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# Comparative Study of Extraction of Oil from Coconut Using Ethanol and Hexane

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## ABSTRACT

*As the economic demand for vegetable oils increases, there is a need for improved recovery from source seeds to offset the rising demand. In many cases, the choice of extraction solvent has become a major concern owing to the different yield performance of different solvents. In most cases, ethanol has often been preferred. This is as a result of combined factors of lack of proper knowledge of several other commercially available alternatives and possibly, the technical and economic advantage it offers. This work, therefore, presents a comparative experimental investigation of two solvents (n-hexane and ethanol) performed at the Department of Chemical/Petrochemical Engineering Laboratory, Rivers State University, Port Harcourt, Nigeria, using a sohxlet extractor. This study primarily focuses on the technical advantage of using n-hexane for seed oil extraction over the conventional ethanol using a two-stage experimental procedure was used – a seed oil extraction stage and a solvent recovery sage. In each stage, the coconut seed sample were subjected to the same experimental conditions and the yield performance is comparatively analyzed. The results of this investigation show that the n-hexane is a better solvent for the extraction of the sample coconut oilseed. The variation of solvent yield with temperature, extraction time and solvent concentration were plotted and analyzed in order to estimate and also forecast the effect of the parameters on solvent yield and also establish an optimal condition for optimal solvent yield. As part of the scope of this work, key recommendations are provided to ensure optimal solvent yield for coconut oil extraction.*

***Key Words:*** *Coconut Oil, N-Hexane, Ethanol, Solvent Yield, Solvent Recovery, Extraction Time.*

## 1. INTRODUCTION

As a result of the oil boom of early 70's, agriculture was left for petroleum and its derivatives. In a more recent time, a seemingly "U" turn has become the case since Nigeria sole dependence on petroleum has not proved so good on the economy [1]. This has been demonstrated by bad economic situations in the country and consequently, the increasingly poorer standard of living. As a way of restructuring the economy, it is evidently shown that agricultural products such as seed oils extracted from local seeds and nuts if properly monitored and harvested can be very helpful in our local economy and also in sustaining global foreign exchange.

From global data, the major sources of protein and vegetable oil are from oil seeds and vegetables [2]. Oil constitutes a well-defined class of naturally occurring substance and are naturally greasy, being soluble in organic solvents but insoluble in polar solvents such as water. From empirical science, oil is a liquid at room temperature.

Oil and fats are generally sourced commercially from certain plant groups which are mostly seeds and nuts and also in some parts of animals [3]. The existence of oil in certain plants has been known for century of years [4]. Depending on the amount of unsaponified matters and impurities present in it, oils can be generally classified as edible and non-edible oils. Edible oil extracted from bread fruits, cashew nut, peanut , coconut etc. are examples of vegetable oil which are naturally occurring esters of higher fatty acids and glycerol, and are predominantly triglycerides with traces of mono and diglycerides, sterples, antioxidants, vitamins, saturated and unsaturated free fatty acids and other minor constituents. They are widely distributed in nature and were first consumed as food. Later, oils were discovered to be used as renewable raw materials for variety of non-food production. For instance; soaps, creams, disinfectants, paints, enamels, inks and more.

## 2. LITERATURE REVIEW

The effect of process temperature on the solvent extraction of oil from coconut has not been previously investigated. In 2013, oil was extracted with a microwave-assisted solvent extraction with hexane and petroleum benzene at elevated temperatures by applying irradiation levels of 200 W and 800 W, though the researchers did not specify the achieved temperature [6].
Generally, an increase in temperature improves the solubility of lipids. This is because at high temperatures, the cohesive and adhesive interactions between oil molecules and oil-matrix molecules respectively is significantly disrupted which increases the diffusion rate of the lipids [7].

In further studies, involving the use of dichloromethane resulted in a slightly higher oil yield than hexane with a possible explanation being the drying process, which was carried out at a temperature of 50 °C and may potentially have led to incomplete moisture removal [8]. Therefore the slightly polar character of dichloromethane may have been responsible for the slight oil yield increase relative to that obtained with hexane, as polar solvents can improve the oil extraction efficiency from wet samples [9]. In 2006, a higher oil yield with heptane comparing to hexane and ethanol extractions was achieved, however, extractions with the various solvents were conducted for different and the extraction time was not specified.

Because of the potential risks to human health and the environment associated with hexane use, many research efforts have been focused on finding alternative solvents [10]. The available alternatives such as short-chain alcohols, especially ethanol and isopropanol, are particularly promising, because they have higher operational safety and low toxicity. These alternatives are generally sourced from bio renewable sources and can be used to extract high-quality oil, and improve the sensory and functional characteristics of the defatted meal. Due to their high polarity, alcoholic solvents can extract higher amounts of phospholipids and unsaponifiable material from solid matrices than hexane, thus increasing the nutritional value of the extracted oils [11].

