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Physicochemical Parameters and Kinetics of Oil Extraction from *Coco nucifera*

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ABSTRACT

This paper involves utilization of cocos nuciferafor oil extraction using n-hexane and ethanol as solvents. The physicochemical properties and kinetics of the coconut oil extraction were determined. The physicochemical properties studied were refractive index, Saponification value, iodine value, free fatty acid, peroxide value and pH. Analysis of the extracted oil shows that refractive index, saponification value, iodine value, free fatty acid, peroxide value and pH has the following parameters using ethanol and hexane: 1.47 and 1.48, 203.1 and 204.7mg.KOH/g, 51.39 and 51.42g/100g sample, 0.51 and 0.59% oleic acid, 4.08 and 4.17 meg.peroxide/kg, 6.27-6.84 and 6.18-6.72 respectively. The result also reveals that as the extraction time increases from 60 to 240 minutes, the volume and weight of the extracted coconut oil increases from 1.5ml to 31.73ml and 8.13g to 26.38g respectively using ethanol. The result further revealed that as the time increases from 60 to 240 minutes, the volume and weight of the extracted coconut oil increases from 11.27 to 28.15ml and 8.61 to 23.88g respectively using n-hexane.The pH determination clearly shows that coconut oil is slight acidic in nature with a pH range of 6.27–6.84 and 6.18–6.72 for ethanol and n-hexane respectively. The First order kinetic model favoured coconut oil extraction from the coconut fruits. The oil extraction using ethanol as a solvent gave a higher percentage yield than oil extraction using n-hexane.

Key words: Coconut oil, *Coco nucifera*, Physicochemical parameters, Kinetics, Extraction

INTRODUCTION

In Nigeria, 70% of the vegetable oils being consumed are often extracted from palm kernel seed. These oils often require a high temperature treatment before it will melt. Hence it is usually stored in the human body as a waste. There is a high tendency of cardiovascular disease which is likely to result from the consumption of palm kernel oil. The consumption of vegetable oils such as sun-flower oil, butter, etc result to increased level of low density lopoprotein (LDP), which is a very bad cholesterol that is quite detrimental to human health.

The quest for improved human diet has prompted the discovery and consumption of vegetable oil as means of deriving nutritional and dietary fats and oils. Coconut oils are the major oils being consumed by human. Coconut oils are edible oil which is being extracted and obtained from matured coconut fruits during batch or soxhlet extraction process [1].

Coconut oils have been utilized by most subtropical and tropical countries for some years. It's often obtained from *cocos nucifera* tree belonging to *Aracaceae* family. The term coconut was devised in 1600s and its provenance is Southern and Central America, India and Africa. It has served as a basic constituent in human daily diet and also being used for other useful purposes. Coconut oils have also found application in medicine, soap manufacturing (production), prevention of rusting and industrial applications. Today researches are underway on the effective use of coconut oils for biodiesel production. Scientific discoveries in 1930s and 1920s affirmed that oils from coconut differ from other oils and fats with respect to its compositions [2-4].

Coconut oils produce distinctive smell and taste. When solidified at reduced temperature, it becomes pure white, but when liquefied at increased temperature, it becomes crystal clear just like water [1]. Coconut oils basically composed of triglycerides, Linolenic acid (0.20%), Caproic acid (1%), Linoleic acid (3%), Oleic acid (8%), trace amount of Palmitoleic acid, Stearic acid (4%), Capric acid (8%), Caprylic acid (10%), Palmitic acid (10%), Myristic acid (21%) and Lauric acid (52%). They are often free from rancidity with a unique and natural fresh coconut aroma [5]. Coconut oil also called Copra oil is consumable oil which oxidizes at slow rate, have numerous applications and possesses higher percentage of saturated fat. It is usually extracted through dry process (involving nut and shell separation with subsequent drying, thereby forming Copra. This copra is adequately dissolved or pressed with solvent resulting to oil formation) or by a wet process (involving the utilization of raw coconut without using dried copra). The dry process is more economical due to high energy demanding, use of mechanized and modern equipment, higher capital and more operational cost of the wet process [6-8].

