SOLVENT EXTRACTION OF CASHEW NUT OIL FROM THE SHELL OF CASHEW NUT

ANACARDIUM OCCIDENTALE

BY

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(89/1135)

THIS THESIS IS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF ENGINEERING.(B.ENG).

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DECLARATION

I hereby declare that this research project has been conducted solely by me under the guidance of my supervisor Mr. Duncan of department of chemical Engineering, Federal University of Technology Minna.

Writers whose work have been referred to in this project have been acknowledged.

ADAM AMJAD .S
STUDENT'S NAME

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SIGNATURE

DATE :__________

DEDICATION

I dedicate this work to my father Mr. S.A. Sulaiman and to my mother, Mrs. Sulaiman.

ACKNOWLEDGMENT

My sincere thanks goes to the Almighty Allah, who has given me the opportunity to present this work. I wish to express my appreciation to my supervisor **Mr. Duncan** whose enormous contributions to this project can not be overlooked and the Head of my department **Dr. K.R. Onifade** for his encouragement

To the entire members of the **Sulaiman's family** most especially **Miss Najla Sulaiman** and **Noha Sulaiman** who made this project a reality.

My best wishes goes to the chairman **Akkary L.T.D Mr Michael Akkary** whose contributions both in cash and kind saw the actualization of this work. It is only God that can pay him back.

To my best friends, **Aisha Abubakar Bawa, Rahana Abdulahi** and **Mrs Usman (Ashia)** who were always there when I need them most. You will forever remain close to my heart.

My heart won't rest without acknowledging the following people. **Hussaini Ado, Niyi Wahab, Shola Odubela.** I wish them the best what this life has to offer.

OBJECTIVE

The project objective is to investigate the effect of size distribution on the amount of CNSL cashew nut shell liquid oil extracted using benzene as a solvent

ABSTRACT

The extraction of cashew nut liquid (CNSL) was performed by using benzene as a solvent on a soxhlet apparatus.The effect of particle size distribution and time on the yield of oil extracted was studied.

In the experiment on a 2.5g sample and 500ml of benzene and a time period of 3 hours the average extract of oil obtained were 0.645g, 0.622g,0.528g, 0.525g,and The corresponding percentage yield are 25.8%, 24.88%, 23.28%, 21.00%. These are all extracted from the average size range of 0.925mm,1.200mm, 1.700mm, 2.400mm,

At the end of the experiment it was observed that the extract of oil and percentage extract varies inversely proportional to particle size. The results obtained agrees with the known postulate ,that the particle size is inversely proportional to the yield. The colour of the oil extracted was black.

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CHAPTER ONE

1.0.0 INTRODUCTION

BOTANICAL NAME:- Anacardium Occidentale

FAMILY :- Anacardiaceac

OTHER NAMES :- Cashew (French)

Caja (Portuguese)

Merci (Spanish)

Cashew nut shell liquid is a visible industrial Raw-material obtained from cashew nut, it constitutes about 25% (1)of the whole cashew nut. It was formerly regarded as a waste by product but now its use as an industrial raw-material is on the increase because it contains considerable amount of alkyl substituted phenols from which many industrial products can be prepared.

Cashew nut shell liquid contains M-Pentcideca dienyl (Cardanol), 5-Penta decadienyl resiranol (Cardol) and 2-Hydroxy-6-Penta deca dienyl benzoic acid (Anacordic acid) as major constituents.(2)

CULTIVATION AND MANAGEMENT OF CASHEW

There are many varieties produced small, medium, and large nuts, the trees are spaced7-10m apart. Planting holes are given during ashed and rock phosphate (120kg per hole).

Complete Fertilizers are applied in the first 2 years, Prunning is necessary for the first 3 years to shape the tree. The tree starts bearing fruits in the third year. Maximum yield are obtained at about 10 years, and life span exceeds 20 years.

CARE

The leaf can be attacked by leaf eating caterpillars e.g Ahacus, Euthalia aconthea and urthaga incarusalis. These are controlled by the use of insecticides. The steam boring Rhytidoderal is also controlled by prunning and treatment with dichlorobenzene.

The production of cashew requires an annual rainfall of 20-150inches and it is best grown on sandy soil with good drainage. Though it is often grown on hill sides which are too dry and too high for other crops.

Cashew is grown largely in India, Tanzania and Mozambique. Presently Nigeria is gradually becoming a producer of this crop. Cashew plantation were initially used for erossion control.Because of the strong nut structure of this trees and to the fact that the tree is hard and draught resistant. It strives under a variety of climate and soil condition, it can be grown from sea level 1-400ft but it is best suited to lower elevations.

1.111 USES

The shell of the cashew nut contains an irritant skin poison that produce blisters and dermatitis, care should be taken soas to avoid contact with the skin. Its versatile uses are however in its converted form as resins, it can be used in the preparation of cements, making of mouldings, acid resistant paints, varnishes, foundry resins, friction modifying mateial in brake and clutch linning. **(3)** It is used as wood preservative because of its germicidal and antimicrobial properties, it is used as black lacquers for decorating vases. It can also be used in the produce photographic developing reagents, drugs, dyes, and quartenary Nitrogen compounds which have germicidal or bacterial diuretics.

1.112 METHOD OF EXTRACTING (CNSL)

There are three different methods generally used in extracting cashew nut seed liquid (CNSL) from cashew nuts. They are :-

[1] Mechanical expression.

[2] Roasting method.

[3] By solvent extraction.

Due to time and equipment limitation only solvent extraction is used in this study. Two types of equipments methods can be used in solvent extraction they are soxhlet extractor and the direct contact method. For the same reason only the soxhlet extractor is used.

CHAPTER 2

2.0.0 LITERATURE REVIEW

2.0 CASHEW PLANT

Cashew tree (Anacardium Occidentale) is one of the proprising tropical cash crops. It is a native of North Brazil and was brought to other tropical countries by the portuguese as early as 400 years ago. The tree has always been appreciated for it's "table fruit".The swollen pendicle of hydrocarp called cashew apple. The "real" part the kidney-shaped nut is attached to the appex of the apple. The apple and its juice can be eaten in its raw but ripe form can be processed into syrup, jams, juices, beaverages or candied fruits.(4) The main products however is the nut.

Cashew can thrive on soils which are too poor and too dry for other crops. The tree grows well at PH of 4.5-6.5. The tree is hard and draught resistant and grows best on well drained sandy soils with an annual rainfall of at least 900mm. Below 500mm rainfall the tree ceases to function as a fruit tree.