In much later study, maximum yields of approximately 44% for hazelnut oil extraction with absolute ethanol at $500^0$ C were recorded. Solubility data for cottonseed oil in ethanol and isopropanol (absolute form or a geotropic mixture) revealed that increasing the temperature results in an increase in the oil solubility in a given solvent [14].
Base on the above cited literatures, this study therefore is focused on comparative performance evaluation of Ethanol and Hexane solvents on oil recovery from coconut. At the same vain, the effect of solvent concentration, Effect of extraction time and Effect of extraction temperature will be investigated.

## 3. MATERIALS AND APPARATUS

**Table 1: Materials and Apparatus**

| S/N | MATERIAL/APPARATUS | UNIT |
|---|---|---|
| 1 | Coconut meal | - |
| 2 | Hexane | - |
| 3 | Ethanol | - |
| 4 | Round Bottom flask | 500cm3 |
| 5 | Measuring Cylinder | 500cm3 |
| 6 | Clamps | - |
| 7 | Stop watch | - |
| 8 | Weighing balance | - |
| 9 | Electric heater | - |
| 10 | Beakers | - |
| 11 | Condenser | - |

## 4. EXPERIMENTAL DESIGN

**PHASE 1: Extraction of Vegetable oil from Coconut using n-Hexane/Ethanol**

The weighing machine was checked for zero error. A clean and dry empty crucible was weighed and weight recorded. The meal is gradually put into the crucible on the weighing machine until its new reading exceeds the former reading by 100g. At this point the meal was transferred into bags before putting it into the thimble of the sox let apparatus. 150cm$^3$ of hexane was measured in a measuring cylinder and poured into the round bottom flask. The experimental set up is shown in figure 3.1 bellow. Heat was supplied to the round bottom flask by the electric heater which makes the hexane to boil. As it boils, its vapour ascends through the siphon of sox let into the condenser which condenses it. Timing starts when the first condensate just appears and falls into the extraction thimble. The condensate dissolves the oil contained in the meal. The mixture of the condensate and the dissolved oil falls back to the round bottom flask where the solvent (hexane) which has lower boiling point keeps on boiling and sending vapours to the condenser which condenses it into the extraction thimble again. Different timing period where used. At the expiration of each time, the electric heater was put off.

At this point the meal was put away after the last condensate has dropped and new meal of the same weight was charged into the thimble for fresh extraction for another timing period.

At the end of these different extraction times, the round bottom flask containing the dissolved oil and the solvent was removed for solvent recovery experienced after reweighing. This procedure is repeated for new coconut meal feed also using hexane as the solvent.

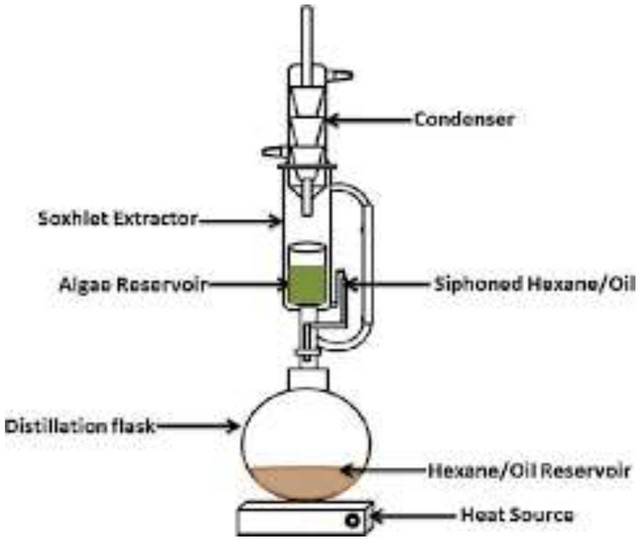


**Figure 1: Experimental Set-up for the Vegetable Oil Extraction using Ethanol and Hexane**

**PHASE 2: Recovery of Solvent (Hexane/Ethanol) from the Mixture of Solvent and Vegetable Oil.**

The apparatus was set up as shown in figure 3.2; heat was applied to the round bottom flask by the electric heater. When the mixture boils the vapour of the lower boiling fraction (Hexane) ascends up and condenses into the beaker by the help of the condenser. The heating process continued until all the solvent in the mixture was evaporated and condensed into the beaker leaving only the vegetable oil in the round bottom flask. The distillate was the Hexane. The volumes of the vegetable oil extracted was measured and recorded accordingly. This process was used to obtain the volume of vegetable oil in 150cm3 of solvent.

