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PRODUCTION OF GLYCEROL FROM PALM KERNEL OIL

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ABSTRACT

Glycerol production using Palm Kernel Oil (PKO) as a potential raw material was investigated. PKO was optimally hydrolyzed at 268 °C and 500psi (34 atm) pressure using only water. A 96.85 percent maximum yield of the extent of hydrolysis at 61.86 percent water and 38.14 percent oil was achieved. The percentage of glycerol from the palm kernel used was 9.8 percent and a recovery of 97.02 percent was obtained from the hydrolysis. The glycerol produced was analyzed and its properties found to be within the acceptable standard.

Key words: Glycerol, Palm Kernel Oil, Water, Hydrolysis

1.0 INTRODUCTION

Glycerol occurs naturally in animal and vegetable cells as triglyceride in the form of such lipids as lecithin and celphalin. Generally, glycerol is obtained from hydrolysis of oil with water or alkali and from synthesis. In some cases, glycerol could be recovered as a by-product from animal and vegetable oil that have saponified in the process of manufacturing soap (Liu et al., 2002; Wang et al, 2001; Yalcin and Ozbas, 2006 and 2008; Vijaikishore and Karanth, 1984; Finar, 1980; Khor et al., 1985).

According to Landau (1999), the importance of glycerol cannot be over emphasized. Therefore, it is necessary to envisage that the abundant oil palm tree grown in Nigeria could be a good source of raw material for the commercial production of glycerol. Some primary products of oil palm are palm oil, palm nuts and fibre. Palm kernel oil is obtained from further processing of oil palm nuts. (Opeke, 1982; FAO, 2009). There are two basic components of palm kernel oil namely fatty acids and glycerides. Fatty acids have a wide variety of applications in industry, ranging from textile, petroleum, paper, leather and cosmetics to pharmaceuticals. They are also used in making surface active agents, protective and decorative coatings, etc. In purified commercial form, glycerol is usually called glycerine. Glycerine can be applied in various products such as lubricants, tobacco, urethane polymers, drugs, cosmetics, wrapping and packaging materials, food, gasket and cork products, and miscellaneous products such as in cement compound, embalming fluid, masking and shielding compound, soldering mixing and compasses, cleaning materials such as soap, detergent and wetting agents, leather, wood treatment and adhesive (McGraw Hill, 1982; Finar, 1980; Hermansyah et al., 2006; Hilditch and Williams, 1986). Thus, glycerol can yield high foreign exchange if produced for export.

For wider diversification of possible products from palm kernel oil, the industrial splitting of the oil to yield fatty acids and glycerol is necessary. One of the methods of splitting oil is by hydrolytic method (Henglein, 1988; Pugahenthi and Kumar, 2004; Noor et al., 2003; Fadiloglu and Soylemez, 1998; Knezevic et al., 1998; Rooney and Weatherly, 2001; Ting et al., 2006; Al-zuhair, 2007). In 1952, Lascary developed the following empirical equation for fat splitting.

$$H=100-0.8G \qquad (1)$$

Where, H = the extent of hydrolysis at equilibrium
G = the percent of glycerol in the sweet water

Due to easy available of water, hydrolysis of oil using water alone was chosen for this study. The products of hydrolysis of oil using water alone are a fatty acids layer and a sweet water layer. The sweet water layer contains glycerol and is processed promptly to avoid further degradation and loss of glycerol by fermentation. Any fatty acids that rise to the top of the sweet water are skimmed-off. Thus, in using water for splitting PKO, the water can serve dual purposes as a catalyst and a medium for glycerol recovery. This method is technologically easy, cost-effective, less rigorous and leads to an optimal yield of glycerol when favorable operating conditions are chosen for (i) the hydrolysis of PKO and
(Ii) concentrating glycerol liquor under vacuum.

Perrin et al. (1980) proposed an empirical relationship in the nature of equation 2 to model the distillation of organic compounds under vacuum.

$$\text{Log } P = 8.586 - 5.703\left(\frac{T+273}{t+273}\right) \qquad (2)$$

Where, T = boiling point in °C at 760mmHg
P is the pressure; t is the temperature in °C.

