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Production of Flexible Polyurethane Foam using Soya Bean Oil and Palm Kernel Oil as Surfactant and Polyol Respectively

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Abstract
The use of local raw materials in industrial processes is an important aspect of technological development. These locally produced raw materials can be substituted for imported raw materials in different production and manufacturing processes. This study investigated the performance characteristics of polyurethane foams produced through partial to total substitution of imported constituents; surfactants (silicone oil) and polyol with locally produced soya bean oil and palm kernel oil. The produced polyurethane foam samples were taken through the required physical tests to investigate their degree of compatibility or otherwise with polyurethane foam produced using 100% imported polyol and silicone oil respectively. The results of various physical tests established that palm kernel oil can be blended with polyol up to 20% formulations; also soya bean oil can be blended with silicone oil up to 20% formulations. This is because the polyurethane foams produced through these formulations compared favorably well at 20% substitution with foam produced using 100% imported polyol and silicone oil respectively while other formulations showed a wide variation from the standard recommended values.
Keywords: Polyurethane, Soya bean oil, Palm kernel oil, Polyol and Silicone oil.

1. Introduction

Flexible polyurethane, otherwise known as expanded polymer products are group of materials developed by the reaction between alcohols with two or more reactive hydroxyl group per molecule (Suru, 2004). Flexible polyurethane foams covers over 50% of the total world foam production. It is mainly used in making furniture and mattresses which involves exclusively flexible foams; the automotive industry which provides a market for flexible foams; filling foams, rigid and flexible integral skin foams as well as elastomers for engineering components; consumer sector which is diversified in a manner similar to the automotive industry; the building industry which is by far the largest consumer of rigid foams as insulation materials and refrigeration engineering, which represents the second largest area for use of rigid polyurethane foams as insulating materials.

Polyol are generally manufactured through one or two possible chemical routes namely alkoxylation and esterification (Khairiah, 2012). At present, polyol used in polyurethane industry are petroleum based where crude oil and coal are used as starting materials. However, these materials have been escalating in prices and rate of depletion is high as well as required high technology processing systems. This necessitates a look at utilizing local materials that can serve as alternative feed stocks of monomers for the polymer industry. Silicone oil is usually being imported and is regarded as a surfactant. The effect of surfactant cannot be over emphasized since it acts as an emulsifying agent that brings together all ingredients used in the chemical mix bringing about homogenous liquid. It stabilizes the bubbles in foam before the liquid phase polymerizes. It also prevent cell collapse during rising stage because as cells are opened by air input, silicone oil keeps it opened to carbon dioxide for diffusion to effect rising. It also prevents fall-back or loss of foam height after achieving fully risen position (Shell chemical, 1994).

Palm kernel oil is saturated vegetable fat. This oil gives the name to the 16-carbon saturated fatty acid (palmitic acid) that it contains. Palm kernel oil gives mechanical and thermal properties as well as dimensional stability.

Soya bean oil is a drying oil which means that it slowly harden on exposure to air forming a flexible transparent and waterproof solid (Sabariraj, 2012). Both palm kernel oil and soya bean oil can be found in the southern latitude of West Africa (Dutta *et al*, 1972).

According to Suru (2004), all good formulations consist of main chemicals, activators, foam stabilizers and water. The addictives and blowing agents are optional. Therefore, the aim of this study is to investigate the suitability of palm kernel oil and soya bean oil as replacement for silicon oil and polyol in foam production and also to investigate the performance characteristics of foams produced by partial to total substitution of silicone oil and polyol with palm kernel oil and soya bean oil respectively.

2. Materials and Method

2.1 Materials

Polyol**,** Toluene-di-isocyanate, Dimethyl ethyl amine, Silicone Oil and Methylene chloride were obtained from Vitafoam Nig. Plc., Lagos while Soya bean Oil and Palm kernel Oil were bought from Oyingbo market in Lagos, Nigeria.