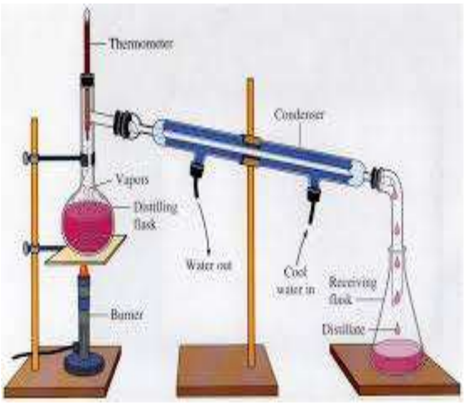


**Figure 2**: **Experimental Set-up for the Recovery of Solvent (Hexane/Ethanol) from the Mixture of Solvent and Vegetable Oil.**

## 5. RESULTS AND DISCUSSION

The results obtained were experimentally gotten from the Chemical/Petrochemical Engineering Laboratory, Rivers State University. The tables below vividly explained the comparative power of extraction of the ethanol and hexane.

**Table 2: Shows the Effects of Temperature on Oil Yield for Extraction using Ethanol and Hexane**

| Temperature (℃) | $y_{Ethanol}$ (%) | $y_{Hexane}$ (%) |
|---|---|---|
| **0** | 0 | 0 |
| **58** | 15 | 20.5 |
| **62** | 15.5 | 21.2 |
| **68** | 16.2 | 21.8 |

**Table 3: Shows the Effects of Time on Oil Yield for Extraction using Ethanol and Hexane**

| Time(min) | $y_{Ethanol}$ (%) | $y_{Hexane}$ (%) |
|---|---|---|
| **0** | 0 | 0 |
| **60** | 20 | 23.2 |
| **72** | 22 | 25 |
| **80** | 24.5 | 27 |

**Table 4: Shows Effects of Solvent Concentration (x (%)) on Oil Yield for Extraction using Ethanol and Hexane**

| Solvent Conc. (x (%)) | $y_{Ethanol}$ (%) | $y_{Hexane}$ (%) |
|---|---|---|
| **0** | 0 | 0 |
| **75** | 19 | 24 |
| **90** | 24 | 28.8 |
| **100** | 27 | 33 |

