OLEO CHEMICAL INDUSTRY IN MALAYSIA - RESEARCH, DEVELOPMENT & COMMERCIALIZATION

Dr. Yeong Shoot Kian,
Malaysian Palm Oil Board
Introduction of MPOB and its Function

- MPOB is the premier government agency entrusted to serve the country’s oil palm industry.
- Its main role is to promote and develop national objectives, polices and priorities for the well being of the Malaysian oil palm industry.
AOTD is a division in the Malaysian Palm Oil Board (MPOB).

- It was established on May 18, 2004 with the objectives:
  - To conduct R&D in non-food applications of palm oil and palm oil products
  - To conduct R&D to add value to palm-based basic oleochemicals
  - To commercialize the R&D findings
  - To provide advisory and technical services in the oleochemical sector
Units and their Functions

- Synthesis and Product Development Unit
- Process Engineering and Design Unit
- Consumer Product Development Unit
- Quality and Environmental Assessment
OLEOCHEMICALS

Chemicals derived from natural oils/fats - could be of animal, marine or vegetable oil sources

Derived from breaking the oils/fats into corresponding constituents, *i.e.* fatty acids, glycerol, fatty esters, *etc.*

Normal process involves hydrolysis or transesterification


Today 2.6 million tonne capacity.
World Oils & Fats: Production in 2013 (189.7 million tonnes)

- Palm & Palm Kernel Oil, 33%
- Soybean Oil, 23%
- Rapeseed Oil, 13%
- Others, 13%
- Sunflower Oil, 7%
- Coconut Oil, 2%
- Animal Fats, 9%

Source: Oil World, 2013
Global Oleochemicals Market, 2013

- Global oleochemical markets are being led by
  - surging demands for renewable based products,
  - favorable government initiatives
  - shifting consumer preferences for sustainable solutions.
- Asia Pacific led by Indonesia, China, and Malaysia, with advantaged feedstocks and markets, account for nearly 70% of the global markets and 60% of the total capacity.

Projected growth

- 2013: 13.5 million tonnes
- 2018 (F): 18.1 million tonnes

Source: http://www.specchemonline.com/articles/view/oleochemicals-opportunities, 1 Aug 2014
Importance of Palm Oil & Its Derivatives

Source of food (global food security): 80%

Oleochemicals: 15%

Biofuels: 2%

Renewable energy source: Potential remains largely untapped through palm biomass

Source: Basiron, 2013
Palm Oil in Malaysia, 2013

CPO 19.22 mil tonnes

mesocarp

Fatty acid composition equivalent to tallow

CPKO 2.27 mil tonnes

kernel

Fatty acid composition equivalent to coconut

Mesocarp

Kernel
## Number of Oleochemical Plants & Capacities: 2013 (tonne/year)

<table>
<thead>
<tr>
<th>State</th>
<th>In Operation</th>
<th>Not In Operation</th>
<th>Under Planning</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Capacity</td>
<td>No</td>
<td>Capacity</td>
</tr>
<tr>
<td>Johore</td>
<td>6</td>
<td>608,900</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Penang</td>
<td>3</td>
<td>791,325</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Selangor</td>
<td>6</td>
<td>817,746</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other States</td>
<td>1</td>
<td>365,000</td>
<td>1</td>
<td>16,000</td>
</tr>
<tr>
<td>Malaysia</td>
<td>16</td>
<td>2,582,971</td>
<td>1</td>
<td>16,000</td>
</tr>
</tbody>
</table>

Source: MIDA/MPOB, 2014
Export Volume of Palm Oil Products: 2013

- Palm Oil: 71%
- Palm Kernel Oil: 4%
- Palm Kernel Cake: 10%
- Oleochemical: 11%
- Biodiesel: 1%
- Finished Products: 1%
- Other Products: 2%

Total Volume, Mil tonnes: 2.57
Total Value, RM Mil: RM 61,363.35

Source: MPOB, 2014

- Export remains predominantly upstream driven since past 5 years
- However, downstream provides a more lucrative per unit revenue stream, approximately 41% more than produce from the upstream sector (source: http://m.thestar.com.my, 21 June 2014)
Malaysian Export Volume of Oleochemical Products, 2013