Cashew plant was believed not to be free from serious pests and diseases. Anthracrose (Geomenella 119) is one of the most harmful pest and has a close correlation between innocullum climatic conditions and stages of development of the inflorescence, was formed.

The nut is made of an outer skin or testa (from which tennis can be extracted). The nut shell and the kennel. The nuts are about 2.5-4.0cm in length, the edible kennel constitutes approximately 25-30 of the whole nut. The kennel is the edible part of the nut which started coming to the market under the name "Cashew nuts". The shell consists of two compact layers separated by a honey comb like structure that contain cashew nut liquid (CNSL) **(1)**

The percentage composition were reported to be as follows; Protein 20%, CNSL 45% Carbohydrate 26% (5) The CNSL is a pale brown viscous oil made up of anacardic acid phenol) in various proportions according to the method of extraction. **(5)**

The CNSL was reported to constitute about 25% of the whole cashew nut. In studying the components of CNSL, by chromatographic method, it was found the compositions were as follows; Anacardic acid (71.7%), Cardol (18.7%), Unknown minor ingredients (2.2%).

Hydrogenation of anacardic acid gave 2-carboxy-3 penta decyl pheno **(1)** Cardol gave 5-penta decyl resorcinol and Cardanol gave 3-penta decy phenol.**(5)**

2.1.0 2.1 WORLD PRODUCTION

The annual production of CNSL for export has varied considerably. But it has always been an upward trend. Estimate for the consumption of CNSL with producing countries are unchangeable but the figure given are in the region of $1x10^9$ tonnes. For Brazil $2x10^9$ tonnes for India with $5x10^8$ tonnes **(3)** seems to be used for Africa.

2.2.0 METHODS OF EXTRACTION

There are three different methods generally used in extracting CNSL from cashew nuts. They are;

(1) Mechanical Expression

(2) Roasting Method

(3) By solvent extraction

However the most common method for commercial extraction of CNSL are Roasting and solvent extraction method methods.

2.2.1 ROASTING METHOD

Under Roasting method, we have the; @ Hot-oil-bath roasting and *(b)* open fire roasting method.

@ HOT-OIL-BATH ROASTING

In this method, the nuts are roasted in a bath filled CNSL at 170-190°C. The nuts are dropped in the bath in wire traps or passed through it in a Screw conveyor or on a special conveyor belt. As the nuts are roasted, the cells in the skin burst, releasing the liquid into the bath. The excess liquid over flows out of the bath and is collected. The CNSL is persumed to be expelled by the rapid volatalization of the water in the shell. About 90% of the CNSL is recovered in this way.

(b) OPEN-FIRE ROASTING

The roasting is done over an open- fire in an open perforated pans of earthen ware or sheet metal at 180-204'C or with perforated rotary cylinders suspended on an inclined position over a furnace. The nuts are being constantly stirred to prevent scorching and to ensure uniform roasting. The CNSL is caught in receptacles though much of it is lost.

Another 'Hot method' is the treatment of the nuts in vertical tanks through which super heated steam of upto 27o°C is passed. About 90% of CNSL is collected in a receptacle placed under the nuts. The liquid obtained by this way is considered to be of better quality than that obtained by other hot methods.

2.2.2 SOLVENT EXTRACTION METHOD

In the Laboratory there are two types of solvent extraction available. These extraction methods are direct and indirect methods. In the Direct method we use the batch extractor.

For the Indirect method Soxhlet extractor is used.For the purpose of this experiment Soxhlet extractor is used.

The extraction of a soluble constituents from a solid by the use of liquid solvent is generally referred to as leaching. The mechanism of leaching may involve simple physical solution or dissolution made possible by chemical reaction.

Leaching is primarily concerned with the recovery of oils from a nut or seed structure which has been prepared to facilitate it's penetration by solvent. That is the size reduction followed by diffusion of the oil-solvent mixture to the surface of the solid.

The rate of transport of solvent into the mass to be leached, or of soluble fraction into the solvent, or of extract solution out of the insoluble material, or some combination of

2.2.4 FACTORS INFLUENCING SELECTIVITY OF THE SOLVENT

In many leaching operations, the suitability of the right solvent influences the type of solvent to be used. These charateristics are as follows:-

(1) PURITY:- The solvent should be free from any impurities. So as to not interfere with extraction

(2) RELATIVE VOLATILITY:- The ability of a liquid to change to vapour or gaseous form is termed volatility. It is required that the relative volubility of the solute to the solvent be favourable.

(3) RECOVERBILITY:- After extraction it is expedient to recover the solvent for reuse. And this is done with the aid of distillation. Therefore it is required that the solvent should not form azeotrope with the extracted solute and the mixture should show high relative volability for low temperature recovery.

(4) VISCOSITY AND FREEZING POINT:- Viscosity is defined as the resistance to flow. It decreases with evaporation and vapour pressure. The greater the vapour pressure the lower the viscosity. The solvent choosen should be able to circulate freely to enable it reach every pore and surface area, for extraction to take place. Therefore the solvent choosen should have a sufficient low viscosity and low freezing point to circulate freely.

(5) INFLAMMABILITY:- For safety reasons it is very necessary that the solvent should have a high flash point above 32.2°C. Generally all liquids with flash points below 32.2°C are flammable.

(6) TOXICITY:- Generally for extraction of edible oils non toxic solvents are used, hexane e.t.c. But since the uses of CNSL are non edible. There is no problem in using Benzene because benzene is considered toxic and moreover cancerous. **(6,7)**

(7) CHEMICAL REACTIVITY:- The solvent choosen should be chemically stable and inert not only with the solute but with the component of the system and common materials of construction.

(8) COLOUR:- Colour of solvent should be distinct from that of the solute.

(9) AVAILABILITY:- The solvent should be easily available.

(10) LESS COSTLY:- The solvent shold not be expensive.

CHAPTER 3

3.0.0 LEACHING

The extraction of a soluble constituent from a solid by the use of liquid solvent is generally referred to as leaching. The mechanism of leaching may involve simple physical solution or dissolution made possible by chemical reaction.

The rate of transport of solvent into the mass to be leached or of a soluble fraction into the solvent, or of extract solution out of the insoluble material or of the solute from the solution in contact with particle to the main bulk of solution or some combination of these rates may be involved and a chemical reaction rate may also affect the rate of leaching.

