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# A Survey on the Use of Nigeria Local Palm Oil for the Production of Polyol for Polyurethane Foam Production in Nigeria

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**Abstract** - This paper reviews the use of Nigeria Local palm oil for the production of polyol for the production of polyurethane foam in Nigeria. In the sub Saharan Africa and in Nigeria in particular, the market for polyurethane products such as rigid and flexible foam is so extensive owing to their vast applications. Currently, the polyol for polyurethane production in Nigeria is petroleum based and it is also being imported. Enormous resources are expended on this importation. Besides, petroleum is a depleting resource and cannot be banked upon. Nigeria is one of the top producers of palm oil and studies have shown that polyol could be synthesized from this palm oil. Polyurethane consumption in Nigeria is very high of which polyol constitute more than 50% of the formulation needed for the production of polyurethane. Polyol is not produced in Nigeria for now. Palm oil being a major source of this polyol and is abundant in the country, if appropriate technology is applied to harness this palm oil for polyol for polyurethane production in Nigeria ,it will bring about job creation, employment of new graduates which will stem the brain drain in the nation. If the resulting product is cost effective, commercializable and the production sustainable, our economy will be highly stimulated and there will be a world market creation.

**Index terms** - flexible foam, palm oil, petroleum, resource, rigid foam, polyurethane, polyol

**Introduction:** Nigeria is the third largest producer of palm oil in the world with approximately 2.3 million hectares (5.7x106 acres) under cultivation, until 1934, Nigeria had been the world's largest producer, both small and large scale producers participated in the industry[1,2]. As such, Nigerian palm oil should be fully utilized. The basic uses of this palm oil in Nigeria include: cooking, soap and detergent making, cosmetics. It is not being utilized in the polyurethane industries. Polyurethane also referred to as urethanes or isocyanate polymers have been one of the fastest growing segments of the polymer industries. Polyurethane consumption in Nigeria has grown tremendously and it is still growing. Major applications of polyurethane are in the production of flexible and rigid foam. Polyurethane foam production makes use of the following materials; polyol, toluene diisocyanate(TDI), organotin, water. Out of the above mentioned materials, polyol constitute by far the highest percentage more than 50%. This makes polyol a major raw material in polyurethane foam making and this is where palm oil comes into play.

[1]The polyol currently used in the polyurethane foam industries in Nigeria is petroleum based, which is being imported from other countries. A huge amount of money is being spent on this importation. Studies have shown that polyol could be synthesized from palm oil.[3]. Polyurethane is a polymer involves the reaction between diisocyanate, polyol and auxiliaries

Diisocyanate + Polyol ⟶ Polyurethane polymer + Heat

-NCO + OH ⟶ -NH-CO-O-

**Table 1: Typical polyether urethane slab foam formulation**

| components | Parts by weight(g) |
|---|---|
| Polyol(trifunctional) | 100.0 |
| Toluene diisocyanate | 46.0 |
| Organotin catalyst | 0.4 |
| silicone | 1.0 |
| Tertiary amine catalyst | 0.2 |
| water | 3.6 |
| monofluorotrichloromethane | 0-15 |

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Palm oil is an edible vegetable oil derived from the mesocarp derived from the (reddish pulp) of the fruit of the oil palms, primarily the African oil palm Elaeis guineensis[4]. In the food industry, palm oil is used as a cooking oil and shortening and in the manufacture of margarine, non-dairy creamers and ice cream. Traditionally, the main non-food uses for palm oil have been in the manufacture of soaps and detergents and in the production of greases, lubricants and candles. More recently, the bio fuels market has provided a significant new non-food use for palm oil where it is used as the feedstock for the production of biodiesel. The fatty acid derivatives of palm oil are used in the production of bactericides, cosmetics, pharmaceuticals and water-treatment products [5]. Developing bio-renewable feedstock from vegetable oils for Polyurethane manufacturing becomes highly desirable for both economic and environmental reasons. The derivatives of vegetable oils exhibit capacity for biological degradation .Polyurethanes are used in the manufacture of flexible, high-resilience foam seating; rigid foam insulation panels; microcellular foam seals and gaskets; durable elastomeric wheels and tires (such as roller coaster and escalator wheels); automotive suspension bushings; electrical potting compounds; high performance adhesives; surface coatings and surface sealants; synthetic fibers (e.g., Spandex); carpet underlay; hard-plastic parts (e.g., for electronic instruments); hoses and skateboard wheels[6]. Rising costs of petrochemical feedstock and an enhanced public desire for environmentally friendly green products raised interest in polyols derived from vegetable oils [7, 8]. The high demand for polyols in the markets is fuelled by demand from end-user industries such as construction, transportations, and consumer durables.