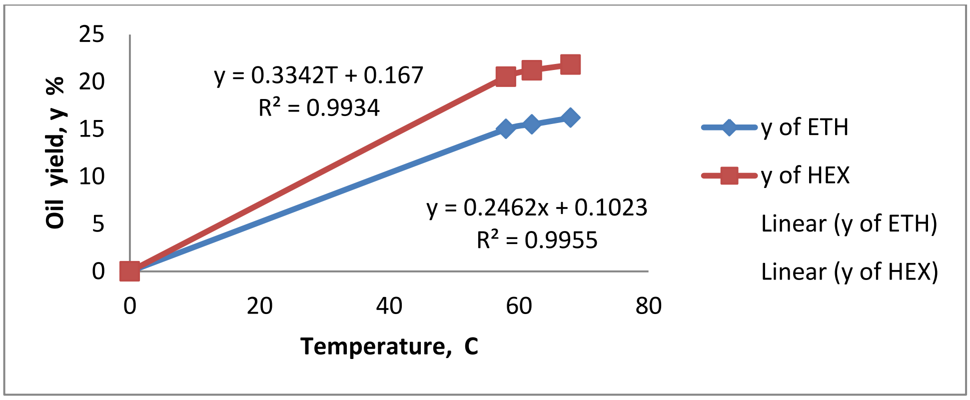


**Figure 3 Plot of Yield of Ethanol and Hexane against Temperature**

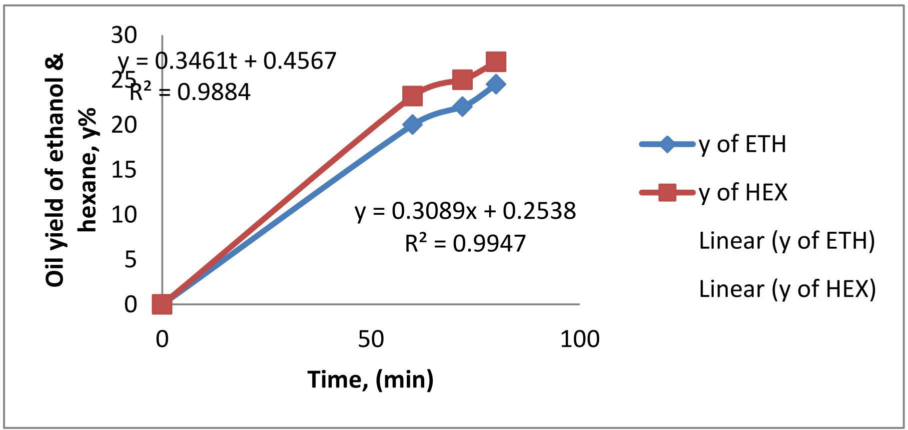

**Figure 4: Graph of Oil Yields for Ethanol and Hexane Extraction versus Time (min)**

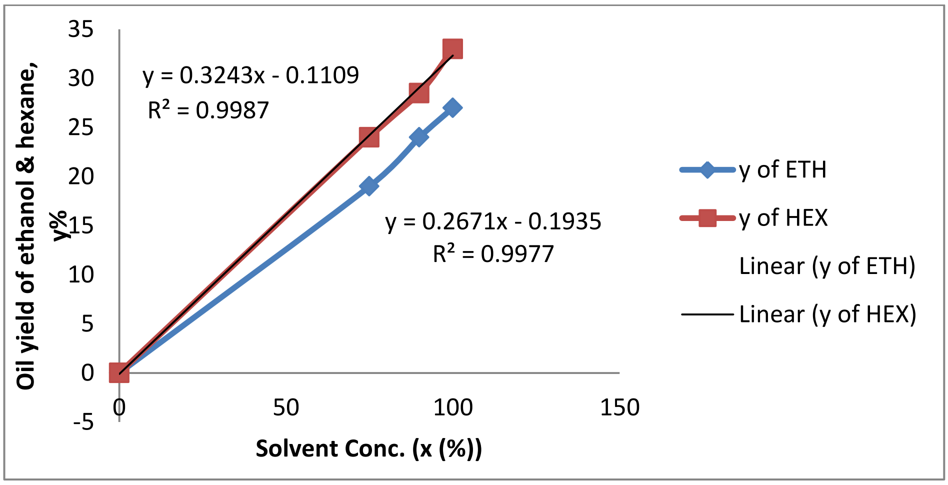


**Figure 5 Variations of Oil Yields with Solvent Concentration (x) in %**

## 5.2 Result Discussion

### 5.2.1: Oil Yield (volume recovery) of Ethanol and Hexane Solvent with Temperature.

The yield of oil extracted from coconut is a function of temperature as shown in the Table (2) and Figure (3)

$$y_{Hex} = 0.334T + 0.167 \quad (1)$$

$$y_{Eth} = 0.246T + 0.102 \quad (2)$$

Where;

$y_{Eth}$ = Oil yield for Ethanol

$$y_{Hex} = \text{oilyield for Hexane}$$

$$T = Temperature$$

As explained in Figure (3), the oil yield is directly proportional to temperature (°C). There is variation in quality of solvents used in the extraction of oil from coconut. From the graph, hexane is a better solvent to ethanol as more oil yield is obtained at the same condition of temperature.

### 5.2.2: Oil Yield (volume recovered) from Coconut with Time (min) using Ethanol and Hexane Solvents

Also, the yield of oil extracted from coconut is a function of time.

$$y_{Hex} = 0.346t + 0.456 \quad (3)$$

$$y_{Eth} = 0.308t + 0.253 \quad (4)$$

Where:

$y_{Eth}$ = oil yield for Ethanol

$$y_{Hex} = \text{oilyield for Hexane}$$

$$t = time$$

As depicted from Table (3) and Figure (4), the yield of oil extracted from coconut is directly proportional to the extraction time in min. At time t=60 min the yield from Ethanol and Hexane are respectively 20% and 23.2%, then as time increases, the yields from the solvents increases too, i.e., at t=72-80 min, yields from Ethanol and Hexane are respectively 22-24.5% and 25 – 27%.However, the quality of the solvents must be emphasized as yield varies with solvent quality. As shown from the figure, Hexane is of better quality than Ethanol because of high yield produced at the same condition of time than Ethanol.

