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Research Article

Comparison of Flexible Polyurethane Foam Produced by using Sunflower Oil, Soybean Oil and Palm Kernel Oil as Polyol

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Abstract

The research for a possible total replacement of petroleum-based polyol with renewable oil for the production of flexible polyurethane foams has been on the increasing recently. This is because of the enormous benefits that lie in renewable oil. In this work, 3 renewable oils namely sunflower oil, palm kernel oil and soybean oil were each used to replace 20% of petroleum-based polyol in polyurethane foam production and the foams produced were labeled S_1, S_2, and S_3 respectively. These were compared with a control sample (S_0) made with only petroleum-based polyol. A density of 24kg/m^3 was used for this work. Tests carried out on the various samples showed that palm kernel oil is a better substituent for petroleum-based polyol than the other oils.

Keywords: Sunflower oil; Soybean oil; Palm oil; Gell time; Rise time; Compression set; Elongation at break point.

Introduction

Polyurethane foams (PUFs) are produced on the basis of an exothermic polymerization between isocyanate groups and polyols [1]. Generally in the production of flexible foam (FF), the isocyanate reacts with the polyol to form urethane groups, and also with water to form CO_2 and urea groups. While the urea and urethane moieties are linked to the hard segment of FF, the polyols form the soft segment [2]. This reaction occurs under room temperature by the addition of small amount of suitable catalysts such as tertiary amines and tin compounds [1]. Large varieties of PUFs grades can be manufactured by controlling and carefully modifying the nature of the starting monomers [3].

Polyols which is one of the chief monomers used to produce PUFs [4,5], usually have the highest percentage by weight of raw material used [6]. Polyols are chemically defined as compounds containing multiple hydroxyl groups [7]. Petroleum-based polyol (PBP) have the ability to create excellent mechanical characteristics in foam but are very expensive because of the high cost of petrochemical feedstocks [8], and are not in agreement with environmental friendly requirements [1]. Hence, the need to harness the opportunities and benefits that lie in renewable oils as possible substitutes.

More so, in recent times, there have been progressive development in the modification, blending and synthesis of various polyols from agricultural harvests including castor oil, soybean oil, linseed oil, palm kernel oil, sunflower oil, sesame oil etc [1,9-13].

Soybean oil have been reported to contain high polyunsaturated fatty acid, are emollient, inexpensive [14], environmentally friendly and most importantly renewable in nature [15]. They are also used in good stuffs [16] and are edible [17]. It have been reported that soybean based polyols can now replace as much as 50% of PBPs in rigid PUFs without any obvious changes [18].

On the other hand, sunflower oil is a polyunsaturated oil with a high amount of linoleic acid [17], and as such are considered to be very good for human consumption because if

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its high ratio of polyunsaturated to saturated fatty acids and its high linoleic acid contents [19,20].

Likewise, palm kernel oil is known for their high iodine value when compared with other edible oils like coconut and groundnut oil [21]. Palm oil has been reported to give mechanical and thermal properties as well as dimensional stability [4]. Palm trees are commonly planted in four tropical regions; Africa, South East Asia, Latin America and South Pacific [22]. The world's largest producer and exporter of palm oil today is Malaysia, producing about 47% of the world's total supply. In Africa, the west lands of West Africa and South Benin are known to host many palm plant plantations [21].

The present research work is an advancement on Aremu MO et al [4] and Victor et al [6]. It is centred on the comparison of physicomechanical properties of flexible polyurethane foams produced by using palm oil, sunflower oil and soybean oil to replace 20% PBP in FF production.

Materials and methods

Materials used

Polyol (PPG 3601), toluene diisocyanate (TDI) (UN 2078), tin compound, dimethyl ethy amine, DMEA (LV-33), power silicone surfactant (L-620/PDR) and water were obtained from the production department of Exotic Foam and Chemical Limited, Nkpor, Anambra State. Sunflower oil, soybean oil and palm kernel oil were purchased from Ose market, Onitsha, Anambra State.

