Parametric Study of Oil Extraction from Wild Mango (*Irvingia gabonensis*) Seed

[1]Esonye, C. and [2]Nwanekezie, M. N.

[1]Department of Chemical and Petroleum Engineering, Federal University, Ndufu Alike Ikwo, Abakaliki,
Ebonyi State, Nigeria.
[2]Department of Chemical Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli,
Anambra State, Nigeria.
Email: [1]eso_vic@yahoo.com, [2]mn.nwanekezie@coou.edu.ng.
Tel: +234(0)803 872 5463

ABSTRACT

This study investigates the effect of the various process conditions such as temperature, extraction duration, particle size and solute/solvent ratio on the seed oil solvent extractions using ethanol, n-hexane and methanol/chloroform (50:50) as solvents from wild mango (Irvingia gabonensis). A 5^4 factorial design was employed to obtain oil yield ranged from 42.15 - 71.49%. The result showed an optimum yield of 70.78 after degumming at particle size of 400µm, temperature of 60ºC for duration of 8hrs and solute/solvent ratio of 1:5. The n-hexane gave the highest yield, followed by ethanol and lowest by methanol/chloroform blend. The physicochemical quality of the extracted oil shows that the oil could be applied in various domestic and industrial uses such as soap, biofuel, surface coating as well as candles and bio- lubricants without competing with its original food application.

Keywords: Wild Mango, Optimization, Oil, Extraction Characterization.

1.0 INTRODUCTION

The modern world cannot overcome challenging demand of industrialization without due attention to the place of vegetable oil and its attendant applications. Oils from various plants are employed in the manufacture of cosmetics, drugs and food [1]. Today more applications of vegetable oil to replace petroleum in the production of biodiesel, bio-lubricant, alkyd resin and surface coating materials have made vegetable oil indispensable in the industrialization of the world. This is because of its eco-friendly and renewable nature. The less availability of this edible and nonedible oil feedstock in Africa has resulted in importation of vegetable oil from most technologically advanced countries and high cost of products from them. The consequence of this is obvious in the inability of the government to realize several economic policies. This has necessitated a concerted effort in research to increase the production of edible and nonedible oil in the underdeveloped countries of Africa and many oil bearing crops have been exploited to solve the above problem [2]. It is a fact that optimization of oil extraction processes is a reasonable step in optimization of the application of vegetable oil.

Wild mango *(Irvinga gabonensis)* is a drupe with a thin epicarp, a soft endocarp encasing a soft dicotyledonous kernel [3]. The fruit is usually collected from the wild, dried and the kernel is split to release the nut. The pulp is used for preparation of juice, jelly and jam [4], while the fruit nuts are used in local food preparation for soup thickening [5]. Joseph, [6] reported that the residual kernel of African Bush mango after fat extraction retained the viscous, gum-like consistence which is highly cherished in local soup making. It means that after oil extraction from the seed, the cake remaining still stand useful as food supplement. Since the soup thickening properties are due to its carbohydrate content [6], and the fat represents about 51-72% of the nut [5]. Ogunsina *et al* [7] obtained 68.37% of crude fat from the nut, Joseph [6] obtained 66.50% of crude fat while Orhevba *et al* [3] studied the engineering properties of the nut at two moisture content levels as relevant to its processing. This important economic tree has been reported of having distribution in Africa [8] and the genetically improved varieties now abound. The integrated use of the oil from the kernel for industrial applications and the cake for its original food purposes would enhance the economic value of wild mango seed oil with consideration to its high oil content.

Oils are extracted from plant source by mechanical extraction, solvent extraction, supercritical fluid extraction and enzymatic extraction processes with many factors affecting the above techniques [9]. Solvent extraction has been reported to be the best approach in removing oil from the plant seed with less than 1% oil residue [10]. Studies on the effect of the process variables on the extraction of oil from the wild mango are rarely reported in the literature, few studies on this never considered optimization of the operating conditions. The knowledge of the optimum process variables in solvent extractions saves time, cost and materials as well as promotes standard operating procedures. The aim of this research work is to investigate the effect of extraction parameters on the seed oil yield as well as realize the optimum conditions using factorial optimization approach.