Leaching is primarily concerned with the recovery of oils from a nut or seed structure which has been prepared to facilitate it's penetration by solvent and diffussion of the oils solvent mixture to the surface of the solid.

The structure of cashew nut shell (CNSL) is quite complicated. The oil is considered as being maintained in small tough cell walls. The C.N.S. flakes are porous and in the cause of extraction the solvent migrate to the pores in order to extract oil.

The design of large scale solvent extraction apparatus must be determined by the rate at which equilibrium is attained between a lean miscella outside the shell particles, and oil-solvent mixture within the particles. The design is also affected by the particle size distribution that would allow optimum extraction of oil.

Based on the porous nature of the flakes a mechanism has been postulated for explaining the leaching of oils. This is called the molecular diffussion theory.

FLOW SHEET SHOWING STEPS INVOLVED IN SOLVENT EXTRACTION OF CASHEW NUT SHELL LIQUID (CNSL)

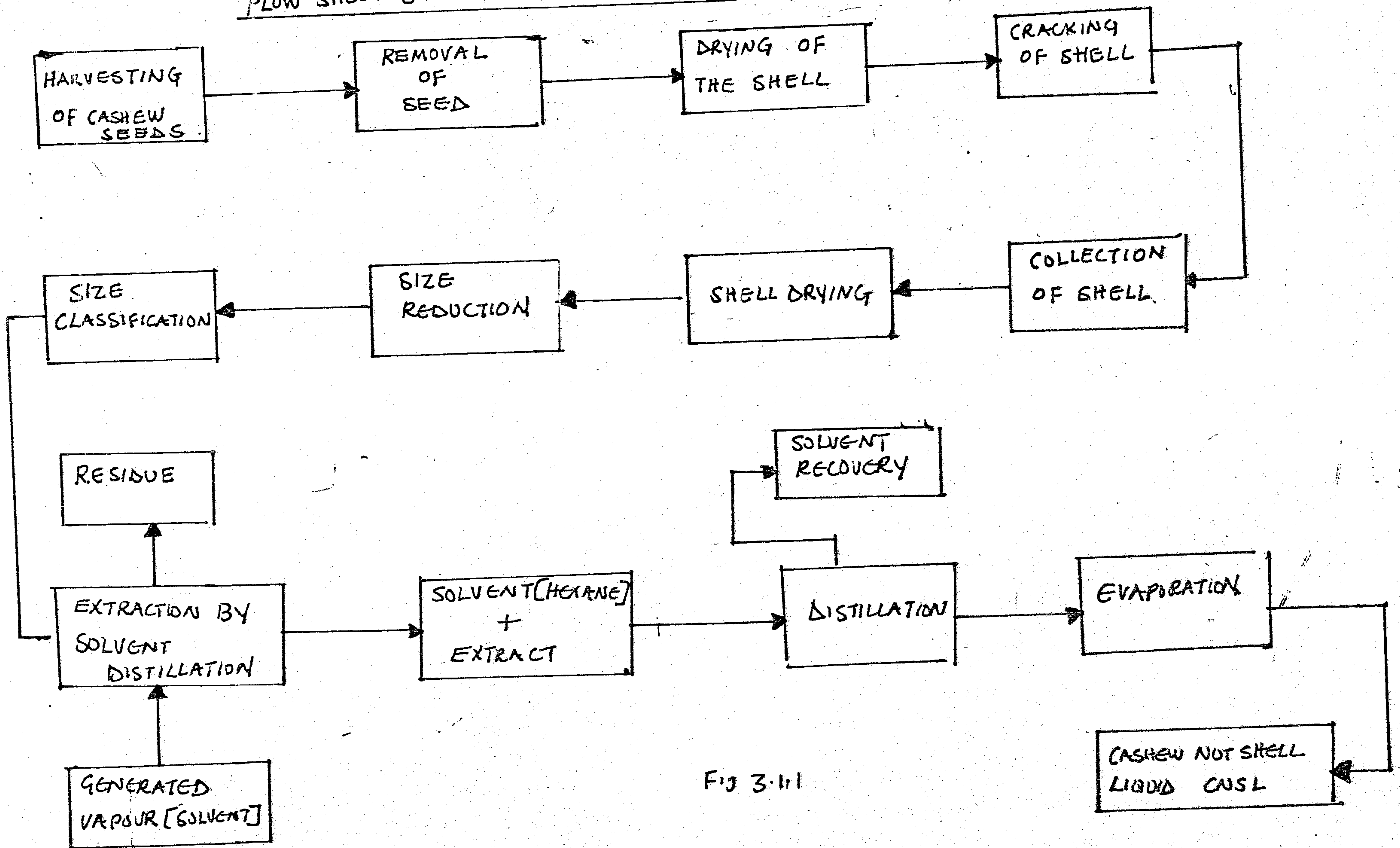


Fig 3.1.1

3.1.0 UNIT OPERATION INVOLVED IN CNSL EXTRACTION

Extraction of oil from cashew nut shell is basically a physical change but chemical conversion may be required in refining and further processing of such oils. The unit operation involved in the extraction of CNSL are :-

(1) Material handling

(2) Drying (sun)

(3) Size reduction

(4) Extraction

(5) Stripping

(6) Filtration and flow of fluids. See fig (3.1.1).

3.2.0 PHYSICAL CHARACTERISTICS OF A SOLID

A knowledge of physical characteristics of the carrier solid is very important to determine wheather a prior treatment is necessary to make the solute more accessible to the solvent.

These prior treatment may involve the following unit operations .

(1) Crushing

(2) Grinding

(3) Cutting into pieces or reforming into special shapes such as flakes.

Solute paricle may exist in the solid in a variety of ways. It may exist on the surface of the solid, may be surrounded by a nature of hard material. May be chemically combined or may exist inside cells or as in the case of many vegetable and animal bodies. Solute adhering to the solid body is readily remiscible by the solvent.

When solute consists in pores surrounded by a matrix of hard material the solvent has to diffuse to the interior of the solid to capture solute and then diffuse out before a separation can result in such case, sub-division of the solid by grinding or cutting decreases the surface exposed to the solvent that is the solvent has to trail a shorter distance to remove the oil. However size reduction into fine particles has it's problems. Insure instead, the ammount of solute to be removed is small in relation to the ammount of material to be treated so that grinding becomes uneconomical.

Too-fine division may result in packing of solids during extraction. Preventing free flowof solvent through the solid bed. In such a case extraction is much more difficult especially when finely divided solids are treated in an unagitated state.