## 2. Materials and Methods

### 2.1 Polyol synthesis from petroleum:

Polyols are compounds with more than one hydroxyl functional groups available for organic reactions. Monomeric polyols referred to as initiators such as glycerine, ethylene glycol and sucrose often serve as starting point for polymeric polyols. These initiators are reacted with propylene oxide or ethylene oxide to produce polymeric polyols. There are two types of polyols; polyether polyols and polyester polyol.

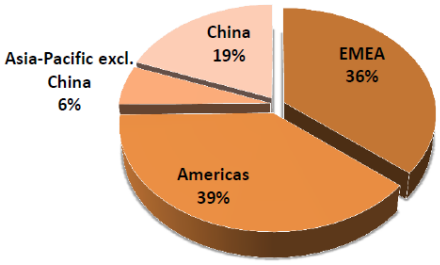


Fig 1:Global consumption of aromatic polyester polyol 2012[http://www.transparencymarketresearch.com/polyols-market.htm]

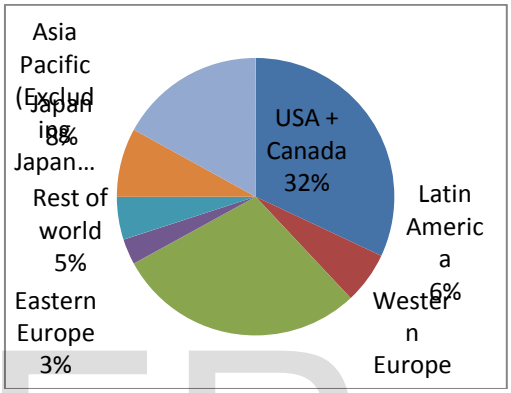


Fig 2Regional production of PU in 1998 (Allport et.al., 2003)

**2.1.1 Polyether polyols**: Polyether polyols are made by reacting epoxides like ethylene oxide or propylene oxide with the multifunctional initiator in the presence of a catalyst , often a strong base such as potassium hydroxide or a double metal cyanide catalyst such as zinc hexacyanocobaltate-t-butanol complex[9]. Common polyether diols include polyethylene glycol, polypropylene glycol, and poly(tetramethylene ether) glycol. Polyether polyols account for about 90% of the polymeric polyols used industrially; the balance is polyester polyols[10]. Usually, polyols having molecular weight between 1,000 and 6,000 and functionality between 1.8 and 3.0 are used in flexible foams and elastomers. Short chain (250<1,000), high functionality (3<12) polyols yield high cross-linked rigid chains and are used in rigid foams and high performance coatings. The molecular weight distribution of polyether polyols follows the Poisson probability equation, being narrower than the polyester distribution (thermodynamically controlled in agreement with the Flory equation)[11].

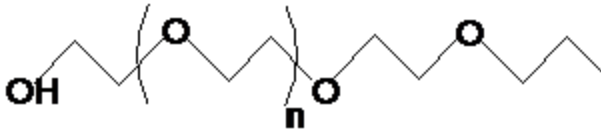


Fig 3 Structure of polyether polyol

Polyether polyols contain the repeating ether linkage –R-O-R- and have two or more hydroxyl groups as terminal functional groups. These are the groups that can react with other substances. Polyether polyols are manufactured by the catalyzed addition of epoxides (cyclic ethers). The most important of the cyclic ethers are propene oxide and ethene oxide but also butene oxide is used. An initiator, such as water, glycols, polyols or amines, starts the process as it contains active hydrogen. A wide variety of compositions are possible. The monomers can be randomly distributed or included as a block. The latter are also called block polymers. Polyether polyols are water soluble polymers with a molecular weight between 200 and 14,000. The physical properties depend on the chain length of the polymer. Most polyether polyols are manufactured for the preparation of soft or rigid polyurethane with different areas of use. Polypropylene glycol is a similar kind of polymer prepared from propene oxide. It is used in the same way as other polyether polyols.

