and concentration on oil yield on coconut showed that increasing the processes parameters appreciably increased the yield of oil from the coconut fruit. The interaction effect of leaching temperature versus concentration shows that at 40°C, increasing the concentration has negligible effect on the oil yield but at 50°C, increasing the concentration increased the yield of oil. The interaction between leaching time and temperature has an inverse relationship with the oil yield from the coconut fruit thus as the process variables increased, the yield of oil significantly decreased.

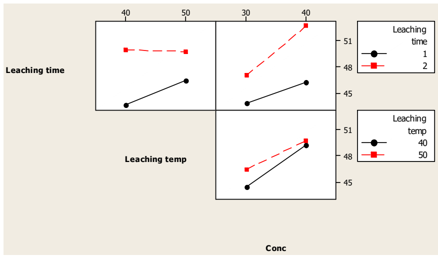

Fig. 2 (a) Interaction Effect of x_1,x_2 and x_3 on oil yield of melon seed

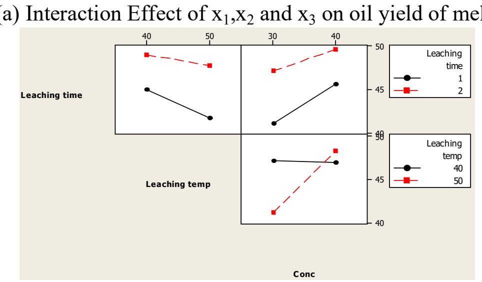

Fig. 2 (b) Interaction Effect of x_1,x_2 and x_3 on Oil Yield of Coconut

The contour plots and 3D plots show the optimization parameters for leaching of oil from melon seed and coconut fruit.

E. Optimization of the Leaching Process

Contour Plot of Oil Yield from the Flour Samples

Figs. 3 (a) and (d) are the contour plots of solute: solvent ratio versus leaching temperature for melon seed and coconut fruit respectively. It could be observed from the figures that the optimal ranges of the process parameters to obtain yield ≥ 52% (melon seed) and ≥ 48% (coconut fruit) are solute/solvent ratio of ≥ 40g/ml and leaching temperature of ≥ 50°C for melon seed; solute/solvent ratio of 39-40g/ml and leaching temperature of 47-50°C for coconut fruit.

Figs. 3 (b) and (e) are the contour plots of solute: solvent ratio versus leaching time for melon seed and coconut fruit respectively. It could be observed from the figures that the optimal ranges of the process parameters to obtain yield ≥ 52% (melon seed) and ≥ 48% (coconut fruit) are solute: solvent ratio of 39-40g/ml and leaching time of 1.85-2.0 hours for melon seed; solute/solvent ratio of 33-40g/ml and leaching time of 1.6-2.0 hours for coconut fruit.

Figs. 3 (c) and (f) are the contour plots of leaching temperature versus leaching time for melon seed and coconut fruit respectively. It could be observed from the figures that the optimal ranges of the process parameters to obtain yield ≥ 52% (melon seed) and ≥ 48% (coconut fruit) are leaching temperature of ≥ 50°C and leaching time of ≥ 2.0 hours for melon seed; leaching temperature of 40-48°C and leaching time of 1.7-2.0 hours for coconut fruit.