Dispersion of the particles in liquid solvent by agitation permits thorough contacting of the solid with the solvent.**(10)** Agitation, while giving good extraction may cause suspension of fine particles in outflowing solute, which may subsequently require a difficult filtration of clarification at a step.

In the case of materials with cellular structure, if the cell walls remain intact, the leaching action involves osmotic passage of the solute through cell walls. It is however impractical and undesirable to grind materials to rupture cell walls, since this may result in addition to the desired solute, creating a purification problem.

Therefore instead of restoring to excessive subdivision many solid of porous structure are cut into wedge shaped slices called "cossetles", crushed and reshaped into flakes, as in the case of vegetable seeds to obtain increased surface, which permits free flow of solvent through the solid and allows a more selective extraction.(5)

3.3.0 MOLECULAR DIFFUSION THEORY

When a porous solid containing a liquid is brought into contact with a solvent, inter diffusion of the molecles of the liquid and solvent, follows. The theory underlining the inter diffussion is that, if a solution containing substances of different molecular weight is kept separated from a more dilute solution of these substances by means of a semi-permeable membrane, the concentration gradient thus established cause the substance to diffuse through a membrane at varying rates of transfer. In the case of cashew nut shell, the shells act as a semi-permeable membrane.

The resistance to diffussion from the interface into the bulk of the solution is small in comparission with that of diffussion in the solid itself and concentration at the surface can be assumed equal to that of the bulk of the liquid.

Under certain idealized condition, the stage efficiency in extracting oils from cellular materials can be estimated based on FICK'S LAW OF DIFFUSSION.

The Fick's law of diffusion is given as $\frac{dx}{dt} = \alpha \frac{d^2x}{db^2}$ ---------------- (1)

where x = Concentration of solute in solution with solid

α = Diffussion constant

b = Distance, measured in direction of diffussion.

t = Time of diffussion.

The above equation (1) is based on the following assumptions.

(a) The diffusivity (α) is constant
(b) The solid can be considered to be made up of very thin slabs of constant density, size and shape.
(c) The concentration X, of the oil in contact with the solid is constant
(d) The initial concentration in the solid is uniform through out the solid.

Based on the above assumptions, when equation (1) is integrated and the boudry conditions can be applied, the result can be written as

$$\frac{\overline{X} - X1}{X - Xi} = \frac{8}{\pi^2} (e^{-\alpha i \beta} + \frac{1}{9} e^{-9\alpha i \beta} + \frac{1}{25} e^{-25\alpha 1 \beta} + ... = \varnothing\beta \text{-----------------(ii)}$$

Equation (ii) can be written as

$$\frac{8}{\pi^2} \quad \frac{1}{(2n+1)^2} \quad e^{-(2n+1)\alpha 1 \beta} = \varnothing(\beta)$$

Where n = 1, 2, 3, 4

$$\beta = \frac{\infty t}{r^2} \quad ; \quad \alpha_1 = \frac{\pi}{2}^2$$

Where

$\overline{X}$ = Average concetration of solute in solid at time t.

Xo = Uniform concentration of solute in solid at zero time

X1 = Constant concentration of solute in bulk of solution at all times

t = Time of contact

2r = Thickness of particle.

CERTIFICATION

This is to certify that this project is an original work under taken by Adam Amjad Suliman 89/1135 and has been prepared in accordance with the regulation governing the preparation of project in Chemical Engineering Department, Federal University of Technology , Minna.

MR DUNCAN   Date

DR. K.R ONIFADE   Date

EXTERNAL EXAMINER   Date

3.4.0 EFFICIENCY OF LEACHING

The efficiency of leaching can be determined by Murpee stage efficiency equations this is given by

$$n = \frac{\text{Oil extracted}}{\text{Extractable oil}} \qquad \text{.......(iii)}$$

$$n = \frac{Xo - \overline{X}}{Xo - X_l} = \frac{Xo - X_l}{Xo - X_l} - \frac{(\overline{X}o - X_l)}{(Xo - X_l)}$$

$$n = 1 - \frac{(\overline{X} - X_l)}{Xo - Xi} \qquad \text{.......(iv)}$$

Putting equation (2) into (4) we have

$$n = 1 - \varnothing(\beta) = 1 - \varnothing \frac{Dvt}{rp^2p} \qquad \text{-------(v)}$$

In order to obtain $\varnothing(\beta)$ a graph of equation (ii) $\frac{X - X_l}{Xo - X_l}$ Vs (β) for

different particle shape is used. This graph is available in most Chemical Engineering texts. [8,9].

3.3.0 FACTORS AFFECTING EXTRACTION

Several parameters affect the extraction process

(1) TIME:- In the extraction of most vegetable seeds and nuts, the rate of extraction initially increases rapidly for the first hour's but later decreases.

(2) SOLVENT:- solvent affects the rate of extraction since some of its properties that affects the rate of extraction like viscosity, boiling point, density, surface tension and vapour pressure differe from solvent to solvent.

3) mass of feed

4) [illegible]

the size, the greater the interficial area between the solid and the solvent hence the higher the rate of transfer of material. Smaller size also means that the solvent has to travel smaller distance within the solid thereby increasing the rate of extraction.

(4) FLAKE THICKNESS :- Like particle size, thickness is also indirectly proportional to the rate of extraction. This is because as flake thickness decreases the cell walls. Thickness also decreases, resulting in higher diffussion.

(5) TEMPERATURE:- This has the effect of decreasing the viscosity of oil and the solvent thereby increasing the diffussion coefficient. However care most be insured so as to prevent explossion of solvent when dealing with flammable solvent.

(6) MOISTURE CONTENT:- This is expressed as the ammount of water contained in the shell. As the moisture content of shell decreases, the rate of extraction increases. Decrease in moisture content lead to decrease in the water in the tissue which encircles the oil from which it is not easy to extract the oil.

CHAPTER 4

4.0.0 LABORATORY METHOD

In the Laboratory, there are two kinds of solvent extraction methods. These extraction methods are the indirect method using the Soxhlet extractor and the direct method.

4.1.0 THE DIRECT METHOD

The direct method apparatus as shown in fig 4.1 consist of a 500ml round bottomed flask and a condenser fitted into it.

4.1.1 METHOD

The feed that is Cashew nut shell (CNS) are placed in the 500ml round bottomed flask and the solvent is added together with it. And the resulting mixture is cooked using a heating mantle. As the flask containing the sample is heated the solvent evaporates and is then condensed into the liquid to extract the required solute. This cycle is repeated several times during the extraction.