Hexane, ethanol and petroleum ether are good solvents mostly used during oil extraction processes from matured coconuts which have lasted for more than two week after harvesting from the *cocos nucifera* tree [6-8]. Several kinetics studies on oil extraction from oil bearing seeds has been conducted by different researchers. Extraction is a process controlled by diffusion due to an oil concentration gradient in the solvent phase. Mohammad et al (2013) conducted a study on the kinetics of Gaharu oil extraction and proved that the second- order mechanism was the best fit.The aim of this paper is to determine the physicochemical properties and kinetic effects on the coconut oil extracted using ethanol and hexane as solvents.

MATERIALS AND METHOD

Sample Collection and Preparation

All the reagents used were of BDH analaR grade and all the glassware and sample bottles were cleaned.The coconut fruits were harvested from coconut tree in Choba, Port Harcourt, Nigeria. The fruits were kept for a period of 3 weeks after which the coconut husks were detached from them, with subsequent removal of the shell from the endocarp (fleshy edible part). The coconut fleshy parts were cut and sliced into smaller pieces and then oven dried at a temperature of 55 to 65^{o}C for a period of 4 days. The dried fleshy parts were properly and duly ground, which were subsequently wrapped in a Whatman filter paper before been subjected to oil extraction by means of soxhlet extraction using ethanol and n-hexane.

Oil Extraction Process from the Coconut Fruits

The analysis was carried out by measuring a known amount of the ground coconut fruit wrapped in a filter paper was placed in a soxhlet extractor attached to a 1000 ml capacity round bottom flask. 500 ml of ethanol was carefully poured in the round bottom flask prior to the attachment of the soxhlet extractor. The round bottom flask was placed in a heating mantle with a temperature regulator for temperature control. The extraction was carried out at different extraction time (60, 120, 180 and 240 minutes). Different temperatures were also employed during the extraction process. The temperatures (60, 70, 80 and 90 ^{o}C) are above the boiling point of ethanol. The coconut oil was separated from the solvent using rotary evaporator. The analysis was repeated using another solvent, n-hexane for coconut oil extraction in order to ascertain the solvent that gave the maximum yield. The percentage yield (% Y) of the coconut oil was further calculated using equation below:

$$\% \text{ Yield} = \frac{M_o}{W_c} \times 100 \%$$

Where M_o is the mass of the extracted coconut oil and W_C is the mass of the fleshy coconut used for the extraction.

Refractive Index Measurement

The refractive index (RI) measurement of the extracted coconut oil were carefully determined by utilizing a refractometer which was connected to a water bath and was duly monitored. It was also controlled thermostatically. The measurement of the refractive index was carried out at a temperature of 45^{o}C.

Saponification Value Determination

In measuring the saponification value (SV), 0.15M of potassium hydroxide and ethanol (95 % v/v) were reacted together and thereafter the mixture was distilled. 4g of extracted coconut oil sample was weighed into 200ml capacity conical flask. The flask was subsequently subjected to boiling until complete saponification of the oil was observed. It was cooled and further titrated with HCL (0.4 M) and phenolphthalein was utilized as indicator.

Iodine Value Determination

The iodine value was measured by pouring 0.003g of the extracted coconut oil sample into a beaker containing 35ml of 2:3 v/v cyclohexane and CH_3COOH solution. Wijs solution (55ml) was carefully added to the mixture. The mixture was thereafter left uninterruptedly in the dark, with subsequent titration with $Na_2S_2O_3$ solution (0.15M)

Free Fatty Acid (FFA) Determination

1.5ml of phenolphthalein solution (2%) was reacted with 20 ml of 1:1 v/v mixture of diethylether and ethanol. Sodium hydroxide solution (0.15M) was then used to neutralize the mixture. 3.5g of the extracted coconut oil sample was carefully added to this neutralized mixture and was further titrated with a solution of NaOH (0.15M). The mixture was thereafter subjected to shaking until a re-occurring pink colour was observed for 12 minute. The free fatty acid (FFA) values were developed from the titre values.

Peroxide Value

42ml of 1:2 v/v chloroform and glacial acetic acid solvent mixture was reacted with 2.5g of potassium iodide (KI), and thereafter the whole mixture was added to 2.5g of the extracted coconut oil sample. The mixture was boiled for a period of two minutes and the resulting hot solution was directly poured in a flask containing 6.0% KIO_3 solution (42ml). Starch solution (4 drops) were gently added, before titrating with $Na_2S_2O_3$ solution (0.03M).

pH Determination

The pH of the coconut oil was also determined using pH meter.