- **Fatty Acids**: 33%
- **Fatty Alcohol**: 19%
- **Methyl Ester**: 19%
- **Glycerine**: 13%
- **Soap Noodles**: 15%
- **Others**: 1%

**Total volume, Mil tonnes**: 2.73
**Total value, RM Mil**: 9,297.66
12 National Key Economic Areas (NKEAs)

- EPP 1: Accelerating the replanting and new planting of Oil Palm
- EPP 2: Improving Fresh Fruit Bunch Yield
- EPP 3: Improving Worker productivity
- EPP 4: Increasing the Oil Extraction Rate
- EPP 5: Developing Biogas Facilities at Palm Oil Mills
- EPP 6: Developing High Value Oleo Derivatives and Bio-based Chemicals
- EPP 7: Commercialising Second Generation Biofuels
- EPP 8: Expediting Growth in Food & Health Segment

Gross National Income by 2020 (mil): RM5,813.50

Projected Jobs by 2020: 5858

• This EPP Attempts to shift focus of production from basic oleochemicals to higher value oleo derivatives.
• Focus development of 6 key products:
  i. Agro chemicals  
  ii. Surfactants  
  iii. Bio-lubricants  
  iv. Bio-polyols  
  v. Glycerol derivatives  
  vi. Bio-based chemicals
The downstream non-food sector consists of a value chain of basic oleochemicals, oleo-derivatives and finally, the consumer/industrial end-products.

- **Basic Oleo-chemicals**
  - Fatty acids
  - Fatty alcohols
  - Methyl Esters
  - Glycerine

- **Oleo-derivatives**
  - Soap noodle
  - Surfactants
  - Dimeric Acids
  - Azelaic Resins
  - Bio lubricants
  - Glycerol derivatives

- **End products**
  - Esters
  - Amines
  - Metal Soap
  - Agrochemicals
  - Bio-polyols
  - Glycerol derivatives
  - Fatty Alcohol Amide
  - Others

~ 20% of world capacity

ETP - target 40% derivatives

Additional GNI RM 5.8 billion (2020)
Global Trends

Green Chemistry

- Environmental sustainability awareness and practices, e.g. RSPO.
- New uses and applications based on green products

Source: Kongkrapan et al., PIPOC 2011
BIO-POLYOL

- Palm Oil-based Polyols
- Soybean Oil-based Polyols
- Castor Oil-based Polyols
- Canola Oil-based Polyols
History of Development of Palm based Polyol in MPOB

• Currently the most common commercially available polyol
  ➢ PETROLEUM BASED POLYOL

• Global awareness of depleting petroleum resources
  ➢ Find new type of polyol

• BIO-BASED POLYOL - palm based polyol

• Concept of using palm oil and palm oil products as the starting material

• Taking the full advantage of natural based product

• Availability of feed stock in this region
R&D Activity

- Early 90s – initiated the R&D
- Process to convert PO → EPO → Polyol
- Process to convert PO → EPO already developed in 80s
- Initially tried to work with Mr Dennis Porter of Natural Resources Group (UK)
- But things didn’t work out
- Through JICA’s contact - learned about PU formulations from Mitsui Chemicals
- July 1992 - obtained our first PU mushroom
- Everyone was excited
- 1994 - signed agreement with InterMed Sdn Bhd
- 1996 - patented our process in Malaysia, Indonesia, Singapore
- 2000, July - commissioned our 1 tonne capacity polyol pilot plant
Palm Oil-based Polyols

- **Raw materials**: oils, esters
- **Process**: epoxidation and alcoholysis
- **Specifications**: wide range of viscosities, hydroxyl numbers & functionalities
- **Applications**: wide range of PU field
- PALM-BASED POLYOL PILOT PLANT (1 TONNE)
- Commissioned in July 2000
- Homegrown technology