After extraction, the content of the flask is fitted using a filter paper or glass wool is preferable. The miscella is then evaporated to recover the solvent.

4.1.2 THE INDIRECT METHOD

In the direct method, the soxhlet apparatus employed (fig 4.2). The soxhlet apparatus consist of.

@ Soxhlet flask (500ml).

(b) Soxhlet tube (500ml).

(c) Water cooled condenser.

(d) Heating mantle.

(e) Filter paper.

(f) Solvent.

(g) Thimble.

4.2.0 MODE OF OPERATION OF SOXHLET EXTRACTOR

The complete soxhlet extractor mounted on the heating mantle is heated. As heat is applied to the apparatus; the solvent evaporates and passes through the tube "b" into the main soxhlet tube. The vapours are then condensed by the water cooling condenser. The condensed solvent flows under gravity and percolates through the bed of the sample to extract the oil. As the condensate process continues the level of miscella in the soxhlet tube as well as tube "a" rises, untill its level reaches the point in the tube "a" which the miscella over flows back to the soxhlet flask. When this occurs, the volume of miscella in the soxhlet tube is emptied into the soxhlet flask. The process is repeated continously. In this way, the sample is continously treated with freshly condensed solvent. After extracting, the sample is removed from the soxhlet extractor and dried using an electric oven and then re-weighed.

The solvent is then recovered using a rotary evaporator.

4.3.0 EXPERIMENTAL PROCEDURE

In the direct method, the soxhlet apparatus is employed.

A mass of 2.5g of sample of a particular size range is put in the thimble of the soxhlet apparatus. As shown in fig (4.2) and 500ml of benzene is droped in the round bottom flask of the soxhlet apparatus, and the apparatus mounted as shown in the figure. And heat is applied at a constant temperature 80°C. As heat is applied to the apparatus; the solvent evaporates and passes through the tube "b" into the main soxhlet tube. The vapours are then condensed by the water cooling condenser. The condensed solvent flows under gravity and percolates through the bed of the sample to extract the oil. As the condensate process continues the level of miscella in the soxhlet tube as well as tube "a" rises, untill its level reaches the point in the tube "a" which the miscella over flows back to the soxhlet flask.