Equipment used

Box mould, MH 887 electronic digital scale, manual stirrer, safety gloves, safety eye glass, stop watch, reaction container for mixing, and beakers were used.

Method used

The present research is advancement on Victor et al [6] and Aremu MO et al [4]. It was based on a density of 24kg/m^3 as formulated by Aremu et al [4]. 20% of the PBP was replaced with palm oil, sunflower oil and soybean oil and was used to produce 3 different samples of foam.

S_0= 100% PBP
S_1= 80% PBP + 20% sunflower oil
S_2= 80% PBP + 20% palm kernel oil
S_3= 80% PBP+ 20% soybean oil

The various raw materials were weighed using the electronic scale and kept separately in various beakers. DMEA and silicone oil were added to the water, mixed properly and kept. This was done in order to ensure that water, DMEA and silicone oil are thoroughly mixed [23]. Polyol was poured into the reaction container followed by the substituting renewable oil. This was followed by tin catalyst. Water-DMEA-silicone mixture was added and the mixture stirred properly. TDI was added last and the mixture was immediately stirred before being discharged into the volume box mould. The cream time, rise time and gell time were noted for each of the samples. The foam sample was removed and aerated for 18 hours to ensure complete curing before characterization [4].

Experimental formulation

The formulation for the substitution of PBP is presented on table 1.

Table 1. Experimental formulation for the susbstitution of PBP

Raw material (g)	S_0	S_1	S_2	S_3
Polyol	500	420	420	420
TDI	250	250	250	250
Water	21	21	21	21
DMEA	2	2	2	2
Silicone oil	5	5	5	5
Tin catalyst	0.8	0.8	0.8	0.8
Sunflower oil	Nil	80	Nil	Nil
Palm oil	Nil	Nil	80	Nil
Soybean oil	Nil	Nil	Nil	80

Results and discussion

From table 2, S_1 had a rise time of 88 seconds. This value is very close to 93 seconds as recorded in [6]. However, the rise time of S_2 is 60 seconds and this shows a large deviation from what Aremu et al [4] reported. Nevertheless, S_2 had the fastest rising time when compared with S_1 and S_3. This signifies that the gas production reaction between TDI and water was fastest in S_2 than it was in S_1 and S_3. Hence, this suggests that palm kernel oil is a better substitute for polyol than sunflower and soybean oil.

In fig. 1, although S_0 had the lowest gell time, S_2 showed a remarkable closeness to S_0 than S_1 and S_3. The low gell time of S_2 infers that it can be quickly retracted from the mould than S_1 and S_3 and this is a positive development.

Table 2. Physicomechanical properties of the foam samples produced

	S_0	S_1	S_2	S_3
Density (kg/m^3)	24.17	28.51	24.43	26.80
Rise time (s)	50	88	60	104
Gell time (s)	200	317	278	325
Elongation at break point (%)	65.69	46.98	66.72	26.08
% Compression set	9.67	8.72	8.33	12.50

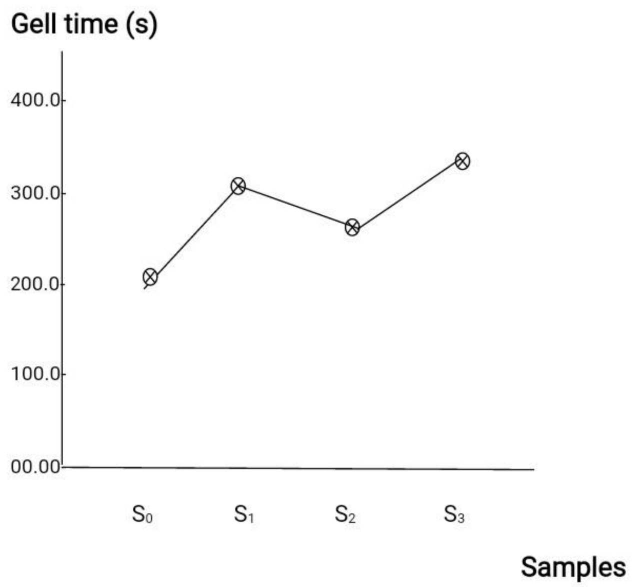

Fig. 1. Graph of gell time of the various samples

From table 2, the density of S_2 is very close to the control sample. However, there is an unsually increase in the densities of S_1 and S_3, with S_1 having the highest value. This increase in density could be because of the closeness and tightness of the interpenetrating polymer network in S_1 and S_3 [4,24].