2.0 MATERIALS AND METHODS
2.1 Materials
The fruits containing the seeds of *Irvingia gabonensis* were harvested from a plantation in Onueke, Ebonyi State Nigeria and separated from dirt and foreign materials. The fruits were peeled to remove the pulp and reveal the kernel. The kernel was dried under the sun for 7 days before being manually cracked to release the seeds. The seeds were equally dried under the sun for 4 days before being ground using a gasoline operated grinding machine. The ground meal was sieved using ASTEM 11-70, EML 200- Haver. Boecker mechanical siever to obtain five different particle sizes (300µm, 400µm, 500µm, 600µm and 700µm). Each of the particle sizes were divided into three portions. All the reagents used were of analytical grade obtained from Sigma Chemical Co. (St. Louis, MO).

2.2 Experimental Design:
A 5^4 factorial experimental design was used to ascertain the optimum conditions. The variables studied were Particle size, Extraction duration, temperature and solute/solvent ratio. The choice of values was based on some preliminary investigations. Optimization of the extraction conditions was done by applying one variable at a time while maintaining other variables constant [11]. Table 1 contains the variables and their ranges.

Table 1: Operating Parameters and their values

S/n	Variables	Values				
1.	Particle Size (µm)	300	400	500	600	700
2.	Extraction Time (hours)	4	6	8	10	12
3.	Temperature (°C)	50	55	60	65	70
4.	Solute/Solvent ratio (g/ml)	$^1/_4$	$^1/_5$	$^1/_6$	$^1/_7$	$^1/_8$

2.3 Oil Extraction
The seed meals from each individual sample were extracted by n-hexane, ethanol and methanol/chloroform (50:50) solvents. The solvent extractions were executed using a 200ml Soxhlet apparatus. About 20g of the ground meal of a particular particle size was subjected individually to the solvent extraction for a particular duration and temperature as contained in Table 1. The oil solutions were filtered and subjected to distillation using rotary evaporator. The oil samples recovered were then weighed.

2.4 Oil Characterization

Characterization of the oil samples obtained from the various extraction fractions were carried out by ascertaining their physico-chemical properties. The percentage (%) oil yield was calculated, the specific gravity was determined using specific gravity bottle; the moisture content was ascertained using oven method, kinematic viscosity was determined using viscometer, saponification value was determined by titrimetry (AOCS Cd 3C-91), acid value, peroxide value and iodine value were also determined by titrimetry according to AOCS Ca5a-40, AOCS Cd8-53, AOCS Cd1-25 respectively. The percentage free fatty acid (% FFA) as oleic was calculated by dividing the acid value by 0.503

2.5 Statistical Analysis

The results, means and Standard Deviations (S.D) of the three essays (three different solvents) were carried out in all the methods.

3.0 RESULTS AND DISCUSSION

Table 2: The Physico-chemical Analysis of the *Irvingia gabonensis* Seed Oil

| S/N	Properties	Results		
		Eth	n –hex	M/C
1.	Average oil yield (%)	50.63(2.51)	70.78(2.14)	49.73(2.80)
2.	Odour	Agreeable	Agreeable	Agreeable
3.	Colour	Light Yellow	Light Yellow	Light Yellow
4.	Specific gravity	0.9418(0.007)	0.9414(0.006)	0.9450(0.005)
5.	Moisture content (%)	2.10(0.05)	2.05(0.045)	2.19(0.038)
6.	Iodine Value (g/100g of oil)	7.80(0.66)	7.75(0.58)	7.90(0.64)
7.	Acid Value (mgkOH/g of oil)	2.50(0.35)	2.50(0.25)	2.50(0.30)
8.	Free fatty acid as oleic (%)	1.25(0.27)	1.25(0.30)	1.25(0.29)
9.	Peroxide value (meq/kg)	1.61(0.02)	1.65(0.03)	1.64(0.02)
10.	Saponification Value (mgKOH/g of oil)	220(3.49)	223(3.50)	222(3.49)
11.	Kinematic viscosity (mm^2/s@ 60°C)	39.03(1.41)	39.50(0.99)	38.97(1.05)