**Table 2: Typical properties of polyether polyols**

| Applications | CASE1 | Flexible Foams | | | Rigid Foams | |
|---|---|---|---|---|---|---|
| | | Conventional | Conventional | HR | | |
| Polyol composition | propylene glycol + propylene oxide | glycerine + propylene and ethylene oxides | amine + propylene oxide | trimethylolpropane + propylene and ethylene oxides | trimethylolpropane + propylene oxide | sucrose + propylene oxide |
| Average MW | 2000 □ 100 | 3000 □ 200 | 3750 □ 200 | 4800 □ 300 | 440 □ 35 | 860 □ 60 |
| OH number (mg KOH/g) | 56 ± 3 | 56 ± 3 | 60 ± 3 | 35 ± 2 | 380 ± 25 | 380 ± 25 |
| OH content (meq/g) | 1.0 | 1.0 | 1.1 | 0.6 | 6.8 | 6.9 |
| Average functionality2 | 2.0 | 3.0 | 4.0 | 3.0 | 3.0 | 5.8 |
| Insaturation (meq/g) | < 0.04 | 0.04 | < 0.04 | < 0.05 | < 0.005 | < 0.005 |
| Viscosity at 25oC (mPa.s) | 250 – 350 | 450 – 550 | 580 – 720 | 750 – 900 | 600 - 700 | 11000 – 15000 |
| Pour point (oC) | - 36 | - 31 | - 35 | - 38 | - 22 | - 2 |
| pH | 6.5 – 8.0 | 6.5 – 8.0 | 8.6 – 9.6 | 6.5 – 8.0 | 6.0 – 7.5 | 6.5 – 8.0 |
| Density, 25oC (g/cm) | 1.00 | 1.01 | 1.00 | 1.02 | 1.03 | 1.1 |



**2.1.2 Polyester polyol:** . Polyesters are formed by condensation or step-growth polymerization of diols and dicarboxylic acids (or their derivatives), for example diethylene glycol reacting with phthalic acid[12].

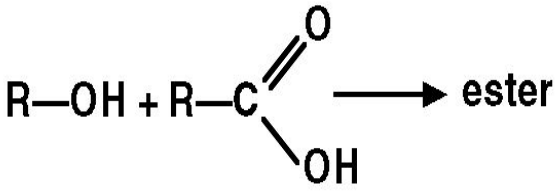


Fig 4 Ester formation

Polyester is currently defined as: "Long-chain polymers chemically composed of at least 85 percent by weight of an ester and a dihydric alcohol and a terephthalic acid.Esters are formed when alcohol reacts with a carboxylic acid[13]

Polymeric polyols are generally used to produce other polymers. They are reacted with isocyanates to make polyurethanes used to make mattresses, foam insulation for appliances (refrigerators and freezers), home and automotive seats, elastomeric shoe soles, fibers (e.g. Spandex), and adhesives[9].

**2.2 Palm oil for polyol production**; Palm oil is one of the most widely used plant oils worldwide . The oil consists of triglycerides (Tri-G) and diglycerides (Di-G) and according to McNeil amd Berger (1993) 95% of the oil is Tri-G and 5% Di-G and carbons of the carboxyls are ranging 10–20 with or without double bonds. Palm oil can be converted to monoglycerides as a new type of polyol by glycerolysis. A yield of the product can reach 70% at reaction temperature of 90 °C by using an alkali catalyst and a solvent[14]. Conversion of triglycerides to monoglycerides is an alternative method for introducing hydrolxyls for palm oil, which becomes a 'palm oil-based polyols (PO-p)'. Monoglyceride (Mono-G) is a fatty acid ester of glycerol, and three main processes are widely known for its preparation: (1) glycerolysis of fats and oils with glycerol, (2) enzymatic synthesis by using lipase catalysts and

