Development of Palm-Based Polyurethhane Foams - An Overview

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INTRODUCTION

Polyurethane foam is a very versatile "plastic" and its products have made our world more comfortable because of their applications in almost every aspect of human life and activities. Generally, the production of polyurethane foams (PUFs) involves the reaction between a polyol and a polyisocyanate in the presence of a blowing agent. Currently, most of the raw materials used in the production of PUFs are petrochemical–based. As environmental pressure increases world-wide, it is necessary to find alternative sources for raw materials to be used in the production of PUFs. Materials from renewable resources such as oils/fats are found to be suitable and offer interesting possibilities for the manufacture of PUFs (US Patent Nos. 4 825 004 and 5 075 417).

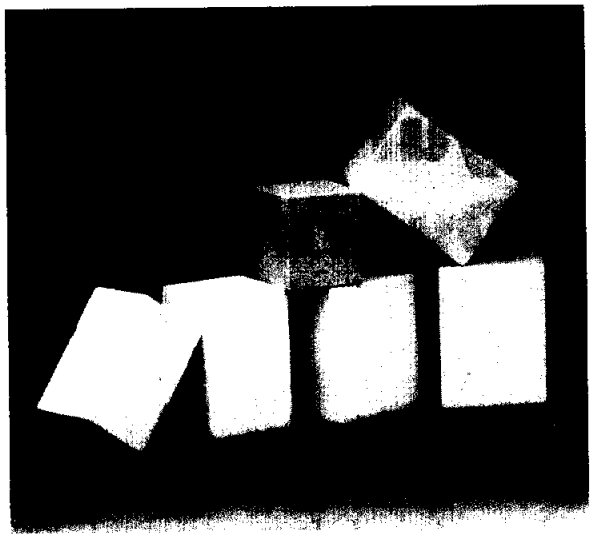
Early findings have indicated that when oils/fats (including palm oil) are epoxidized, they react with any polyhydric alcohols to yield polyols (Hassan *et al.*, 1993, US Patent Nos. 4 508 853 and 4 742 087). These polyols can be reacted or mixed with diisocyanates in the presence of a blowing agent to yield PUFs. In Malaysia, the interest to produce polyols from epoxidized palm oil started in the late eighties. The starting materials used for the production of palm based PUFs are polyols (derived from epoxidized RBD palm olein, ERBDPOo), methylene diphenyl diisocyanate (MDI), water and some additives.

SELECTION OF RAW MATERIALS

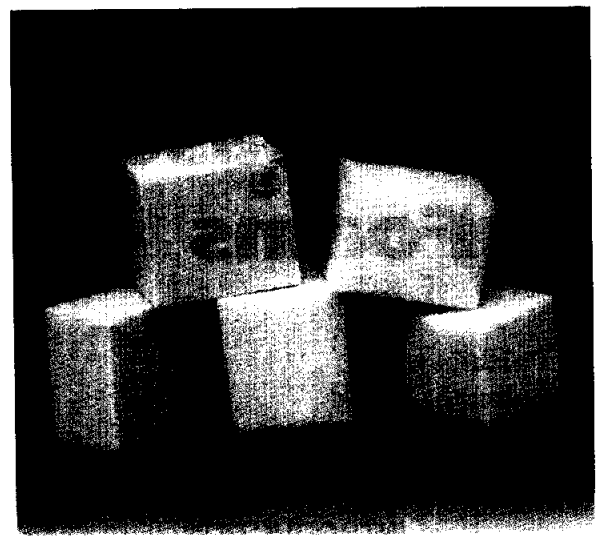
The selection of polyols was made based on the oxirane oxygen content (OOC) of the epoxidized palm oil. Based on our studies, it was noted that the higher the OOC in the epoxidized palm oil, the better will be the quality of the PUFs produced. Since ERBDPOo has the highest OOC compared to other types of epoxidized palm oil, it is preferred as the starting component for the production of palm-based polyols. Oxirane oxygen content for various types of epoxidized palm oil are shown in *Table 1.*

TABLE 1. OXIRANE OXYGEN CONTENT OF VARIOUS EPOXIDIZED PALM OIL

Types of Epoxidized Palm Oil	Oxirane Oxygen Content (OOC)%
Epoxidized Crude Palm Oil	2.32 – 2.45
Epoxidized Crude Palm Olein	1.89 – 2.40
Epoxidized RBD Palm Oil	2.61 – 2.84
Epoxidized RBD Palm Olein	2.84 – 3.12
Epoxidized RBD Palm Stearin	1.72 – 2.05



Palm-based polyurethane foams.