2.2 Equipment

Reaction containers, Electric stirrer, Carbon lined with brown paper, Safety gloves, Eye – wear, Stop watch, Stirrer or mixer, A volume box with inner paper lining, 5 liter volume bowls, Weighing balance, 2 liter volume bowls, Conical flasks.

2.3 Method

The 24kg/m^3 density was chosen as basis for flexible foam production in this study based on market survey. All the required chemicals (Polyol, Dimethyl ethyl amine, Silicone oil, Methylene chloride, Tin catalyst and Water) were weighed in separate containers and added in their required proportion into the mixing vessel. 250g of TDI was added last. The addition of TDI was immediately followed by mixing. The mixing was very necessary for the following reasons; to prepare coagulation of some chemicals and to input atmospheric air into the mixture, which helps to open the cells. After adequate mixing, the mixture was quickly poured into the prepared mould. The cream and rise time were recorded using stop watch. The produced foam was afterward removed from the mould for inspections. The foam samples were aerated for 18 hours before characterization in order to ensure complete curing. The mould was cleaned and prepared for another batch.

2.4 Experimental design

The experimental formulation for substitution of polyol with palm kernel oil used in this study is presented in Table 1. The experiment was designed in such a way that palm kernel oil was progressively substituted for polyol from formulations A to E.

Table 1: Experimental formulation for Substitution of polyol with palm kernel oil

Chemicals PKO	Industrial formulation 0% (Control)	Formulation A 5%	Formulation B 10%	Formulation C 15%	Formulation D 20%	Formulation E 25%
Polyol	500g	480g	460g	440g	420g	400g
PKO	Nil	20g	40g	60g	80g	100g
TDI	250g	250g	250g	250g	250g	250g
Water	21g	21g	21g	21g	21g	21g
Amine	2g	2g	2g	2g	2g	2g
SO	5g	5g	5g	5g	5g	5g
Tin Catalyst	0.8g	0.8g	0.8g	0.8g	0.8g	0.8g

*PKO = Palm Kernel Oil
*SO = Silicone Oil

The experimental formulation for substitution of silicone oil with soya bean oil is given in Table 2. The experiment was designed in such a way that soya bean oil was progressively substituted for silicone oil from formulations A to E.

Table 2: Experimental formulation for Substitution of silicone oil with soya bean oil

Chemicals SBO	Industrial formulation 0% (Control)	Formulation A 5%	Formulation B 10%	Formulation C 15%	Formulation D 20%	Formulation E 25%
Polyol	500g	500g	500g	500g	500g	500g
TDI	250g	250g	250g	250g	250g	250g
Water	21g	21g	21g	21g	21g	21g
Amine	2g	2g	2g	2g	2g	2g
SO	5.00g	4.83g	4.67g	4.49g	4.33g	4.16g
SBO	Nil	0.17g	0.33g	0.51g	0.67g	0.84g
Tin Catalyst	0.8g	0.8g	0.8g	0.8g	0.8g	0.8g

*SBO = Soya bean oil
*SO = Silicone oil

3. RESULTS AND DISCUSSION

3.1 Results of Physical Tests

For the substitution of polyol with palm kernel oil and silicone oil with soya bean oil, physical tests such as density, compression set and indentation force deflection (IFD), rise time and cream time were carried out on the samples of foam produced. The results of the tests are presented in Tables 3 and 4 respectively.

Table 3: Result of physical tests for foam produced by substitution of polyol with palm kernel oil.

	S_O	S_A	S_B	S_C	S_D	S_E
Density(kg/m^3)	24.210	24.213	24.214	24.212	24.215	24.232
Compression Set (%)	11.54	11.48	11.42	9.92	13.40	11.24
Indentation – force - deflection (IFN)(N) 25%	111.00	110.90	112.74	111.02	111.34	113.90
40%	121.20	122.00	123.50	125.02	127.00	128.32
65%	170.20	172.00	168.00	174.00	180.30	183.55
Rise time(s)	82	93	99	104	109	112
Cream time(s)	14	17	18	21	23	27

Note: S_O, S_A, S_B, S_C, S_D and S_E are control sample, sample A, sample B, sample C, sample D and sample E respectively.