500 to 800 kg/batch

More polyols are being developed
# Properties of Palm-based Polyols

<table>
<thead>
<tr>
<th>Palm-based polyol</th>
<th>OHV, mg KOH/g</th>
<th>Viscosity @ 25°C, cP</th>
<th>Patent No./Patent Application No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>POP Pioneer</td>
<td>110-150</td>
<td>4800-7500</td>
<td>PI20070797 and US 2008-0293913-A1</td>
</tr>
<tr>
<td>POP Primer</td>
<td>140-180</td>
<td>11000-15000</td>
<td></td>
</tr>
<tr>
<td>POP Premier</td>
<td>64-90</td>
<td>500-700</td>
<td></td>
</tr>
<tr>
<td>Poly-EG</td>
<td>130-150</td>
<td>5000-10000</td>
<td>MY-114189-A</td>
</tr>
<tr>
<td>PolyMO</td>
<td>180-220</td>
<td>500-1000</td>
<td>US 7,629,478 B2 and CN 1962601B/ PI 20055231</td>
</tr>
</tbody>
</table>
Palm Based Polyols

Polyurethanes (PU) are very versatile polymers used in a variety of applications such as insulators for refrigerators and roof, construction materials such as ceiling and wall panels, furniture, corners, parts of cars, etc. Polyurethanes are usually formed by reacting polyol with isocyanates.

In the year 2000, the world consumed about 8.65 million tonnes of PU comprising 4.64 million tonnes polyols and 3.81 million tonnes isocyanates. In the same year, Malaysia consumed about 9947 t of polyol and 17945 t of isocyanates. Assuming 1/1 ratio of polyol to isocyanates, this implies a consumption of about 35 860 t of PU products. All these raw materials are petrochemical-based. Due to fast depletion of petroleum, R&D to look into alternative sources for PU raw materials have been ongoing. But to date, only the production of polyol based on renewable materials such as oils/fats and starch have been reported. Research into the production of epoxidized palm oil (EPO) was initiated by the Palm Oil Research Institute of Malaysia (PORIM) in the early eighties. From EPO, a process to produce polyol was then developed. InterMed Sdn. Bhd., a local company, was interested in the technology to produce palm-based polyol and in March 1994 an agreement to produce and commercialize epoxidized palm oil, palm-based polyol and their products (in particular PU) was signed. Arising from this collaborative work, a process to produce polyol from palm oil was patented in Malaysia, Singapore and Indonesia.

Palm Based Polyols and Polyurethanes

by Salmiah Ahmad; Ooi Tian Lye; Norin Zamiah Kassim Shaari and Tuan Noor Maznee Tuan Ismail

MPOB Information Series • ISSN 1511-7871 • June 2008

MPOB TT No. 153

FATTY ACID-BASED POLYOL

by: Hoong, S S; Kosheela Devi, P P; Tuan Noor Maznee, T I; Mohd Norhisham, S; Nurul 'AIN, H; Hazimah, A H and Salimah, A

MPOB Information Series • ISSN 1511-7871 • June 2008

MPOB TT No. 395

With soaring petroleum prices, polyols from vegetable oils are increasingly viable alternatives to petroleum polyols. MPOB has developed a palm-based polyol for the polyurethane (PU) industry, which consumes 4.5 million tonnes worldwide annually.

The polyol is produced from palm fatty acids, and can be made into PU coating, adhesives, sealants and elastomers. The fatty acids used as raw material is a by-product from the oleochemicals industry - palm kernel oil after removal of lauric and myristic acids for the production of surfactants. The by-product mainly contains oleic acid with small amounts of other fatty acids, like linoleic, and it is a co-product of the jatropha.

Figure 1. Process for preparing fatty acid-based polyol.

IMPROVED PALM-BASED POLYOLS: POP PIONEER, POP PRIMER AND PREMIER

by Tuan Noor Maznee, T I; Nurul‘AIN, H; Kosheela Devi, P P; Mohd Norhisham, S; Hoong, S S; Yeong, S K and Hazimah, A H

MPOB Information Series • ISSN 1511-7871 • June 2008

MPOB TT No. 394

Three palm-based polyols (POP) were produced from blending different oils. By varying the blending ratio and using oils with different degrees of unsaturation, a wide range of polyols (with different hydroxyl numbers and viscosity) can be produced. The wider the range of hydroxyl numbers, the more the types of polyols that can be produced for polyurethane (PU) foam products. PU foams can be rigid, semi-rigid or flexible for construction, furniture and automobiles.