2.0 MATERIALS AND METHOD

2.1 Materials

The materials in this study include palm kernel oil, water, a parr pressure batch reactor, vacuum evaporator, used-engine-oil employed as heating oil, density bottle, refracometer, conical flask, canon-Fenske Viscometer (E300), reflux condenser, Lovibond tintometer, oil bath and chemicals such as potassium hydroxide, sulphuric acids, etc.

2.2 Method

A Parr Pressure batch reactor as seen in Figure 1 was used. 300ml of water and 200ml of palm kernel oil were charged into reactor. The reactor and contents were heated to a temperature of 268°C and pressure 500psi (34 atm) using used-engine-oil as the heating oil. Samples were collected at hourly intervals and analyzed for acid value. When there was little or no change in acid value between consecutive tests, the reaction was stopped. The samples collected at designated intervals of time were

At the end of hydrolysis, the product or contents of the reactor were removed into a container. The fatty acid rapidly separates as top layer from the sweet water (glycerol liquor) being the bottom layer because of its much higher density. The fatty acid layer was carefully decanted after about 15 minutes of setting. Any or trace amount of fatty acid remaining at the top of the sweet water was removed by careful scooping.

The glycerol liquor was concentrated using a vacuum evaporator as shown in Figure 2 at 600mbar. 200ml of sweet water was poured into the sample flask of the vacuum evaporator, and then heated in an oil bath at 140°C for about 3h. At this temperature and time, a high percentage of water was evaporated leaving behind a thic

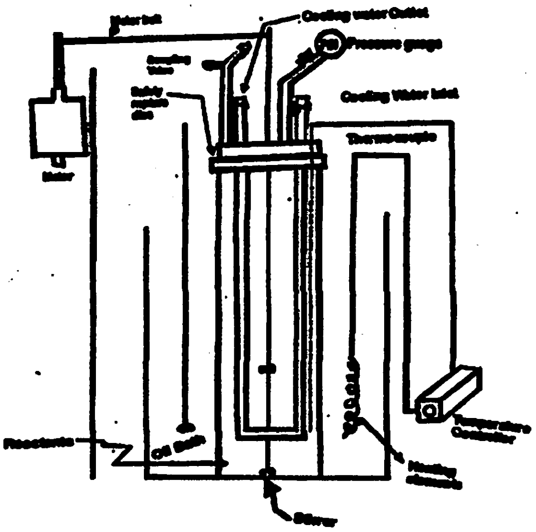

FIGURE 1: SKETCH OF A PARR PRESSURE BATCH REACTOR

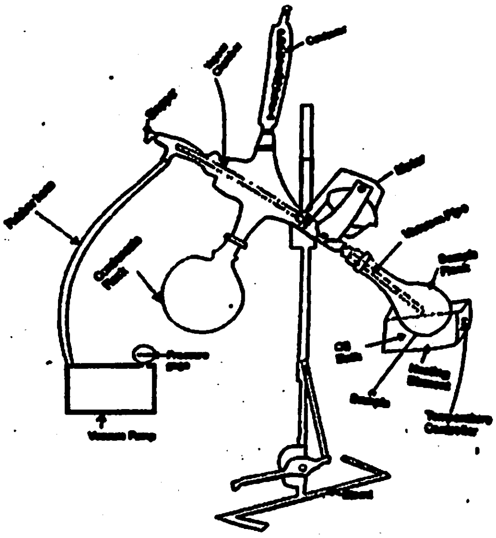

FIGURE 2: SKETCH OF A VACUUM EVAPORATOR

viscous liquid which is the crude glycerol . The crude glycerol obtained was decanted and stored. A drop of the glycerol sample obtained was heated with one gram of powered potassium bisulfate. A very penetrating and irritating odour was produced and noted. The odour is that of acrolein formed during the heating; and this identifies that this sample is glycerol.

Some major properties of PKO used and glycerol produced were determined (Cock and Rede, 1986; Parrin et al., 1980; Considane, 1984). The PKO properties analyzed were: density, acid value, color, refractive index, viscosity, saponification value, free and combined glycerol. The glycerol properties analysed were: viscosity, density, Mong-matter (organic), non-glycerol sugar and other polyhydric alcohol; ash in glycerol percent by weight and glycerol water content.

3.0 RESULTS AND DISCUSSION

The PKO used for the production of glycerol was analysed for some basic properties as reported in Table 1. These properties conform with the British standard (1987) recommendations for PKO. The combined glycerol was found to be 9.8 percent. The high acid value of 51.2 obtained is an indication of high fatty acid liberation during glycerol production. This confirms the high value of 95.18% free fatty acid obtained at the end of the production (see Table 2).