Values are means of Triplicate determination and Standard Deviation (SD) are given in parenthesis, Eth – Ethanol, n-hex – n-hexane

M/C – Methanol/Chloroform

Table 2 contains the physico-chemical properties of the seed oil extracted from the wild mango seed. The oil appears solid at ambient temperature. The acid value and moisture contents as well as the saponification value, peroxide value and iodine value are in close agreement with the values obtained by Ogunsina *et al* [7]. These results compare favourably with other seed oil applied for edible and industrial purposes.

Table 3: *Irvingia gabonensis* Seed Oil yield at different operating conditions and solvents

| S/N	Operating Parameters	% Yield before degumming			% Yield after degumming		
		Eth	n-hex	M/C	Eth	n-hex	M/C
Particle Size (µm)							
300		45.22	65.91	49.92	43.86	65.21	45.92
400		50.41	69.67	53.61	50.90	68.97	49.32
500		48.94	67.11	50.22	47.50	66.44	46.20
600		43.55	64.41	48.48	42.24	63.99	44.60
700		42.90	62.50	48.50	41.71	61.86	44.62
Extraction Time (hours)							
4		41.50	64.02	40.19	40.26	63.40	36.17
6		46.19	67.58	47.55	44.85	66.90	43.75
8		47.99	68.98	50.63	46.30	68.29	46.59
10		48.01	68.89	50.91	46.73	68.20	46.83
12		48.50	68.90	51.50	47.05	68.21	46.46
Temperature (°C)							
50		43.67	66.89	50.11	42.36	66.22	46.10
55		45.19	68.77	52.16	43.83	68.10	47.98
60		48.66	71.49	58.56	47.20	70.78	49.73
65		49.19	71.30	57.12	47.60	70.58	47.95
70		52.20	71.50	57.40	50.63	70.29	48.21
Solute/Solvent Ratio (g/ml)							
1:4		42.15	66.91	43.99	40.89	66.24	40.47
1:5		47.31	67.92	48.11	45.89	67.24	44.26
1:6		47.50	67.50	49.00	46.10	66.82	45.08
1:7		47.50	67.61	49.05	46.15	66.93	45.13
1:8		47.50	67.50	49.05	47.50	66.78	45.08

M/C – Methanol/Chloroform
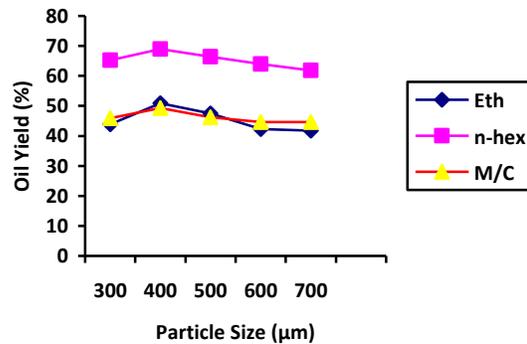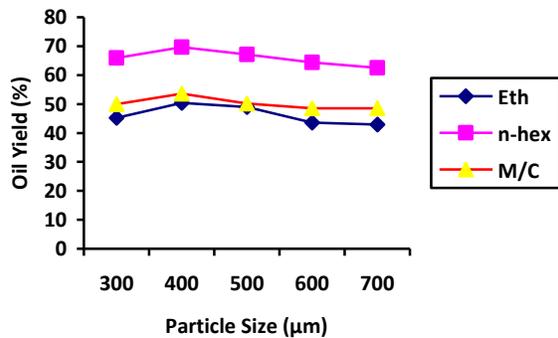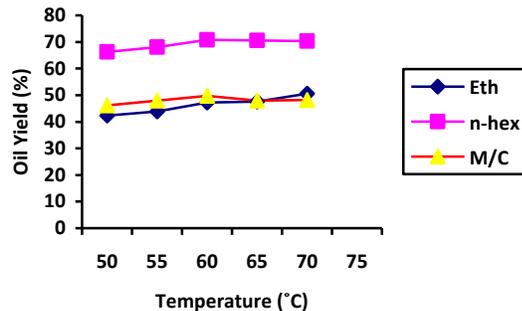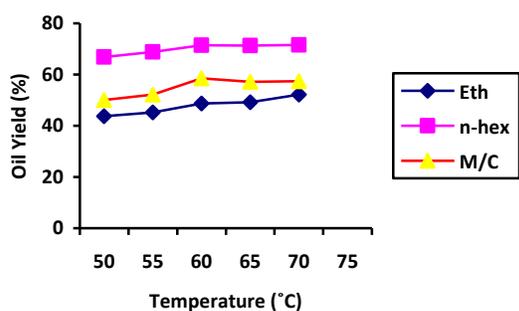
(a)