RESULTS AND DISCUSSION

Physicochemical Parameters

Table -1 Physicochemical parameters of the extracted coconut oil

S/N	Sample parameters	Coconut oil extracted with ethanol	Coconut oil extracted with n-hexane
1	Refractive index	1.474	1.488
2	Saponification value (mg. KOH/g)	203.1	204.7
3	Iodine value (g/100g of sample)	51.391	51.426
4	Free fatty acid (% oleic acid)	0.513	0.594
5	Peroxide value (meq. Peroxide/kg)	4.08	4.17
6	Ph	6.27 – 6.84	6.18 – 6.72

The values obtained for the refractive index measurement are 1.474 and 1.488 for coconut oil extracted with ethanol and hexane respectively as shown in table 1. Refractive index is one of the paramount parameters often employed in edible oils' identifications. Refractive index is also imperative in determining coconut oil composition. An increased value of refractive index connotes an increased fatty acid chain length of triglycerides and also indicates increased unsaturation. These values (1.474 and 1.488) obtained showed that coconut oils have a long fatty acid chain length. The results obtained are similar to the result reported by Mohammed and Ali, 2015.

The results obtained for the Saponification value determination are 203.1 and 204.7 for coconut oil extracted with ethanol and hexane respectively. Saponification value entails the quantity of potassium hydroxide needed to saponify 1 gram of the oil. It is often utilized in oil characterization. A high saponification value implies that any soap that will be produced from the oil, will demonstrate a greater solubility. The high values obtained from the saponification values determination clearly indicate that coconut oils could be utilized commercially for soap production.

The values obtained for the iodine value determination are 51.391 and 51.426 for coconut oil extracted with ethanol and hexane respectively. Iodine value often referred to as iodine index or number implies the quantity of iodine in gram usually consumed by unsaturation (inform of double bond) in fatty acid. An increased or higher value of iodine index of oil shows higher degree of unsaturation of oils, making them more prone to oxidation and decreases their stability. A low iodine value shows that the oil is quite saturated, and can resist oxidation.The result obtained shows that coconut oil extracted with hexane and ethanol are quite stable and also exhibit some level of resistance to oil oxidation due to their low iodine value. Furthermore, this result proved that coconut oils are also suitable for soap making (production) due to their iodine value.

The result obtained for the Free fatty acid determination are 0.513 and 0.594 for coconut oil extracted with ethanol and hexane respectively. Free fatty acid specifically entails percentage by mass of any fatty acid. Free fatty acid value is always affected by oil's moisture content, deodorizing agent used, refining method and natural variation. High amount of free fatty acid in vegetable oil is highly undesirable because it can reduce oil's shelf life and also result to bad flavour in the oil.These values (0.513 and 0.594) obtained demonstrated that the coconut oil extracted with both ethanol and hexane (solvent) exhibited lower percentage of free fatty acids. Hence, possesses a high shelf life and good flavour.

The results obtained for the Peroxide value determination are 4.08 and 4.17 for coconut oil extracted with ethanol and hexane respectively. Peroxide value is often used to show the extent of oxidation the oil undergoes. Higher degree of unsaturation of oil often results from increased peroxide value. Oxidative rancidity always occurs due to increased peroxide value.These values (4.08 and 4.17) obtained revealed that the coconut oils rarely undergo oxidative rancidity. The pH of the oils extracted from coconut are in the range of 6.27 – 6.84 and 6.18 – 6.72. This clearly shows that coconut oils are slightly acidic in nature.