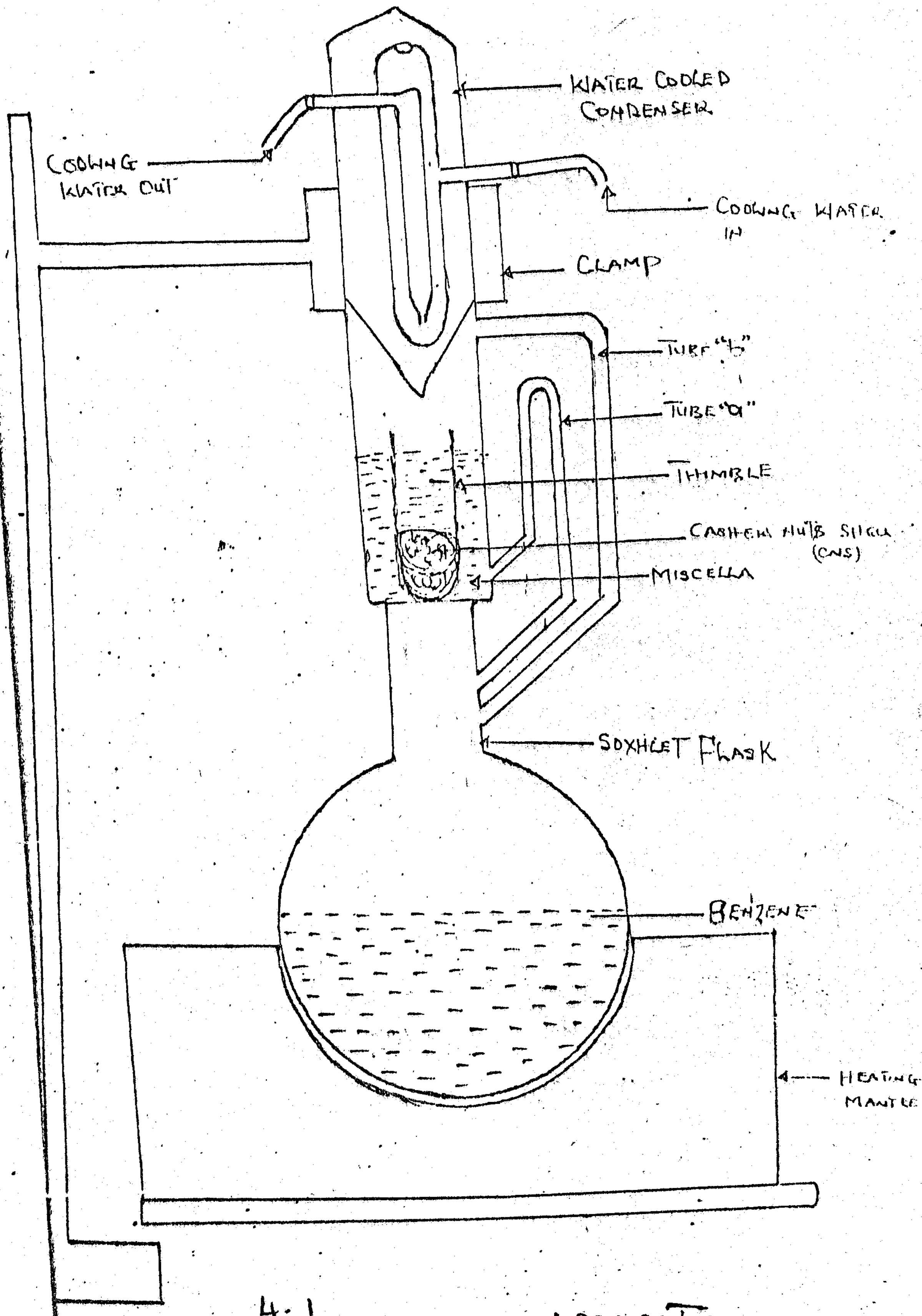


FIGURE 4.1: SOXHLET APPARATUS

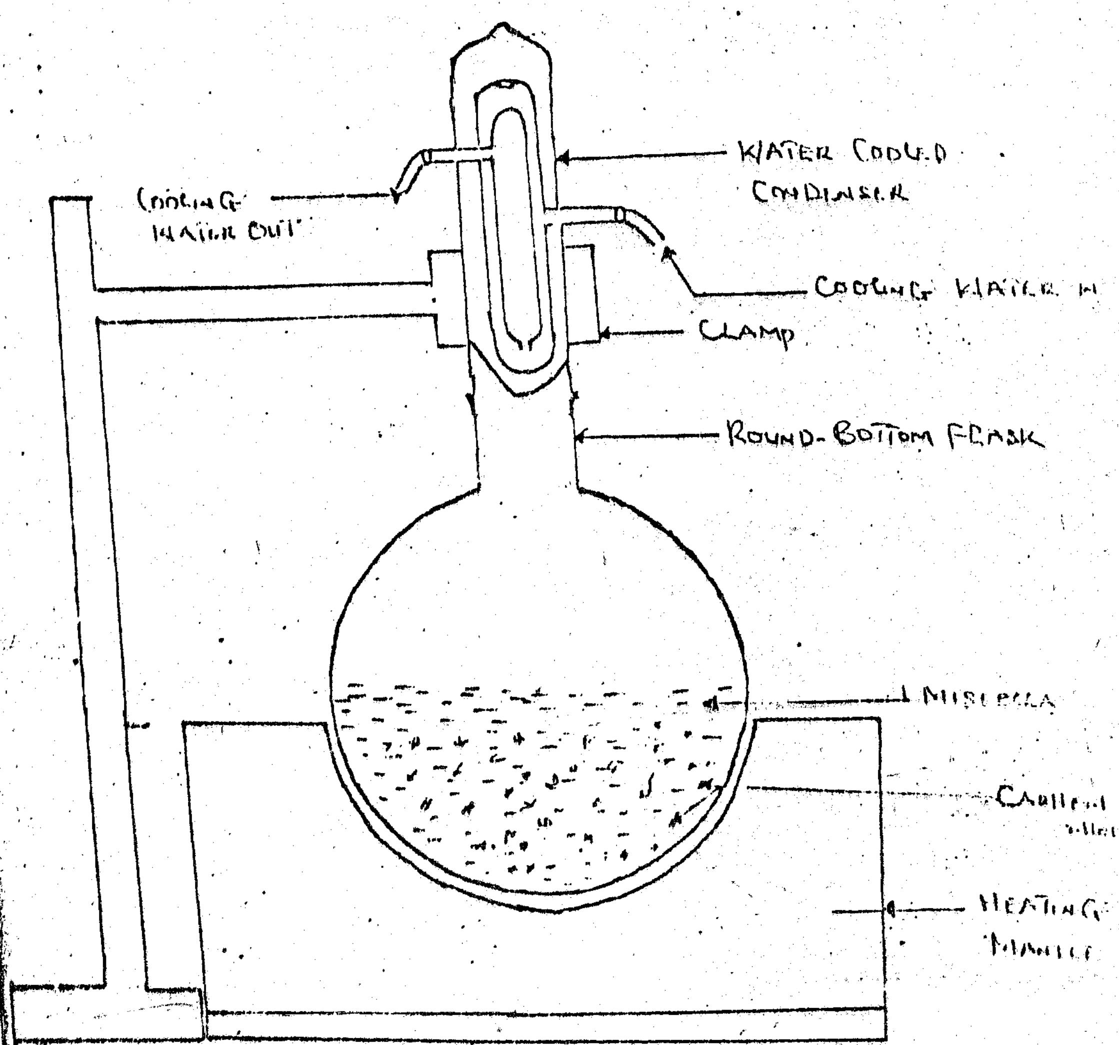


FIGURE 4.2: DIRECT METHOD APPARATUS

CHAPTER 5

5.0.0 RESULT

In this experiment, the size of CNSL was varied while other parameters like temperature, duration of extraction, time and mass of sample 80°C, 3 hours and 2.5g respectively was kept constant.

TABLE A A.

SIZE RANGE (mm)	AVERAGE PARTICLE SIZE (mm)	MASS OF CNSL (g)		AVERAGE MASS OF CNSL EXTRACTED (g)
		RUN(1)	RUN(2)	
(A) 0.850 --- 1.000	0.925	0.660	0.640	0.65
(B) 1.000 --- 1.400	1.200	0.610	0.59	0.60
© 1.400 --- 2.000	1.700	0.58	0.58	0.58
(D) 2.000 --- 2.800	2.400	0.53	0.51	0.52

5.1.0 CORRELATION AND REGRESSION

5.1 APPENDIX A

The value for the yield has to be plotted against particle size on a graph. The graph may be either a curve or a straight line, to determine this, correlation method is employed. If it gives + 1 or a value very close to 1 i.e linear relation could be used for the regression analysis.

REGRESSION ANALYSIS FOR 3 HOURS

TABLE BB

A	X	Xi	Xi^2	Yi	XiYi	Yi^2
1	0.850 - 1.0	0.9250	0.8560	0.650	0.6013	0.4225
2	1.0 - 1.40	1.200	1.440	0.600	0.7200	0.3600
3	1.40 - 2.00	1.700	2.890	0.580	0.9860	0.3364
4	2.00 - 2.800	2.400	5.7600	0.5200	1.2480	0.2704
		6.225	10.946	2.350	3.555	1.389

Correlation factor ⟹ R^2

$$R^2 = \frac{n \sum x_i y_i - (\sum x_i)(\sum y_i)}{\sqrt{(n \sum x_i^2 - (\sum x_i)^2)(n \sum y_i^2 - (\sum y_i)^2)}}$$

Putting in the values in the formula. In equation (A)

$$\frac{4(3.555) - (6.225)(2.35)}{4(10.946) - (6.225)' \times 4(1.3893) - (2.35)}$$

$$= \frac{14.22 - 14.629}{(43.784 - 38.75) \times (5.5572 - 5.22)}$$

$$= \frac{-0.409}{(5.034)(0.034)}$$

$$R^2 = \frac{-0.409}{0.418} = -0.979$$

Linear equation can now be used since correlation factor is - 0.979 where is approximately -1

Assuming equation of a straight line is

$$Z = Y + BX$$

Our equation becomes

$$Z = Y - BX \text{ ------------------ (B)}$$

$\bar{B}$ == x coefficient

$$\bar{B} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{n\sum x_i^2 - (\sum x_i)^2} \quad \text{.........} (C)$$