Preparation of Improved POP

The preparation of POP involves two chemical reactions - epoxidation followed by alcoholysis (Figure 1). The final product obtained is neutralized to pH 7.
Green & Bio-Polyol Market 2012 vs 2018

Green & Bio-Polyol Market, 2012 vs 2018 ($ Million)

- North America: 2012 - 585.1, 2018 - 1053.3
- Europe: 2012 - 496.9, 2018 - 887
- Asia Pacific: 2012 - 463.9, 2018 - 1023.8
- ROW: 2012 - 64.4, 2018 - 112.8

Green & Bio-Polyol Market Volume by Type of Polyols, 2012 vs 2018 (Metric tonnes)

- Polyether Polyols: 2012 - 144.3, 2018 - 230.2
- Polyester Polyols: 2012 - 479.7, 2018 - 874.4

Source: Marketsandmarkets, 2014
## Manufacturers for Palm Oil-based Polyols in Malaysia

<table>
<thead>
<tr>
<th>Producer</th>
<th>Capacity (Tonnes per annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maskimi Polyol</td>
<td>21,900</td>
</tr>
<tr>
<td>Polygreen Chemicals</td>
<td>10,000</td>
</tr>
<tr>
<td>Wansern Biotechnology</td>
<td>10,000</td>
</tr>
<tr>
<td>Total</td>
<td>41,900</td>
</tr>
</tbody>
</table>

Source: UTECH 2010
Application of Polyols

Palm Polyol

Palm Polyurethane

Feedstocks

Automotive

Adhesives, Sealants & Binders

Coatings & Elastomers

Building & Constructions

Footwear

Appliances
Chemically complex polymeric materials formed by the reaction of \textit{isocyanates} with compounds containing \textit{active hydrogen}.

Usually requires:
Surfactant, catalyst, cross-linking agent and blowing agent.

\[
\text{H} - \text{O} \quad \text{R'}
\]

\[
\begin{align*}
\text{R-N=C=O} & \quad \xrightarrow{\text{catalyst/heat}} \\
& \quad \text{R'-N=C=O-R'}
\end{align*}
\]
2010 NAFTA total production 2.85 million tonnes*
2010 World wide total production 13.65 million tonnes

Source: Sendijarevic, V., 2011
*Source: Research and Markets, Plastermart.com, Aug 30, 2011
PU MARKET: Asia-Pacific Region

PU Raw Material Consumption in Asia-Pacific by End-Use, 2009

- Flexible foam: 35%
- Rigid foam: 20%
- Adhesives & Sealants: 15%
- Elastomers: 9%
- Coatings: 21%

PU Raw Material Consumption in Asia-Pacific by End-Use, 2014

- Flexible foam: 35%
- Rigid foam: 20%
- Adhesives & Sealants: 18%
- Elastomers: 17%
- Coatings: 10%

Source: IAL Consultants, 2011
Palm-Based Flexible Foam - Slabstock & Automotive Components

Polyurethanes, or PU, constitute a group of polymers with highly versatile properties and a wide range of commercial applications. The material is used in almost every aspect of human life, in a multitude of applicative automotive: mattresses, building, etc.

PU is formed using catalysts with monomer molecules, producing polyols. Generally, rigid and flexible polyols can be used to produce valuable polymers. Many of us may not realize that we are surrounded by polymeric materials such as polyethylene, polypropylene, and polyurethane (PU).

Vegetable oils like palm oil, being the triglycerides of fatty acids, have a number of excellent properties and can be used to produce valuable polymers. Many of us may not realize that we are surrounded by polymeric materials such as polyethylene, polypropylene, and polyurethane (PU).