Petrochemical-based polyurethane foams.

The concept of using polyols derived from epoxidized palm oil is designed to take full advantage of the natural chemistry of palm oil and its availability in Malaysia.

Water is used in the polyurethane formulation to react with MDI to yield carbon dioxide (gas) which acts as the principal source for blowing in the manufacture of palm-based PUFs. The common blowing agents added in the polyurethane formulation used to be chlorofluorocarbons (CFC's). However, because of the harmful effects of CFC's to the ozone layer, other blowing agents are being sought after with pentane and cyclopentane being the main targets. In our studies, the choice of using water as the blowing agent was made after taking into consideration the environmental aspects and the cost. Even though water blown system could not be applied without sacrificing the production speed and foam physical properties, it is the ideal blowing agent (zero ozone depletion potential, zero global warming potential and very low in terms of cost) in the future. As such, development work towards this all-water blown system was intensified. The environmental properties (ODP and GWP) of various blowing agents are shown in *Table 2*.

TABLE 2. ENVIRONMENTAL PROPERTIES OF VARIOUS BLOWING AGENTS

Blowing Agent		ODP[a]	GWP[b]
CFC 11	CCl_3F	1.0	1.0
HCFC 141b	CH_3CFCl_2	0.22	0.09
HCFC 22	$CHClF_2$	0.05	0.34
HCFC 142b	CH_3CF_2Cl	0.06	0.36
HFC 134a	CF_3CFH_2	0.0	0.26
Carbon dioxide	CO_2	0.0	0.0
n-pentane	C_5H_{12}	0.0	0.0
i-pentane	C_5H_{12}	0.0	0.0
cyclo-pentane	C_5H_{10}	0.0	0.0
water	H_2O	0.0	0.0

Source : ICI Polyurethanes

[a] Ozone Depletion Potential
[b] Global Warming Potential

The common isocyanates which are available in the market are toluene diisocyanates (TDI) and methylene diphenyl diisocyanates (MDI). Owing to the high volatility of TDI, MDI is gaining in popularity. In the production of palm-based PUFs, the isocyanates of preferred use is MDI.

Additives are added in the manufacturing process of palm-based PUFs, in order to control and modify both the polyurethane reaction itself and the properties of the final polymer. These additives include catalysts, chain

extenders, cross-linking agents, surface active materials and flame retardants.

PROCESS DESCRIPTION

Figure 1 illustrates the process route for the production of palm based PUFs.

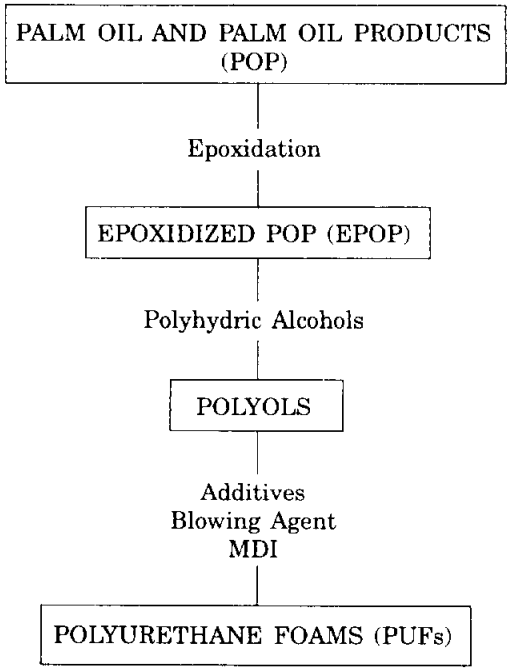


Figure 1. Process route for the production of palm-based PUFs.

PRODUCT DEVELOPMENT

Laboratory scale studies carried out at Palm Oil Research Institute of Malaysia (PORIM) have indicated that by varying the mole ratio between polyhydric alcohol and the degree of unsaturation (originally present in RBD palm olein that has been converted into epoxide rings to form ERBDPOo), polyols of various formulations can be obtained. An analysis has been carried out to determine the hydroxyl value of the polyols (derived from ERBDPOo) which can be used as a basis in predicting the nature of the PUFs to be produced (patent application in Malaysia PI 950 2302). The data obtained from the analysis are tabulated in *Table 3*.