Substituting in the value in the equation ©

$$\bar{B} = \frac{4 \times 3.555 - 6.225 \times 2.35}{4(10.946) - (6.225)'}$$

$$= \frac{14.22 - 14.629}{43.784 - 38.751}$$

$$B = \frac{-0.409}{5.033} = -0.0813$$

$$Z = Y - BX$$

Where

Y = Average or mean value of Yi

X = Average or mean value of Xi

i.e

$$X = \frac{0.925 + 1.200 + 1.700 + 2.400}{4}$$

$$= 1.56$$

$$X = 1.56$$

$$Y = \frac{0.65 + 0.60 + 0.58 + 0.52}{4}$$

$$= 0.59$$

Therefore substituting in the values in equation (B) we have

$Z = 0.59 - (-0.0813)(1.56)$

$Z = 0.59 + (0.1268)$

$Z = 0.59 + 0.13$

$Z = 0.72$

The regression values of Y was obtained from the equation (B)

$Z = Y - BX$

$Y = Z + BX$

$Y = 0.72 - 0.0813 X$ ------------------(D)

Where x = particle size

Substituting in the values of x (0.925, 1.200, 1.700, 2.400) to obtain corresponding values of Y.

$Y = 0.72 - 0.0813 (0.925)$

$Y = 0.645$

$Y = 0.72 - 0.0813 (1.200)$

$Y = 0.622$

$Y = 0.72 - 0.0813 (1.700)$

$Y = 0.582$

$Y = 0.72 - 0.0813 (2.400)$

$Y = 0.525$

TABLE BB

X	0.925	1.200	1.700	2.400
Y	0.645	0.622	0.582	0.525

The percentage yield is calculated as follows

$$Y1\% = \frac{0.645}{2.5} \times 100 = 25.8\%$$

$$Y2\% = \frac{0.625}{2.5} \times 100 = 24.88\%$$

$$Y3\% = \frac{0.582}{2.5} \times 100 = 23.28\%$$

$$Y4\% = \frac{0.525}{2.5} \times 100 = 21.00\%$$

TABLE CC

X	0.925	1.200	1.700	2.400
Y	0.645	0.622	0.582	0.525
Y%	25.8	24.88	23.28	21.00

Plotting the value of X (particle size) Versus the corresponding value of Y (yield) and plotting the value of Y% (percentage extract) Versus the corresponding value of X (particle size). Is shown on the graph.

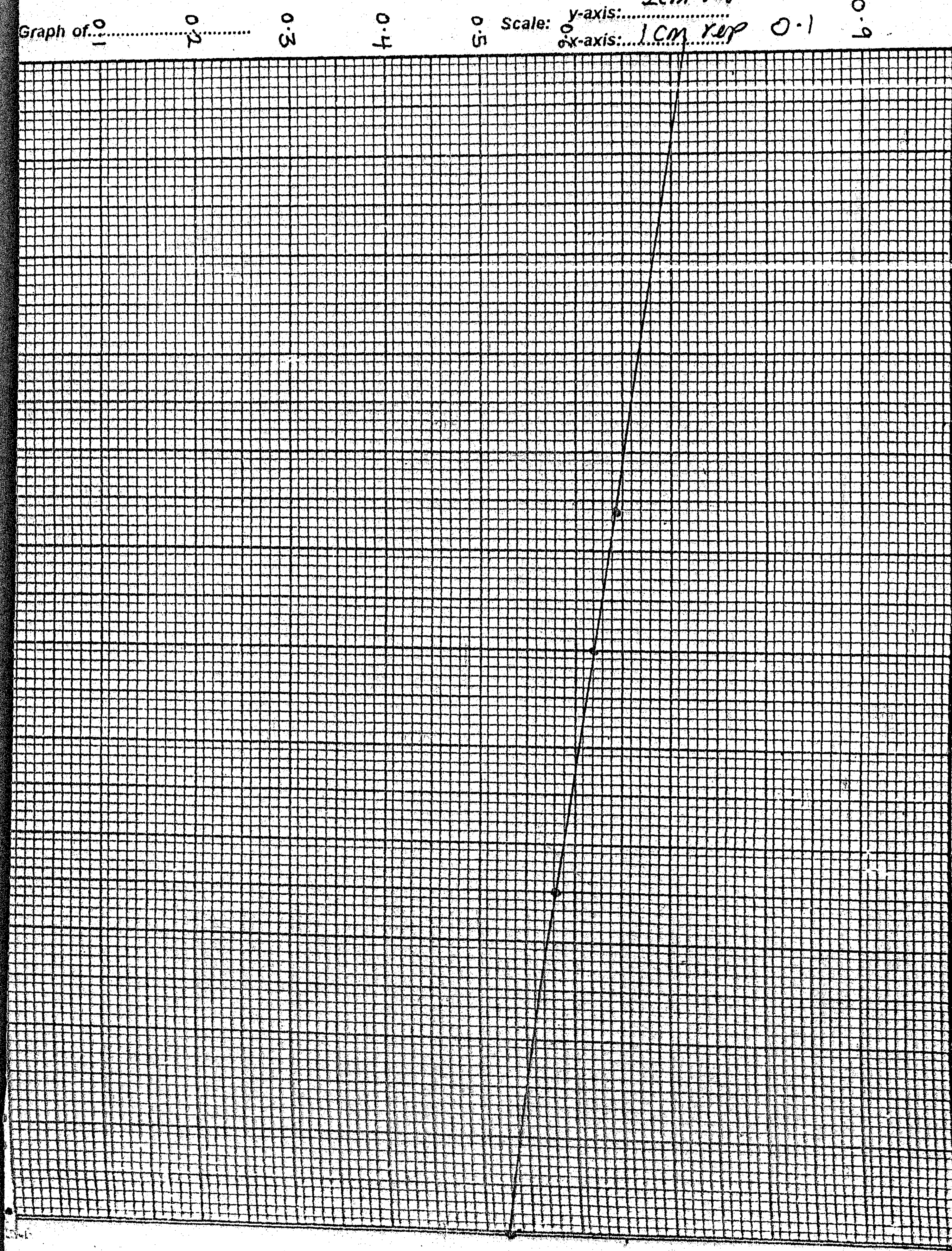
Graph 1 shows Y versus X where Y is on the y- axis and X on the x- axis.

Graph 2 shows plot of the percentage yield Y% versus particle size (x-axis).