The nature of PU foams and products depends very much on their formulations. The foams can be rigid, semi-rigid or flexible, and their characteristics determine their applications either in furniture and mattresses, construction and building materials, adhesives and coatings, thermal insulators, automotive industry, etc. The major reactants are polyols and isocyanates. The polyols are mostly from petrochemicals, but new ones can be replaced by natural-based resources like palm oil polyols. Some catalysts and the appropriate additives are also added to give the complete formula.

The typical properties and specifications of a polyol from palm oil are shown in Table 1. Flexible PU foams constitute more than 40% of the total global urethane market and are the single largest application of polyurethanes. Polyurethanes are made from two basic raw materials: polyols and diisocyanates. A key advantage of polyurethanes is that specific parts and combinations of each chemical group can be chosen to create the desired end products. The targeted applications for these end-products are numerous, the major ones being in automobiles, medicines, comfort mattresses, buildings, paints, coatings, adhesives and packaging materials. In addition, the chemistry of polyurethanes allows for the synthesis of foams (flexible and rigid) or thermoplastic polyesters, depending on their synthesis conditions. Flexible polyurethane foams are widely used, and their market segment is in excess of 40% of the total global urethane market, and is the single largest application for urethanes. Main sectors of application are the automotive and aircraft industries, in upholstered furniture and mattresses. The important characteristics of the flexible foams are density, hardness, resilience and damping behaviour of the polyurethanes.

RESEARCH ON PALM-BASED POLYOLs IN MPOB

The quest to make palm-based PU products from palm-based polyols in MPOB began in the early 1990s, and today, this patented technology has been fully tested. The research started by looking at the production of palm-based polyols one of the major ingredients in making PU. To date, MPOB has developed several blends of palm-based polyols (POP) which can be formulated into a variety of PU foams. All the polyols have been produced at pilot plant scale, at about 400-500 kg per batch. Some of the properties of POP polyols are given in Table 1.

PU FORMULATIONS

A number of trials on PU formulations for pad dash panels and carpet underlays were carried out. The
Flexible Foams

Pillow and seating foams

Carpet underlay

Pad dash panel
Palm-Based Rigid & Memory Foam

Several types of polyols can be produced by MPOB’s pilot plant (800 kg capacity per batch). The polyols are obtained by reacting epoxidized palm oil with a short-chain alcohol, such as glycerol or ethylene glycol. These polyols can then be reacted with suitable isocyanates to give a variety of polyurethane (PU) products. The PU foams are used in pillows, upholstered furniture, flooring underlays, cushioning, and as foams for noise and vibration harshness (NVH) control.

Unlike conventional flexible polyurethane (PU) foams, memory foams are characterised by their slow recovery after compression. For example, when the human hand is positioned (Figure 1) on the memory foam, the foam progressively conforms to the shape of the hand, and after the hand is removed, the foam slowly returns to its initial shape. In general, memory foams are used in pillows, upholstered furniture, flooring underlays, cushioning, and as foams for noise and vibration harshness (NVH) control (Figure 2).

Memory foams are produced mostly via slab-stock process with toluene diisocyanate (TDI) based formulations. Recent trend in development of methylene diphenyl diisocyanate (MDI) based formulations for manufacturing of both slab-stock and molded memory foams are driven by the need for performance and processing improvements as well as environmental (regulatory) demands and safety concerns (Nowakowski and Neti, 2006).

This technology relates to the development of environmental-friendly memory foams made from palm oil-based polyols (Pioneer E-120 and Pioneer ES-145). These memory foams contain MDI as the polyisocyanates component, palm oil-based polyols and petroleum-based polyols in the presence of additives and water as a blowing agent.