TABLE 3. HYDROXYL VALUE OF POLYOLS (Derived From ERBDPOo) AT VARIOUS MOLE RATIO

Mole Ratio (A : B)*	Hydroxyl Value (OHV) (mg KOH/g polyol)
1 : 3	285 – 305
1 : 2	240 – 275
1 : 1	325 – 345
2 : 1	515 – 600
3 : 1	480 – 530

* A – Polyhydric Alcohol
B – Degree of unsaturation originally present in the RBD palm olein that has been converted into epoxide rings to form ERBDPOo.

The characteristic of the polyols, in terms of OHV, used to produce flexible and rigid polyurethanes are shown in *Table 4*.

TABLE 4. CHARACTERISTICS OF POLYOLS

Characteristic of Polyols	Flexible PUFs	Rigid PUFs
Hydroxyl Value (mg KOH/g polyol)	28 – 160	250 – 1000

Source : George Woods (1987)

Based on a comparative study between the OHV obtained (*Table 3*) and the OHV required (*Table 4*), palm-based polyols are found to be suitable for the manufacture of rigid and semi-rigid polyurethane foams.

Another method of varying the properties of the palm-based PUFs (derived from ERBDPOo) is by varying the amount of water used in the formulation. In our studies, the effect of adding various amounts of water on the physical properties and foam characteristics was investigated. The results are summarized in *Table 5*.

TABLE 5. EFFECTS OF WATER ADDITION ON THE PHYSICAL PROPERTIES AND FOAM CHARACTERISTICS

Amount of Water (ml)	*	Rigidity and Cell Structure@				
		1:3	1:2	1:1	2:1	3:1
5	w.o.fr.	SR,f	SR,f	SR,f	R,f	R,c
	w.fr.	SR,f	SR,vf	R,vf	SR,vf	SR,vf
10	w.o.fr.	SR,f	SR,c	SR,c	SR,c	SR,c
	w.fr.	SR,f	SR,vf	R,vf	R,f	SR,f
20	w.o.fr.	SR,c	SR,c	SR,c	SR,c	SR,c
	w.fr.	SR,f	SR,vf	R,vf	SR,f	SR,f
30	w.o.fr.	SR,c	SR,c	SR,c	SR,c	SR,c
	w.fr.	SR,f	SR,f	R,vf	SR,f	SR,f
40	w.o.fr.	SR,c	SR,c	SR,c	SR,c	SR,c
	w.fr.	SR,c	SR,f	R,vf	SR,f	SR,f
50	w.o.fr.	SR,c	SR,c	SR,c	SR,c	SR,c
	w.fr.	SR,c	SR,f	R,vf	SR,f	SR,f

*w.o.fr. – without flame retardant, w.fr. – with flame retardant

@ Rigidity
R – Rigid
SR – Semi-Rigid

Cell Structure
vf – very fine
f – fine
c – coarse

Based on the results obtained, it was clearly seen that the addition of water has a significant effect on the cell structure and the rigidity of the PUFs. The cell structure can be varied from very fine to coarse while the rigidity from rigid to semi-rigid, all depends on the amount of water added in the polyurethane formulation.

APPLICATIONS OF PALM BASED PUFs

There are two types of PUFs which can be manufactured from palm based PUFs, *e.g.* rigid and semi-rigid. Rigid polyurethane foam is one of the most effective practical thermal insulation materials used in applications ranging from buildings to the modest domestic refrigerator. Semi-rigid foam on the other hand can be used as energy absorbing padding in vehicles and in packaging.

MARKET POTENTIAL OF PALM-BASED PUFs

The polyurethane market in Asia Pacific region is growing rapidly especially in China and South Asia. The Asia Pacific polyurethane market grew an average of 10% per annum from 1982 to 1992 and now represents greater than 25 % of the total world demand. China and South Asia's polyurethane demand are expected to increase by almost three folds by the year 2000 when compared to 1990 figure (Zenzola, 1995). The current polyurethane demand in South Asia (including Malaysia) is forecasted to grow in the area of rigid and flexible PUFs. This is an enormous market, and it is hoped that through our R & D in PORIM, polyurethane from palm-based polyols will secure a slice of it.

CONCLUSION

The future of polyurethane lies towards high quality products that are environmental friendly, recyclable and safe to use. In order to achieve this vision, PORIM will intensify its development work towards these environmental friendly based raw materials (palm-based polyols) in the manufacture of PUFs to meet the industrial requirements. ■

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