(3) direct esterification of fatty [15].Nowadays, several methods for conversion of vegetableoils into polyols are known. All of them are based on chemical modification of ester groups or double bonds in unsaturated chains of fatty acids. The most common conversion methods are direct oxidation , ozonolysis ,epoxidation followed by ring opening , hydroformyl-ation , and transesterification . Each of them has advantages and disadvantages . Various types of vegetable oils differ in the composition of saturated and unsaturated fatty acids . The diversity in unsaturation degree allows the synthesis of oil polyols with variable hydroxyl number acids or their alkyl esters with glycerol. After the glycerolysis, 90% of unreacted glycerol is removed by the purification process using *n*-hexane. Polyurethane foams are prepared using the palm oil-based polyol (PO-p), mixed with polyethlene glycol (PEG) or diethylene glycole (DEG). Chain motion of polyurethane becomes more flexible at the higher PO-p content in the polymer.

**Table 3: Polyurethane market by product Polyurethane market by end use**

| | |
|---|---|
| Rigid foam | Furniture interiors |
| Flexible foam | construction |
| coatings | Electronics and appliances |
| adhesives | automotives |
| sealants | footwear |
| elastomers | packaging |
| others | others |

**Table 4 Polyol market by product Polyol market by application**

| | |
|---|---|
| Polyether polyol | Rigid foam |
| Polyester polyol | Flexible foam |
| | coatings |
| | Adhesives |
| | elastomers |
| | sealants |
| | others |

[http://www.transparencymarketresearch.com/polyols-market.htm]

The profiled leading players of polyurethane and polyol industry include: BASF SE (Germany), The DOW Chemical Company (U.S.), Cargill Inc. (U.S.), Mitsui Chemicals (Japan), Petopur GmBH (Germany), Rampf Ecosystems (Germany), Emergy Oleo chemicals (H) SDN BHD (Malaysia), etc[http://www.markets and markets.com/market reports].

## 2.3 Advantages of using palm oil polyol

Availability of raw material(natural palm oil)
Increasing prices of crude oil
Lower carbon footprint which encourages higher sustainability
Polyols offer good mixing capability and
Easy machine handling, resulting in better quality

## 3 A review of the use of polyol from locally produced palm oil in Nigeria

Nigeria with a population of over one hundred and fifty million people and the third largest producer of palm oil is ripe enough to commence its production of polyol from her palm oil for polyurethane production. This polyol has wide applications in foam industries. These foam industries are largely concentrated in Onitsha, Anambra state, Lagos, Aba, Umuahia, Nnewi, Ogun and,Kano states. They are mainly into production of rigid and flexible foams. These industries provide employment for the masses and also get revenue from the large Nigerian market. The major Polyurethane producers in Nigeria are listed in table 5

**Table 5: Major Polyurethane Producers in Nigeria that make use of imported polyol from petrochemical companies**

| S/N | Company's Name |
|---|---|
| 1 | Joy Foam |
| 2 | Vono foam products plc |
| 3 | C.Ugwu Nigeria Merchandise |
| 4 | Current Foam Industries and Chemicals Limited |
| 5 | Esco Foam Chemical Industry Limited |
| 6 | Mouka foam Limited |
| 8 | Royal Foam Products Nigeria Limited |
| 9 | Sara Products Limited |
| 10 | Sharaton Foam And Chemical Industries Limited |
| 11 | The Unifoam Group |
| 12 | Vitafoam Nigeria Plc |
| 13 | Vono Products Plc |
| 14 | Bode foam industries |
| 15 | Arco foam |

## 4. Conclusion

The utilization of local palm oil in Nigeria for polyol production will go a long way in enhancing the economy of the country. It will save enormous

resources that go into foreign exchange for importation of polyol. There will be increase in our technological development and a corresponding increase in employment opportunities in Nigeria as well as high alleviation of poverty .

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