(b)

Fig. 1: The effect of Particle Size on Oil Yield (a) before degumming, (b) after degumming
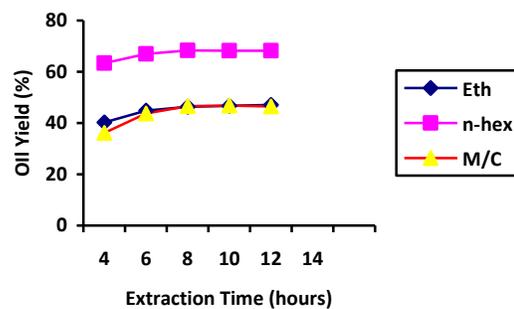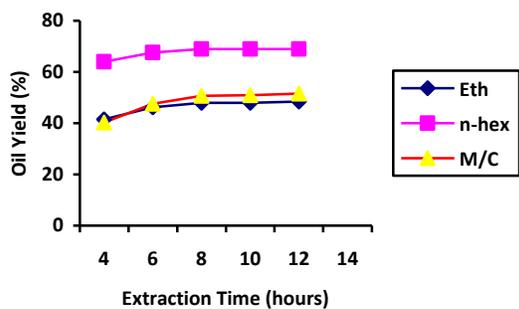
(c)

(d)

Fig. 2: The Effect of Extraction Time on Oil Yield (c) before degumming, (d) after degumming

(e)

(f)

Fig. 3: The effect of Temperature on Oil Yield (e) before degumming, (f) after degumming

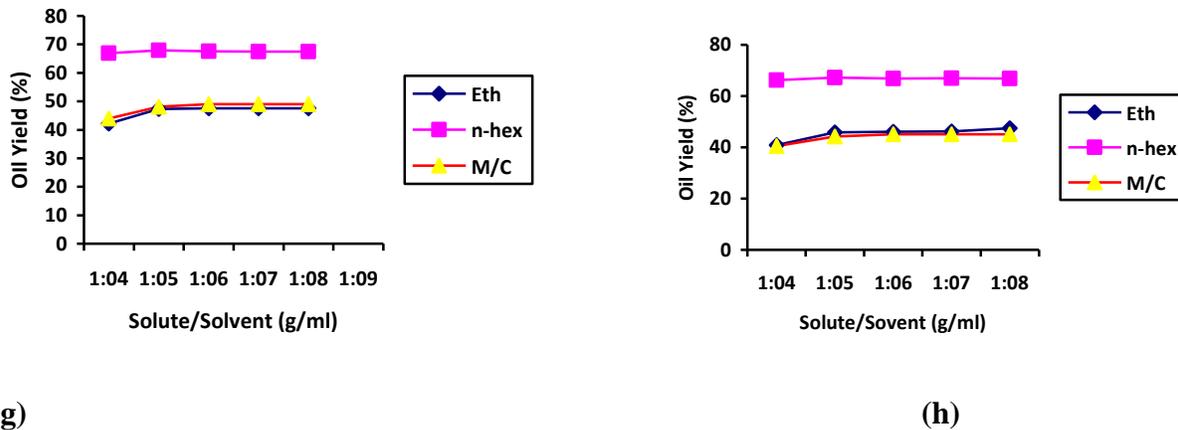**(g)**   **(h)**

Fig. 4: The effect of Solute/solvent ratio on Oil Yield (g) before degumming, (h) after degumming