A GRAPH OF YIELD (Y) g Versus Particle SIZE mm

Y (g)

Graph of: .... Scale: y-axis: 2cm rep 0·1
x-axis: 1cm rep 0·1



A graph of Percentage yiled grams (Y) y-axis

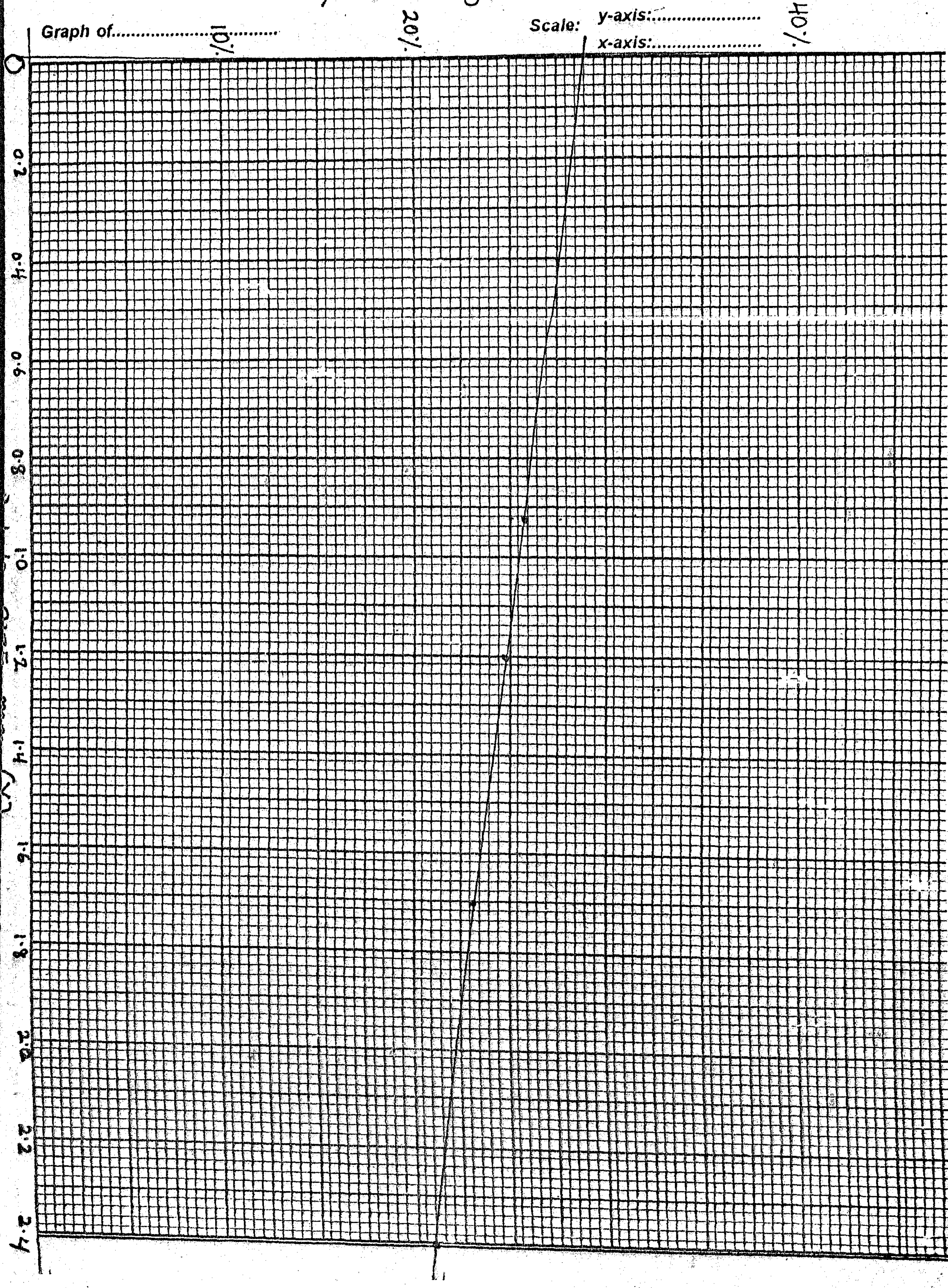
Versus

Particle size mm (x) x-axis

% yiled y%

Graph of......................................

Scale: y-axis:........................ x-axis:........................



5.2.0 DISCUSSION OF RESULT

The graph mass of oil extracted against size shows that, mass of oil extracted varies inversely proportional to the size particle. This is because, decrease in size results in greater interficial area between the rate of transfer of the oil. Small size also means that the solvent has to travel smaller distance within the solid thereby increasing rate of extraction. The great difference in yield of the experimental size range is because the major resistance to diffussion of cashew nut shell liquid lies in the shell of the nut. This results conforms with known theories of leaching. Also the graph of percentage yield against particle size shows that yield varies inversely proportional to size.

CHAPTER SIX

6.0.0 APPENDIX A

PROPERTIES OF BENZENE (SOLVENT)

Molecular weight = 78.11g

Colour = Colourless

Specific gravity = 0.879

Melting point = $5.5^{0}C$

Boiling point = $79 - 80^{0}C$

Solubility in water = 0.07

" in alcohol = soluble

" in ether = ∞

6.1.0 APPENDIX B

Molecular mass of CNSL = 1272g

Molar volume of CNSL = $1240.2 cm^{3} g\ mol^{-1}$

Density of CNSL = $0.945 g/cm^{3}$

Viscosity of pure benzene at 305k using Eyring theory the equation is written as

$$\mu = \frac{Nh}{V} e^{3.8 \frac{Tb}{T}}$$

Where

h = planck constant

Tb = boiling point temperature

N = avogardos number

6.20 CONCLUSION AND RECOMMENDATION

It is shown from the results obtained that the particle size affects the ammount of CNSL oil extracted and it can be concluded that for larger quantity of oil to be obtained from a given CNSL. There is need to reduce the CNSL to acceptible size as has been shown in the project.

The maximum average size used was 2.40mm while the minimum was 0.925mm. From table B the highest percentage of oil extracted which was 25.8% was from the minimum size while the minimum percentage of oil which was 21.00% was from the maximum size.

The ammount of cashew nut shell liquid extracted from cashew nut using benzene is found to vary inversely proportionally to shell size. For average shell size of 0.9250mm, 1.200mm, 1.700mm, 2.400mm, the ammount of CNSL extracted was 0.65g, 0.600g, 0.580g, and 0.520g respectively.

6.2.1 RECOMMENDATION

More work should be carried out to determine the three major constituents (Cardol, Cardanol and anacardic acid) in the CNSL. This will enable the researcher to know the percentage constituents of the CNSL at each stage of extraction.

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