In fig. 2, the elongation at break point of the various samples was presented as the percentage (%) increase in length before deformation. As shown on the graph, S_2 have a remarkable elongation at break point. This infers that S_2 have a better elasticity than the other samples and is less prone to deformation.

More so, in fig. 3, the % compression set is presented as the percentage of the foam length that collapsed. There is a gradual decrease in % compression set from S_0 to S_2, and then a sharp increase in S_3. From the graph, S_2 is shown to have the lowest % compression. This implies that S_2 was less prone to bottoming-out as only 8.33% of its original length collapsed. This is a great development as foams which are less prone to collapse are found to be of superior quality than their counterparts.

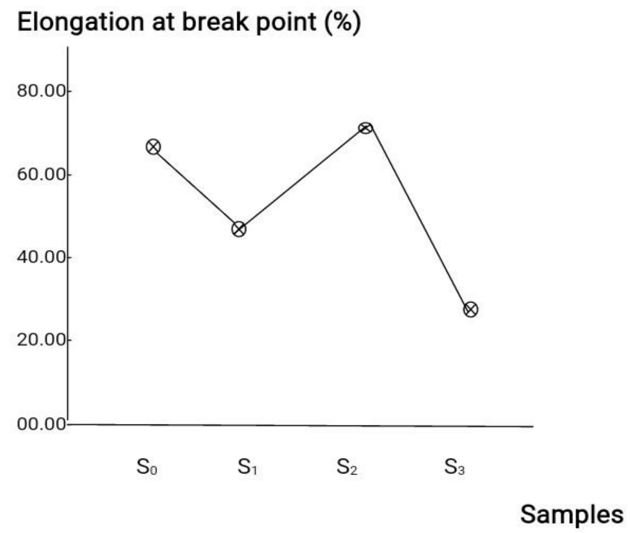

Fig. 2. Graph of elongation at break point of the samples

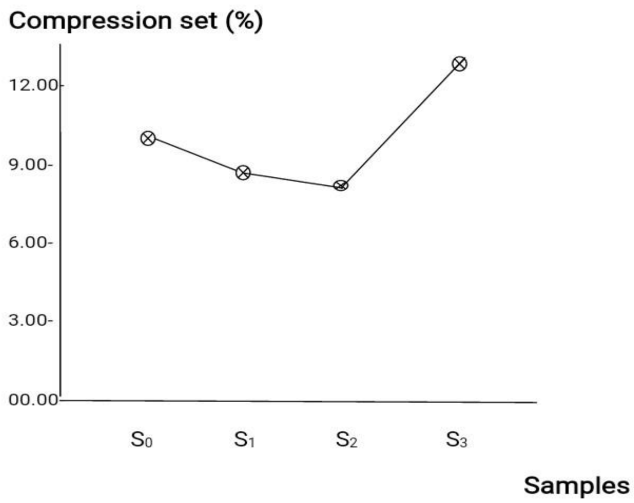

Fig. 3. Graph of compression set of the samples

Conclusions

The tests carried out on the various samples have shown that palm kernel oil can effectively be used to substitute petroleum based polyol in flexible polyurethane foam production and still have outstanding qualities. This study has also shown that although sunflower and soybean oil can be used, palm kernel oil has proven to be of a better substituent than them. Hence there is a need to harness the benefits that lie in using palm kernel oil to produce polyol as this will consequently reduce to a great extent the cost of production as palm kernel is readily available in Nigeria and other tropical parts of the world. Some school of thought might propose that there will be a competing need for the use of palm kernel oil as food and also as a substitute for petroleum based polyol. However, it is important to note that the benefits of using palm kernel based polyol outweigh the supposed competition.

Conflicts of interest

Authors declare no conflicts of interest.

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