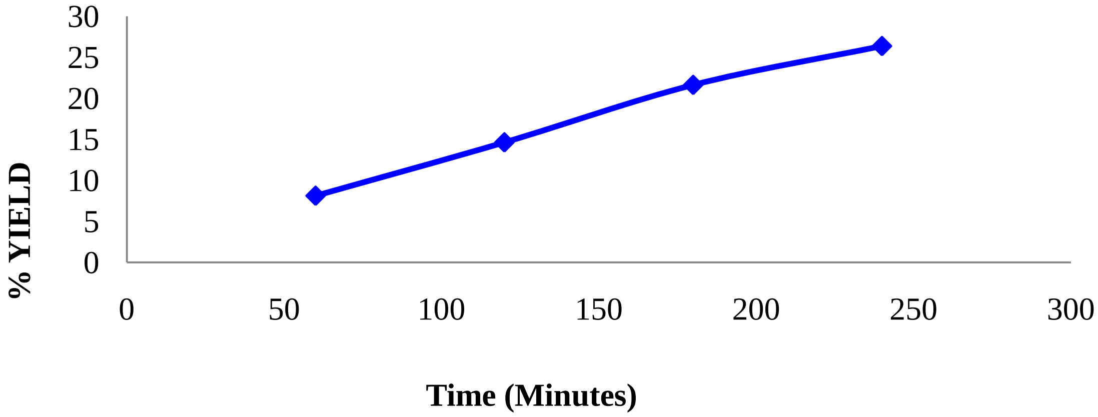

Fig. 1 Effect of extraction time on percentage yield using ethanol

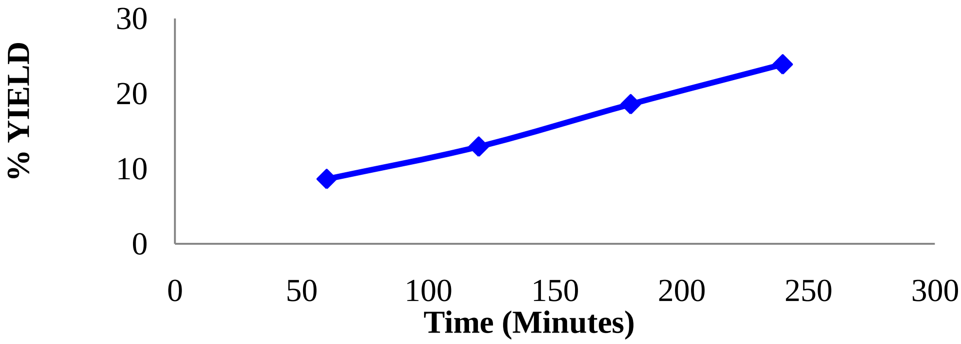

Fig. 2 Effect of extraction time on percentage yield using n-hexane

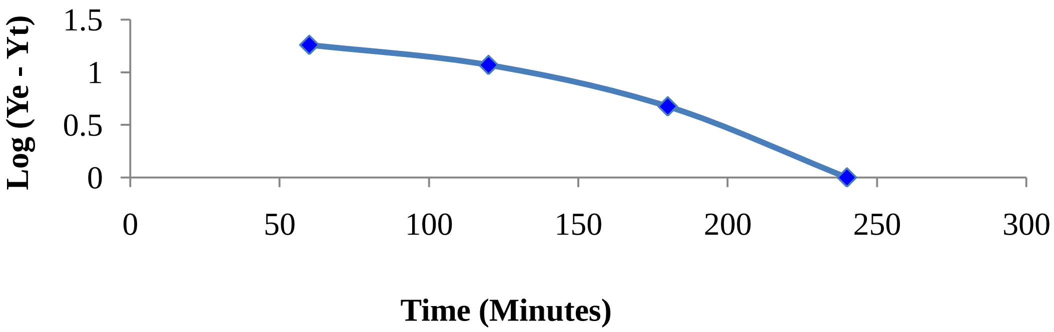

Fig. 3 First Order Kinetics of coconut oil extraction using ethanol

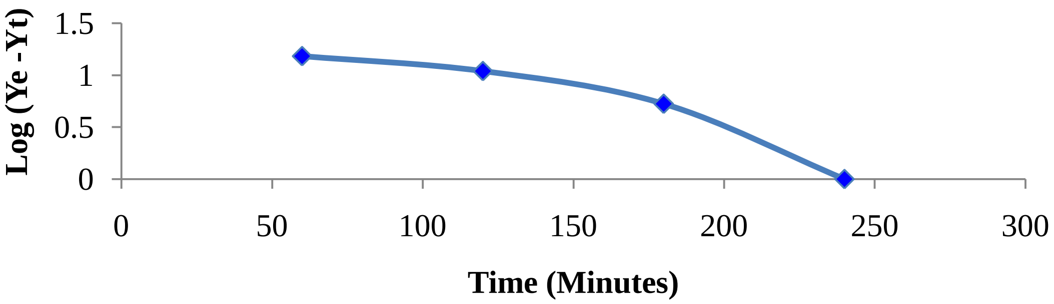

Fig. 4 First Order Kinetics of coconut oil extraction using n-hexane

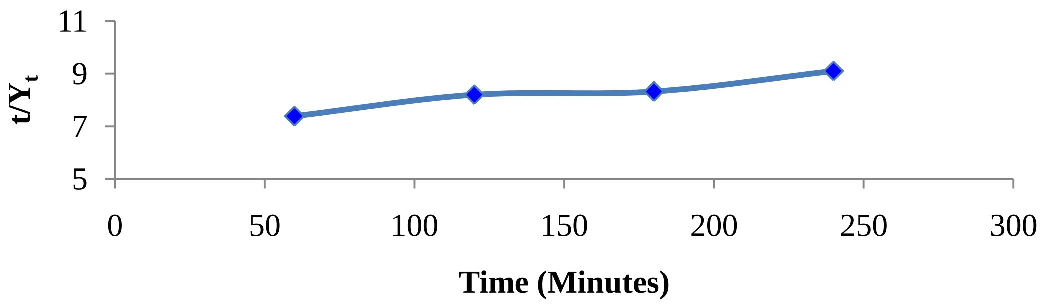

Fig. 5 Second Order Kinetics of coconut oil extraction using ethanol

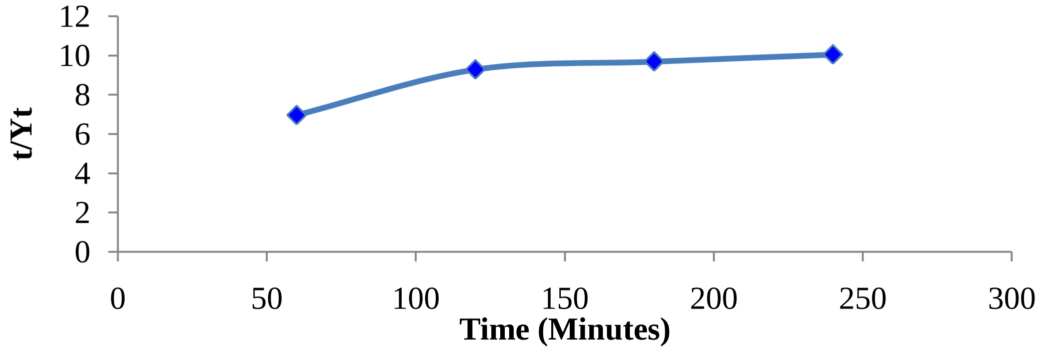

Fig. 6 Second Order Kinetics of coconut oil extraction using n-hexane

Table -2 Coconut oil extraction using ethanol at varying time

Vol. of Ethanol used (ml)	Wt. of Coconut (g)	Time Taken Per Extraction (mins)	Vol. of Oil Produced (ml)	Wt of Oil Produced (g)
500	100	60	10.5	08.13
500	100	120	19.9	14.64
500	100	180	25.8	21.15
500	100	240	31.73	26.38

Table -3 Coconut oil extraction using n-hexane at varying time

Vol. of Ethanol used (ml)	Wt. of Coconut (g)	Time Taken Per Extraction (mins)	Vol. of Oil Produced (ml)	Wt of Oil Produced (g)
500	100	60	11.27	8.61
500	100	120	15.59	12.92
500	100	180	23.21	18.57
500	100	240	28.15	23.88

Table -4 Kinetic properties of extracted coconut oil using ethanol

S/N	Time (mins)	$Y_{e(experimental)}$	Y_t	Log $(Y_e - Y_t)$	t/Y_t	Ye (cal) 1st order	R^2 1st order	Ye (cal) 2nd order	R^2 2nd order
1	60	26.38	8.13	1.261	7.380	62.517	0.9365	113.64	0.9379
2	120	26.38	14.64	1.070	8.197	62.517	0.9365	113.64	0.9379
3	180	26.38	21.64	0.676	8.318	62.517	0.9365	113.64	0.9379
4	240	26.38	26.38	0	9.098	62.517	0.9365	113.64	0.9379