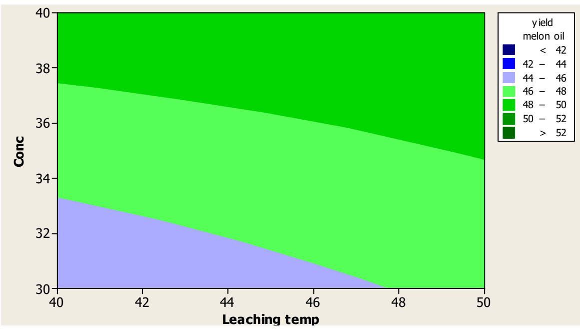

Fig. 3 (a) Contour Plot for oil yield of Melon seed

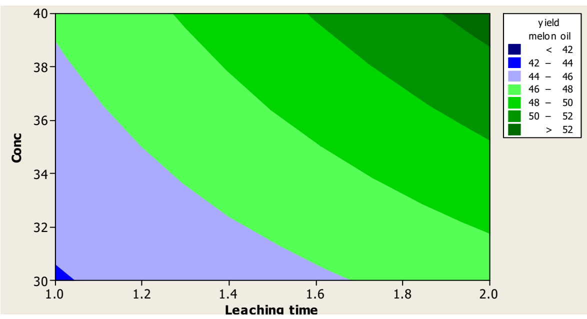

Fig. 3 (b) Contour Plot for oil yield of Melon seed

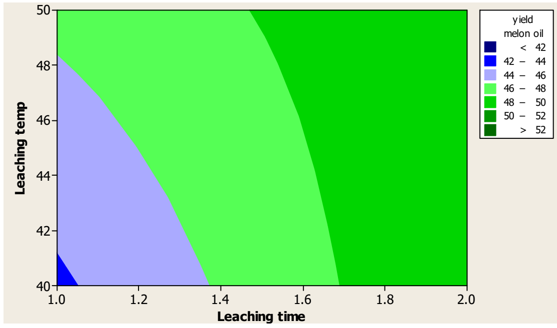

Fig. 3 (c) Contour Plot for oil yield of Melon seed

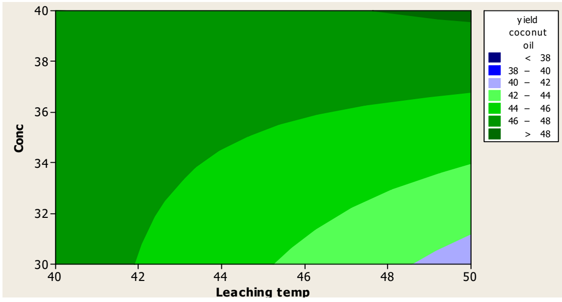

Fig. 3 (d) Contour Plot for oil yield of Coconut

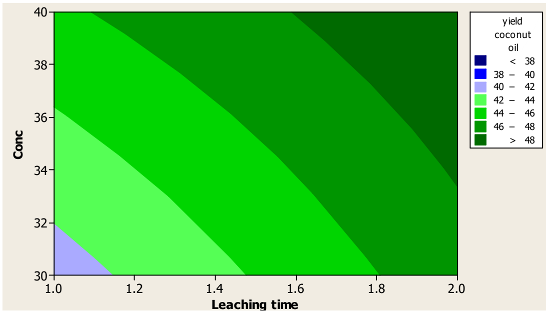

Fig. 3 (e) Contour Plot for oil yield of Coconut

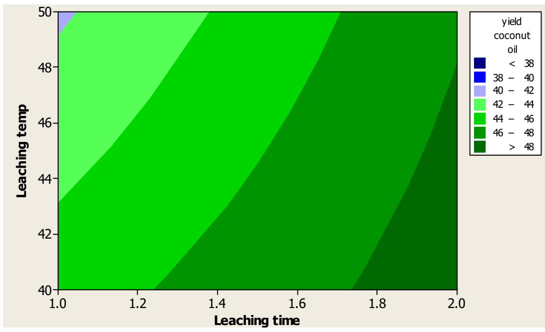

Fig. 3 (f) Contour Plot for oil yield of Coconut

Surface Plot of Oil Yield from the Flour Samples

Figs. 4 (a) and (c) show surface plot of oil yield from melon seed and Figs. 4 (d) and (f) show the surface plots of oil yield from coconut fruit.

Figs. 4 (a) and (d) show the surface plot of solute: solvent ratio versus leaching temperature to obtain a yield. It could be observed that the optimal conditions to obtain highest oil yield ≥ 52% (melon seed) and ≥ 48% (coconut fruit) were solute: solvent ratio of 40g/ml and leaching temperature of 50°C for both melon seed and coconut seed.

Figs. 4 (b) and (e) show the surface plot of solute/solvent ratio versus leaching time to obtain a yield. It could be observed that the optimal conditions to obtain highest oil yield ≥ 52% (melon seed) and ≥ 48% (coconut fruit) were solute/solvent ratio of 40g/ml and leaching time of 2 hours for both melon seed and coconut fruit.

Figs. 4 (c) and (f) show the surface plot of leaching temperature versus leaching time to obtain a yield. It could be observed that the optimal conditions to obtain highest oil yield ≥ 52% (melon seed) and ≥ 48% (coconut fruit) were leaching temperature of 50°C and leaching time of 2 hours for both melon seed and coconut fruit.