The reacting mixture represents 38.14 percent PKO and 61.86 percent water by weight. The product mixture represents 44.59 percent fatty acid layer and 55.41 percent sweet water by weight. Applying equation 1, the extent of glycerol was estimated as 93.40%. This value closely approximates the 96.86 percent measured from glycerol production. The finding further confirms that the water to oil ratio affects the extent of hydrolysis and hence that of glycerol yield. The percentage weight of glycerol in sweet water was measured as 8.25% about 93.59% crude glycerol after concentrating the sweet water. Additionally, at the end of glycerol production, 17.59 grams of glycerol was obtained from the 185 grams of palm kernel oil used. The glycerol content is 9.8 percent by weight of oil leading to the 97.02 total percent glycerol recovered a showed in Table 3. Table 4 records the results of test carried out to determine some basic properties of crude glycerol. The density, kinematics viscosity and refractive index conform closely to the standard properties of glycerol. Other properties such as water content, MONG matter (organic), non-glycerol percentage by wet and ash content were found respectively, to have the following percentages: 5.04, 1.33 and 0.032. These properties may be as impurities and can further be reduced by a sound method of refining. When concentrating

Table 1: Properties of palm kernel oil used.

Properties	Values
Density @ 28^0	923kg/m^3
Refraction index @ 28^0C	1.444
Acid value	51.20
Saponification value	248.24
Dynamics viscosity @ 28^0C	47.07×10^{-3} NS/m^2
Kinematic viscosity @ 28^0C	5.1×10^{-5} m^2/Sec
Free Glycerol	-
Color	1.4 Yellow
%wt Combined Glycerol	9.8
Specific Gravity @ 28^0	0.923

Table 2: Parameters of hydrolysis reaction and production at 268 ^0C, Pressure 500psi (34atm), time 5 hours.

Parameters	Values	
Acid Value		240.43
Extent of hydrolysis (%)		96.85
% Weight of Reactant	Water	61.86
	Palm Kernel Oil	38.14
% Weight of Product	Fatty Acid Layer	44.59
	Sweet Acid Layer	55.41
% Weight of Glycerol in Sweet Water Layer		8.25
% Weight of Glycerol in Fatty Acid Layer		95.18
% Weight of Glycerol in concentrated Sweet Water Layer		93.5
% Weight of water consumed During Hydrolysis		34.31

Table 3: Data of Glycerol recovery at temperature 140 ^0C, pressure 8.7psi (0.6atm), time 3 hours.

Parameter	Values
Mass of sweet Water (g)	231.77
Volume of Sweet Water (cm	210.20
Mass of Glycero	17.69
Volume of glycerol (cm	14.00
Glycerol % by Weight Recovered	97.02

Table 4: Properties of crude glycerol produced.

Properties	Values
Glycerol % by Weight	93.59%
Dynamic viscosity @ 28^{0}C	1.226Ns/m
Kinematic viscosity @ 28^{0}C	9.76 x 10^{-4} m^2/s
Density @ 28^{0}C	1256kg/m^3
Water Content (%)	5.04
Sugar Content (%)	
Refractive Index @ 28^{0}C	1.466
MONG matter (organic non Glycerol % by weight)	1.338
Ash % by weight	0.032

The sweet water, rapid evaporation of water was observed resulting in glycerol with 5.04% water content when a temperature of 140°C and pressure of 0.6bar (8.7psi) under vacuum were applied.

4.0 CONCLUSIONS

From this study the following conclusion are made:

Water to oil ratio influences the extent of hydrolysis and hence the rate of glycerol production. At the temperature of 268 °C, water to oil ratio of 1.622 by weight, pressure of 500psi (34atm) and time of 5h, maximum yield of glycerol and free fatty acid were found to be 97.02% and 95.18%, respectively. However, the induction period for the production of glycerol could be reduced to less than 3 hours if oil and water are raise to 268 °C temperature and 500psi (34atm) before they are brought into contact with the reactor.

The crude glycerol produced was found to be of good quality and conforms to the official standard (1987) specifications for glycerol. The indication is that a marketable quality of glycerol can be produced by this method.

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