**5.2.3: Variation of Oil Yield Extracted from Coconut using Ethanol and Hexane Solvents with Solvent Concentration (x %).**

Solvent concentration in % is one of the parameter that determines the quantity of oil extracted from coconut using Ethanol and Hexane. Solvent Concentration is the amount of solvent diluted in $H_2O$. The result obtained as shown in Table (4) and Figure (5) indicates that the more the solvent present in water, the more the quantity of oil extracted from coconut. Hence oil yield is a function of solvent concentration.

$$y_{Hex} = 0.324x - 0.110 \quad (5)$$

$$y_{Eth} = 0.267x - 0.193 \quad (6)$$

Where:

$$y_{Eth} = oil\ yield\ for\ Ethanol$$

$$\mathrm{y_{Hex} = oilyield\ for\ Hexane}$$

$$x = solventconcentrationin\ (\%)$$

The figure also present to us that the solvent concentration of Hexane is better in quality than solvent concentration of Ethanol. Hence Hexane is a better solvent to Ethanol as oil yield extracted is higher than that obtained from Ethanol.

## 6. CONCLUSION

Having conducted this project, it has been shown that the extraction power of Hexane is the better when compared to that of Ethanol. Hence, Hexane is a better solvent for extraction of oil from coconut meal when compared to Ethanol. The variation of oil yield with extraction temperature and extraction time at fixed solvent concentration at 100% as shown in chapter 4, it was observed that as the extraction time is kept constant 90 min and also increasing the extraction temperature from 58,62 and 68, there was an increase in extraction yield from 15, 15.5, and 16.2 % . When the temperature is kept constant at $65^0$c, and increasing extraction time from 60, 72 and 80 min, extraction yield increasing from 20, 22 and 24.5 % thus, extraction time has more effect in increasing oil extraction yield compared to change in extraction temperature. Also when extraction temperature is kept constant at $65^0$c with the variation of extraction time and solvent concentration, it was observed that as the extraction time is kept constant at 90 min and also increasing the solvent concentration from 75, 90 and 100 %, there was an increase in extraction yield from 19, 24 and 27%. When solvent concentration is kept constant at 100%, and also increasing the extraction time from 60, 72 and 80 min, extraction yield increase from 20, 22 and 24.5% thus, solvent concentration have more effect in increasing oil extraction yield compared to extraction time and extraction temperature.

## Recommendations

1. Base on this project finding, Hexane is a better extractive solvent when compared to Ethanol. When used to extract coconut oil from coconut meal. In general, all companies involved in using Ethanol for extracting coconut oil is advised to change to Hexane.
2. The oil extracted from coconut meal can be further processed to serve as a raw material for chemical processing plants e.g. for the production of cheese, butter, hair and body creams, candles , vegetable oil, wax etc.
3. Finally, more research work should be carried out on coconut oil so as to get vast information on its physical and chemical properties for characterizing and classifying coconut oil.

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## APPENDIX

## EXPERIMENTAL RESULT AND CALCULATIONS

### EXPERIMENT A

**Extraction and Recovery Experiment using Ethanol as Solvent**

- **Effect of Extraction Temperature on Oil Yield**

**Experimental Values**

Mass of coconut meal = 00g

Solvent concentration = 100%

Extraction time = 90 min

Extraction temperature = $58^0$c

Mass of extracted oil = 15ml

**Calculation**

$\frac{mass of extracted oil}{mass of coconut meal}$ = oil yield

$\frac{15}{100} \times 100 = 15\%$

The above calculations were repeated for the different temperature ranges used in the experiment

- **Effect of Extraction Time**

**Experimental Values**

Mass of coconut meal = 100g

Solvent concentration = 100%

Extraction time = 60 min

Extraction temperature = $65^0$c

Mass of extracted oil = 20ml

**Calculation**

$\frac{mass of extracted oil}{mass of coconut meal}$ = oil yield

$\frac{20}{100}$ × 100 = 20%

The above calculations were repeated for the different time ranges used in the experiment

**EXPERIMENT B**

**Extraction and Recovery Experiment using Hexane as Solvent**

- **Effect of Extraction Temperature on Oil Yield**

**Experimental Values**

Mass of coconut meal = 100g

Solvent concentration = 100%

Extraction time = 90 min

Extraction temperature = $58^0$c

Mass of extracted oil = 20.5 ml

**Calculation**

$\frac{mass of extracted oil}{mass of coconut meal}$ = oil yield

$\frac{20.5}{100}$ × 100 = 20.5%

The above calculations were repeated for the different temperature ranges used in the experiment

- **Effect of extraction time on oil yield**

**Experimental Values**

Mass of coconut meal = 100g

Solvent concentration = 100%

Extraction time = 60 min

Extraction temperature = $65^0$c

Mass of extracted oil = 23.2ml

**Calculation**

$\frac{mass of extracted oil}{mass of coconut meal}$ = oil yield

$\frac{23.2}{100} \times 100 = 23.2\%$

The above calculations were repeated for the different time ranges used in the experiment