Table 4: Result of physical tests for foam produced by substitution of silicone oil with soya bean oil.

	S_O	S_A	S_B	S_C	S_D	S_E
Density (kg/m^3)	24.210	24.212	24.215	24.217	24.219	24.222
Compression Set (%)	11.54	11.52	11.28	10.09	11.52	13.04
Indentation force – deflection (IFN)(N) – 25%	111.00	112.30	110.65	111.04	111.29	109.82
– 40%	121.20	121.21	121.23	121.24	121.25	121.27
65%	170.20	167.32	161.00	174.13	169.54	169.82
Rise time (s)	82	77	72	63	88	92
Cream time (s)	14	15	18	20	21	25

Note: S_O, S_A, S_B, S_C, S_D and S_E are control sample, sample A, sample B, sample C, sample D and sample E respectively.

Graphical representation of values for the substitution of polyol with palm kernel oil

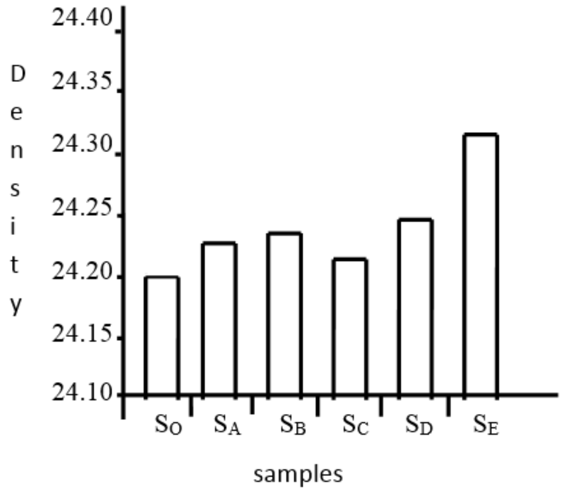

Fig1: Density test of samples of foam produced

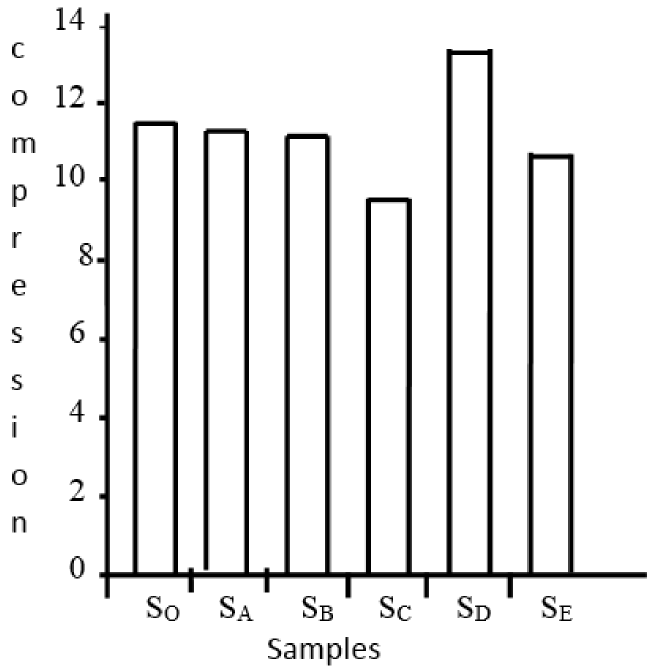

Fig2: Compression test of samples of foam produced

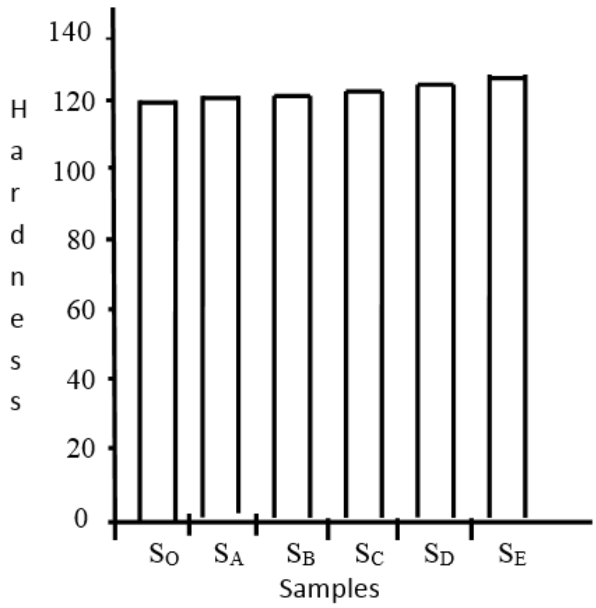

Fig3: Hardness test factor for samples of foam produce

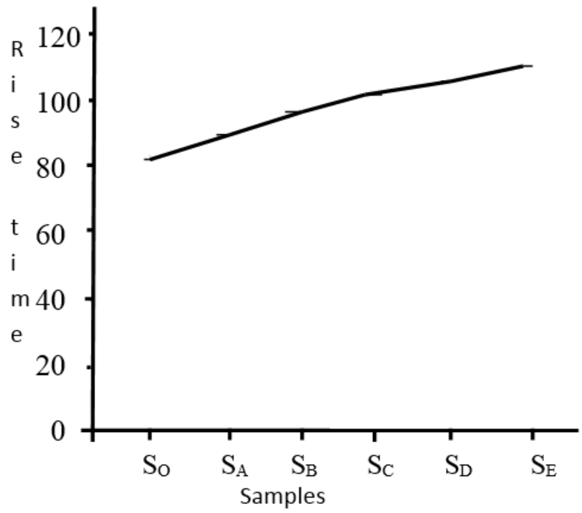