Ye = Percentage yield at equilibrium. Yt = Percentage yield at time, t. R^2= Correlation factor

Table -5 Kinetic properties of extracted coconut oil using n-hexane

S/N	Time (mins)	Y_e (experimental)	Y_t	Log $(Y_e - Y_t)$	t/Y_t	Ye (cal) 1st order	R^2 1st order	Ye (cal) 2nd order	R^2 2nd order
1	60	23.88	8.61	1.184	6.969	50.582	0.8955	62.111	0.8037
2	120	23.88	12.92	1.040	9.288	50.582	0.8955	62.111	0.8037
3	180	23.88	18.57	0.725	9.693	50.582	0.8955	62.111	0.8037
4	240	23.88	23.88	0	10.050	50.582	0.8955	62.111	0.8037

Ye = Percentage yield at equilibrium. Yt = Percentage yield at time, t. R^2= Correlation factor

The result revealed that the volume (ml) and weight (gram) of coconut oil produced using ethanol increases with increasing extraction time. As the time increases from 60 to 240 minutes, the volume and weight of the extracted coconut oil increases from 1.5 ml to 31.73 ml and 8.13 gram to 26.38 gram respectively as shown in Table 2.
Theweight (gram) and volume (ml) of coconut oil produced using n-hexane also increased with increasing extraction time. As the time increases from 60 to 240mins, the volume and weight of the extracted coconut oil increases from 11.27 ml to 28.15 ml and 8.61g to 23.88g respectively as shown in Table 3.
The reaction kinetics is graphically presented in figures 1 to 6 and the reaction kinetic parameters are presented in tables 4 and 5. Two reaction kinetic models were utilized in this study, first order reaction kinetics and second order reaction kinetics. The experimental percentage yield (Ye_{exp}) of the coconut oil extracted using ethanol is 26.38. The calculated percentage yield from the first order kinetics and second order kinetics are 62.517 and 113.64 respectively. The correlation factor, R^2 obtained from the first and second kinetic model for oil extraction using ethanol are 0.9365 and 0.9379 respectively, which indicates a linear plot of the first and second order kinetics.
The extraction of coconut oil from the coconut fruits by soxhlet extractor using ethanol is favoured by the first order kinetics because the calculated percentage yield (Ye_{cal}) of the first order kinetics are more closer to the experimental percentage yield (Ye_{exp}) than the calculated percentage yield (Ye_{cal}) of the second order kinetics.
The experimental percentage yield (Ye_{exp}) of the coconut oil extracted using n-hexane is 23.88. The calculated percentage yield from the first order kinetics and second order kinetics are 50.582 and 62.111respectively. The correlation factor, R^2 obtained from the first and second kinetic model for oil extraction using n-hexane are 0.8955 and 0.8037 respectively, which indicates a linear plot of the first and second order kinetics.
The extraction of coconut oil from the coconut fruits by soxhlet extractor using n-hexane is favoured by the first order kinetics because the calculated percentage yield (Ye_{cal}) of the first order kinetics is closer to the experimental percentage yield (Ye_{exp}) than the calculated percentage yield (Ye_{cal}) of the second order kinetics

CONCLUSION

Soxhlet extractor was utilized in this study for coconut oil extraction from matured coconut fruits using ethanol and n-hexane as solvents. The result confirmed that time is a paramount extraction properties, which affect the quantity and the percentage yield of coconut oil extraction from coconut fruits, using ethanol and n-hexane because the volume (ml) and weight (gram) of coconut oil produced using both ethanol and n-hexane increased with increasing extraction time. The extraction of coconut oil from the coconut fruits by soxhlet extraction using n-hexane and ethanol is favoured by the first order kinetics because the calculated percentage yield (Ye_{cal}) of the first order kinetics is closer to the experimental percentage yield (Ye_{exp}) than the calculated percentage yield (Ye_{cal}) of the second order kinetics. Therefore, first order kinetic model favoured coconut oil extraction from the coconut fruits. The pH determination clearly shows that coconut oil is slight acidic in nature with a pHrange of 6.27 – 6.84 and 6.18 – 6.72 for ethanol and n-hexane respectively.

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