Properties of Palm Oil-Based Polyols

Palm oil-based memory foams can be formulated using two palm oil-based polyols; Pioneer E-120 and Pioneer ES-145 polyols (Table 1). The technology relates to the development of environmental-friendly memory foams made from palm oil-based polyols (Pioneer E-120 and Pioneer ES-145 polyols (Table 1). The technology relates to the development of environmental-friendly memory foams made from palm oil-based polyols (Pioneer E-120 and Pioneer ES-145 polyols (Table 1).
Bio-based Polyurethane Foams developed in collaboration with Local Industries

- Rigid – insulation and ornamental products

Cargo Insulated with PU (Cargo Texture)

Ceiling & Wall Insulated with PU

Aesthetic Designs for Decorative Panels
Palm-Based Coating, Adhesives, Sealants & Elastomers

RESEARCH ON PALM-BASED POLYOLS IN MPOB

Over the last 10 years, MPOB through Advanced Oleochemical Technology Division has put in a lot of efforts to search for new palm-based polyols. The current MPOB palm oil polyol (POP), which can be produced at a pilot plant scale, can be applied on the laboratory scale and the teams are actively trying to optimize the synthesis work for scaling up purposes.

2K-PU COATING FROM PolyMO

PolyMO was first converted into an alkyd resin through an esterification with a dibasic acid, which applications. The production of the PolyMO has been achieved at laboratory scale and the teams are actively trying to optimize the synthesis work for scaling up purposes.

LAMINATED PALM-BASED POLYURETHANE SHEET

Over the last 10 years, MPOB through its Advanced Oleochemical Technology Division, has put in much efforts to produce new palm-based polyols. The current MPOB palm oil polyol (POP), which can now be produced in pilot plant scale, can be formulated into various polyurethane (PU) foams rigid, semi-rigid and flexible for use in the building, furniture and automotive industries. Currently, MPOB is developing a new class of PU-laminated palm-based PU sheet.

LAMINATED PALM-BASED POLYURETHANE SHEET

This project is the process for preparation of PU sheet and PU sheet laminated with some suitable materials. The PU sheet was prepared by blending palm-based polyol and the additives with the use of a stirrer. The isocyanate was then added to the blended polyol. The mixture was stirred for 2K-PU COATING FROM PolyMO

PolyMO was first converted into an alkyd resin through an esterification with a dibasic acid, which

Figure 1. Polyurethane sheet without lamination material.

Palm-Oil-Based Adhesives for Fibreboard

Over the last decade, MPOB has embarked on research and development that is aimed at producing polyols from palm oil derivatives which can further expand the usage of palm oil in the non-food related sectors. The current MPOB palm oil-based polyol (POP resin), which can be produced on a pilot plant scale, can be formulated into various types of polyurethane (PU) foams. The PU foams can be rigid, semi-rigid or flexible, and are suitable for such industrial sectors as building, furniture, bedding and automotive parts. However, there is a sector of the PU industry which is known as CASE (coating, adhesive, sealant and elastomer) that cannot be satisfied by the current triglycerides-based polyols (POP resin).

In view of this limitation, MPOB has put in efforts to prepare a suitable palm oil-based polyol for CASE. The new polyol is made from oleic acid and from rubber wood fibres, and urea-formaldehyde (UF) resins are used as binders. The implementation of strict regulations in the European countries and Japan that require zero emission of formaldehyde is discouraging the use of UF resins in the local fibreboard industry. This scenario creates an opportunity for palm oil-based PU adhesives to be deployed by local fibreboard manufacturers. The palm oil-based PU adhesive formulation consists of isocyanate and PolyMO.

Figure 2. Fibreboard bonded with palm-based adhesive.

PROCESS TO PRODUCE FIBREBOARD

One of these palm-based polyols, polyol from palm oil and ethylene glycol (PolyEG) when blended with PolyMO (MPOB TT No. 278 for more information on PolyMO), a new natural polyol from palm oil, is found suitable for adhesive applications.

ADHESIVES FROM PolyEG and PolyMO

PolyEG and PolyMO were mixed in appropriate ratios and reacted with a suitable isocyanate to produce an adhesive. The adhesives passed the screening test (or a quick test) according to DIN EN 205. In the quick test (Figure 1), the adhesive was applied to a wooden sample and after 24 hours, the sample was tested for its strength.
Interested party

For more information kindly contact:

Director-General
MPOB
P. O. Box 10620
50720 Kuala Lumpur, Malaysia.
Tel: 03-87694400
Website: http://mpob.gov.my
Telefax: 03-89259446
THANK YOU