Fig.4: Rise time for samples of foam produced

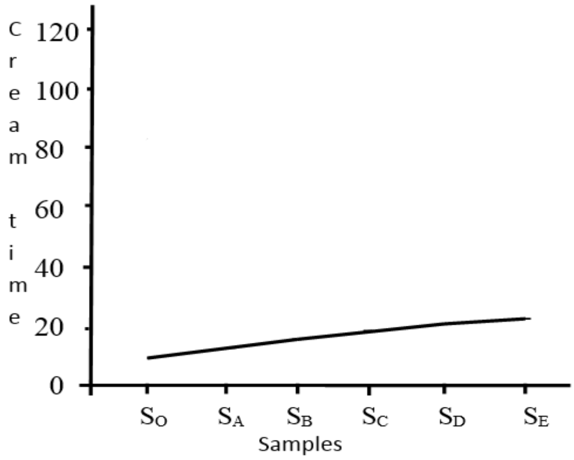

Fig.5: Cream time for samples of foam produced

In Fig. 1, the result of density test showed that samples S_O, S_A, S_B, S_C, S_D, gave closer values to the control sample, but a wide deviation was noticed in sample S_E. This can be explained as a result of the closeness and tightness of the interpenetrating polymer in S_E.

It was shown in Fig. 2 that the values obtained for samples S_A, S_B, S_E are closer to that of the control S_O, while samples S_C and S_D shows wide variation from sample S_O.

The results in Fig.3 showed a corresponding increase in hardness with progressive increase in palm kernel oil for all foam samples. This implied that a higher load bearing capacity can be achieved with increased palm kernel oil in foam production. It was observed that although the value of TDI index which is responsible for foam hardness was kept constant, hardness increases progressively with increase in palm kernel oil substitution for polyol.