The Effect of Particle Size:

Figure 1 shows the result of the effect of particle size on the oil yield. Among the four particle sizes used, 400µm gave the highest yield in the three different solvents used. It is expected that the smaller the particle size the more the yield because of the effective surface area but 300µm gave smaller yield than 400µm. This could be explained to be as a result of the agglomeration which could have reduced the surface area in contact [1]. The yield of the oil equally decreased from 500µm and least at 700µm. This decrease could equally be explained to be as a result of increase in particle sizes that reduced the available surface area for the solute and solvent contact. This means that based on this study, the effective particle size for solvent extraction of *Irvingia gabonensis* seed oil is 400µm.

The Effect of Extraction Duration

It was observed from Figure 2, that the longer the time of extraction the higher the oil yield but there was no significant difference between the yield at 8hours and 10hours. Therefore, allowing for extra 2hours beyond 8hours in the extraction process would not have any economic justification. Consequently, 8hour observed to be the optimum extraction duration. This agrees with the results of Musa *et al*, [1].

The Effect of Temperature:

The results obtained from Table 3 and Figure 3 clearly show that 60˚C gave the highest oil yield. Between 50-55˚C, the yield was poor because the temperature might not have been able to supply enough heat energy required to break the bonds of the ground meals. While at above 60˚C (65 and 70˚C) the yield was smaller probably because of the fading of some active components at those high temperatures [12]. It is observed that ethanol solvent yield at 70˚C was higher than at 60˚C and 65˚C. This is because the boiling point of ethanol (78˚C) was not reached at those low temperatures but was closer at 70˚C which means that the solvent molecules at 70˚C had more kinetic energy because of the high heat content while the boiling points of n-hexane (68.7˚C) and methanol/chloroform (68˚C/61.2˚C) were almost close to 65˚C. Therefore, solvent extraction using ethanol as solvent will require more energy consumption than n-hexane. Therefore, the application of n-hexane would make more economic sense than ethanol.

The Effect of Solute to Solvent ratio:
Considering the result of this study, the optimum ratio of solute to solvent is 1:5 as shown in Figure 4. The ratio 1:4 gave a lowest yield of the oil among the three solvents while above 1:5 (1:6 and 1:7) showed no significant increase in the oil yield. It implies that increasing the solute/solvent beyond 1:5 would only increase cost without an appreciable output while below 1:5 could not extract appreciable quantity of the oil from the ground meal. The result is in agreement with the results of Anwar *et al* [15] and Borcharic *et al* [16]. The result of the oil yield among the three solvents showed that n-hexane has the highest yield, followed by methanol/chloroform and least in ethanol before degumming. The methanol/chloroform had a higher yield than ethanol because of the closeness of the boiling point. After degumming, 3.0%, 1.0% and 8.0% gums were obtained from ethanol, n-hexane and methanol/chloroform extractions because of the ability of the polar solvents to overcome forces that hold the fats within the sample matrix [13]. This justifies the fact that polar solvents have the ability to extract more gums which are water soluble [14].

CONCLUSION
The oil content from the seeds of Wild Mango showed that this oil could be applied successfully as a source of edible and industrial oils. It contains high oil yield. The extraction process optimization process proved n-hexane as the best solvent, at 60˚C temperature, 8hours duration, solute/solvent ratio of 1:5 and particle size of 400µm. The production of useful oil from its seeds could be of economic benefit without negative effect to its food application.

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