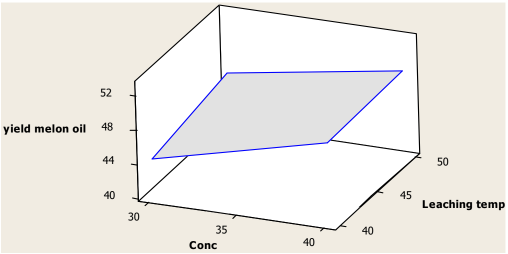

Fig. 4 (a) Surface Plot of oil yield of melon seed

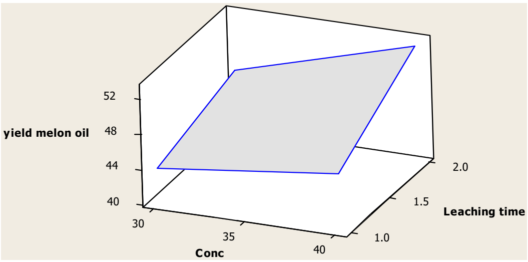

Fig. 4 (b) Surface Plot of oil yield of melon

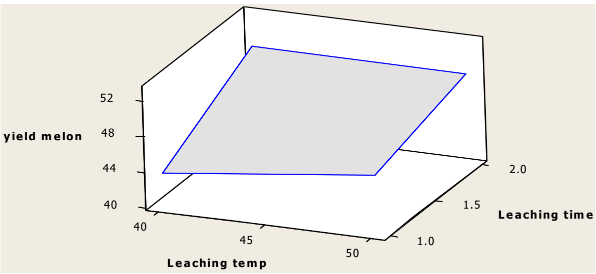

Fig. 4 (c) Surface Plot of oil yield of melon

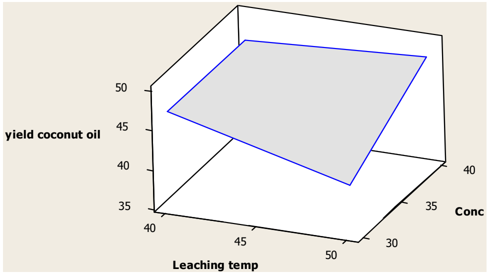

Fig. 4 (d) Surface Plot of oil yield of Coconut

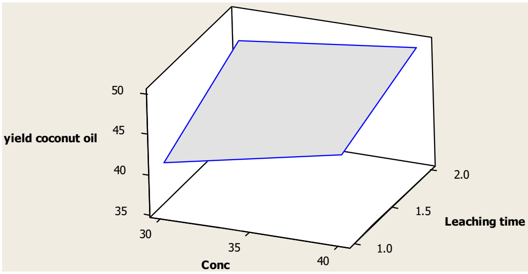

Fig. 4 (e) Surface Plot of oil yield of Coconut

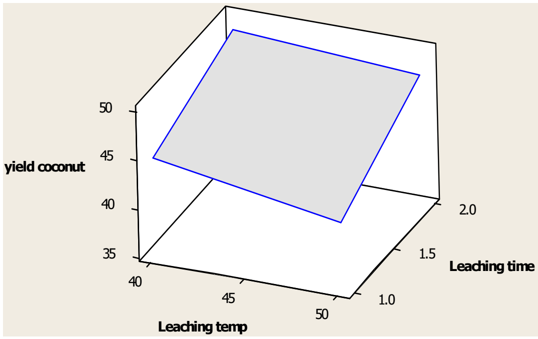

Fig. 4 (f) Surface Plot of oil yield of Coconut

Statistical Analysis of Factors Affecting Oil Yield

The statistical software (SPSS version 17.0) and Minitab version 16.0 was used to analyze the processes for both melon seed and coconut fruit. The response or yield of oil extracted from them were used to develop two mathematical models that correlate the yield of oil to the process variables studied for the samples respectively.

$$Y_{(melon)} = 47.458+2.40x_1+0.648x_2+2.025x_3-0.745x_1x_2+0.828x_1x_3-0.395x_2x_3+0.773x_1x_2x_3 \quad (3)$$

$$Y_{(coconut)} = 45.936+2.479x_1-1.116x_2+1.801x_3+0.466x_1x_2-0.551x_1x_3+1.879x_2x_3-1.39x_1x_2x_3 \quad (4)$$

V. Conclusion

Comparative analysis of melon seed and coconut fruit and their extracted oil was evaluated in this study. The samples examined were shown to be nutritionally potent with high level of nutrients and energy. The relatively low moisture content of coconut fruit studied as compared to melon seed studied promises longer shelf life for coconut fruit before cultivation. The samples were also shown to contain high level of good quality oil whose characteristics (iodine value, peroxide value, acid value etc.) compared favorably with most conventional vegetable oils sold in Nigeria markets. The relatively high carbohydrate and oil contents of the samples suggest them as good source of energy. The treatments combinations (leaching time, leaching temperature and solute: solvent ratio) on the flour samples were investigated in order to maximize the oil yield from them. Both samples gave a high oil yield at the same optimal conditions. The optimal conditions to obtain highest oil yield ≥ 52% (melon seed) and ≥ 48% (coconut fruit) are solute: solvent ratio of 40g/ml, leaching time of 2hours and leaching temperature of 50^{o}C. The two samples showed the potential of yielding oil with melon seed giving the higher yield.

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