In Fig. 4, it was observed that the rise time increases in ascending order with sample S_A closer to control while sample S_E has the highest rise time.

In Fig.5, it was shown that the cream time also increases progressively with sample S_A having the closest value to S_O while sample S_E is the farthest from the control.

Graphical representation for the substitution of Silicone Oil with Soya Bean Oil

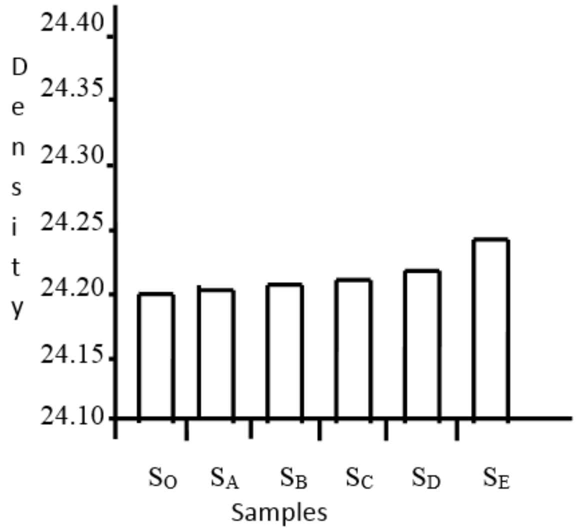

Fig. 6: Density test of samples of foam produced

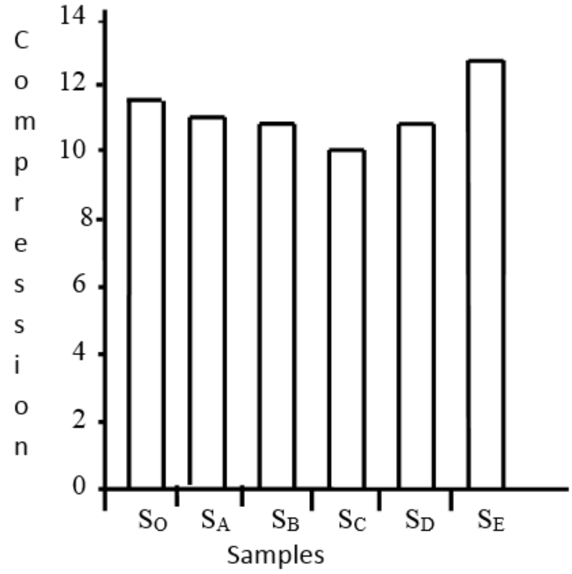

Fig.7: Compression test of samples of foam produced

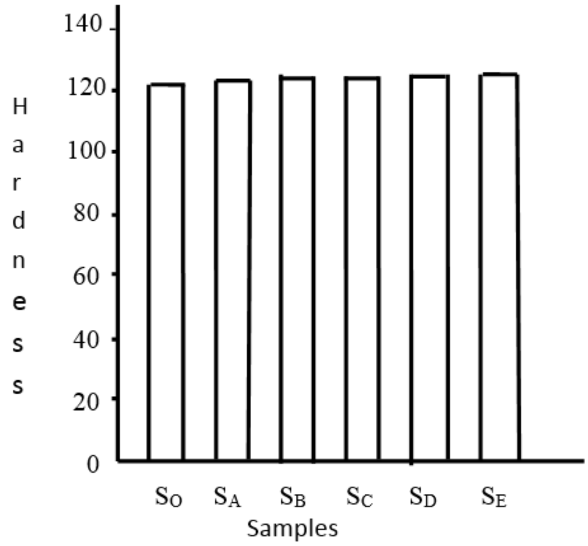

Fig.8: Hardness test for samples of foam produced

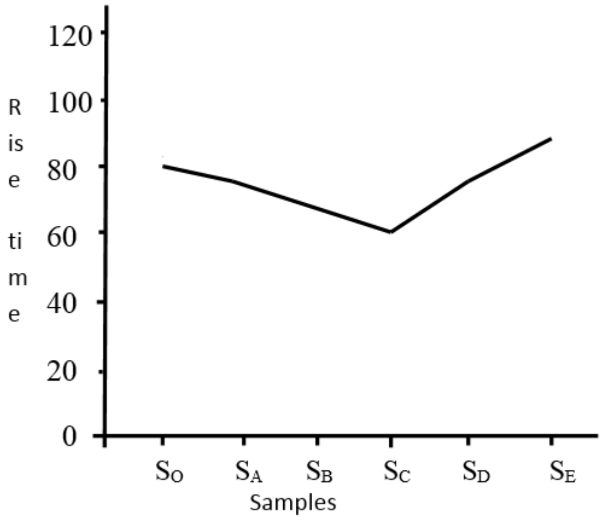

Fig.9: Rise time for samples of foam produced

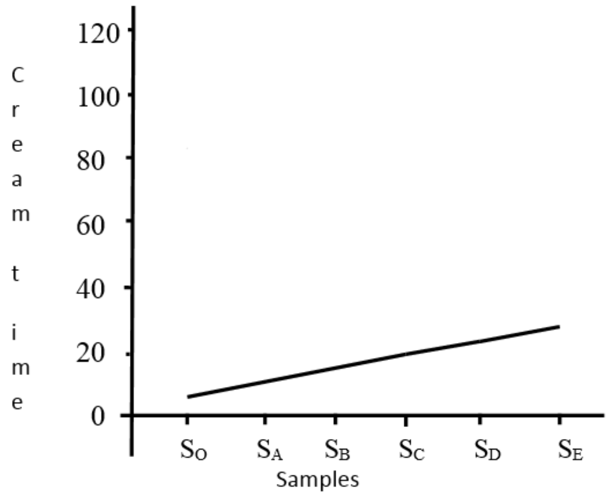

Fig.10: Cream time for samples of foam produced

In Fig. 6, it was observed that the density of foam increased gradually with sample SA being the closest to control SO. This means that density increases as the concentration of soya bean oil increases.

Fig.7 revealed that the compressive strength decreases gradually from SA to SC but increases for samples SD and SE. However, sample SA has the closest value to control SO with sample SC having the lowest. This compressive strength was observed to vary proportionally with isocyanate.

The hardness of foam samples produced increased gradually with increasing value of soya bean oil from SA to SE as revealed in figure 8. The value of sample SA is closer to the control SO. It was also observed that although the value of TDI index which is responsible for foam hardness was kept constant, yet the hardness of foam samples produced kept increasing with increasing substitution of polyol with soya bean oil.

It was observed in figure 9 that the rise time of samples of foam produced decreases from SA to SD with sample SC having the lowest rise time but the time re-increases again with sample SE having the highest rise time. Rise time is the period when the entire foam expansion takes place.

It was observed in Fig. 10 that the cream time increases from SA to SE with SA closer to control SO.

4. Conclusion

Polyurethane foams were produced from palm kernel oil based polyol, and also from soya bean oil based surfactant. The experimental results demonstrated that the results of physical tests for sample S_A (20% substitution) in the progressive substitution of polyol with palm kernel oil and that for progressive substitution of silicone oil with soya bean oil is comparable to the results of the control sample.

The local content policy typically require a certain percentage of intermediate goods used in the production processes to be replaced with local materials, therefore, the results of this study has established that palm kernel oil can be substituted with polyol up to 20% while soya bean oil can be substituted with silicone oil up to 20% in the production of flexible polyurethane foam. Also, based on the 20% to 80% proportion of substitution of polyol with palm kernel oil and silicone oil with soya bean oil respectively, there will be significant decrease in the cost of production when compared with foam production with 100% imported polyol and silicone oil respectively, and this will translate to increased profit.

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