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Effect of Castor Oil as an Auxillary Stabilizer in the Production of Flexible Polyurethane Foams

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Abstract: *In Nigeria, the polyurethane industry depends mostly on imported feedstocks which are relatively expensive. Furthermore, emissions from some of these chemicals during processing have been reported to cause negative environmental impact effects and also carcinogenic to both animal and humans.*
The effect of castor oil as an auxiliary stabilizer in the production of polyurethane foams was studied. Laboratory mixture was carried out to produce different foam samples of various densities (20 kgm^{-3}, 25 kgm^{-3}, 30 kgm^{-3}, 35 kgm^{-3} and 40 kgm^{-3}) using castor oil as a substitute for silicone oil at different percentages.
The physical and chemical test carried out on the foam samples showed that silicone oil cannot be totally substituted with castor oil, but it can act best as a partial substitute for silicone oil at higher densities to an extent of 75 %.

I. Introduction

Polyurethane products abound everywhere, they are found in every area of human endeavor, such as offices, household seats, electronic packaging, cars etc. The cost of materials used in producing polyurethane products has led to the increase in the prices of these products consistently over the years. This in turn, necessitated the incorporation of variety of renewable fillers in foam samples (Onuegbu et al., 2012), in order to reduce the cost of production.

Presently, the majority of industrial raw materials are derived from non-renewable sources, essentially from fossils. The development of cost-effective, readily available, eco-friendly alternatives or supplements especially from renewable sources is desirable and points to many commercial opportunities that would reduce the growing concerns about environmental degradation and protect our ecosystem in the long run (Materials Raw Research and Development Council Publication, 1990). These excellent natural characteristics are now being taken advantage of in research and development, with vegetable oil derived polymers/polymeric materials/composites being used in numerous polymer industry.

Generally, industrial raw materials whether organic or inorganic have been grouped into three classes; Agricultural, Fossil and Inorganic sources (Scott, 1985; Ulmanns, 2001). The agricultural sources of raw materials include carbohydrates, proteins, lipids (fats and oils), resins, gums, phytochemicals and so on. These constitute the renewable resources while the fossils sources of industrial raw materials are petroleum, natural gas and coal from which various chemicals and petrochemicals are obtained as feed-stocks for the industries (Mohammed, 1981; NNPC Publication, 1995). Furthermore, the inorganic sources of industrial raw materials are the mineral elements and their compounds obtained from the earth crust such as iron, copper, tin, columbite, aluminum and their compounds including the gases from the atmosphere such as N_2, O_2, CO_2 (Hill, 1992). The agricultural and the fossil sources of raw materials provide the bulk of raw materials for the process and manufacturing industries (Monts, 1978). However, both the fossil and earth crust inorganic sources are exhaustible while the agro-based sources are renewable.

Vegetable oils have contributed immensely to the growth of the economies of many developing nations, for instance, olive oil remains a factor in the agricultural economies of Greece, Spain and Italy just as palm oil in the domestic and export economies of West Africa (Nigeria) and Malaysia as well as castor oil in Brazil and India (Sutherland, 1986; Food and Agricultural Organization of the United nations, 2008).

The Raw materials used in the manufacture of flexible polyurethane foams are, polyol and toluene di-isocyanate (TDI) as the chemicals, amine and stannous octoate as the activators, silicone oil as the stabilizer the additives used are the pigments, fillers and flame retardants. Other raw materials include water and auxiliary blowing agent. Flexible polyurethane foams, can be broadly divided into polyester and polyether foam, polyester foams are produced using polymeric polyol containing ester groups in the molecular chain or inside chains, while polyether foams are produced using polymeric polyols containing ether linkages.

However, foams produced from polyester linkages, proved unable to withstand many in-use temperature and humidity conditions and often failed by crumbling away. Foams obtained with polyether linkages, proofs to have more advantages over polyester foams in terms of elasticity, cost of production, and has a wider application over polyester foams.

Silicone oil is light colored and moderately viscous liquid, for any given foam formulations, a minimum level of silicone oil is required to have well-structured foam. The silicone oil is used as surfactant which acts as an emulsifier, lowers bulk surface tension, enhances the formulation of cells, prevents cell collapse and also aids the introduction of solid into the foam production. The cost of purchase and importing silicone oil into the country is relatively high, it is therefore, imperative to find a suitable raw material to act as stabilizer in the production of polyurethane foam in place of silicone oil, to cushion the high cost of importing polyol.

Castor oil is readily distinguishable from other oils by its high specific gravity, viscosity and acetyl value and by the presence of –OH group on the main fatty acid. The double bond and –COOH group are the functional groups responsible for the large number of reactions of industrial importance (Naughton, 1974). It is a colorless to very pale yellow liquid with mild or no odor or taste. Its boiling point is 330 °C and its density is 961 kg/m^3 (Aldrich Handbooks, 2003). It is a triglyceride in which approximately 90 percent of fatty acid chains are ricinoleic acid. Oleic and linoleic acids are the other significant components (Morrison, 1991). Ricinoleic acid, a monounsaturated, 18-carbon fatty acid, is unusual in that it has a hydroxyl functional group on the 12 th carbon, this properties therefore enhances the choice of castor oil as a replacement for silicone oil in this research work.

In this study, flexible polyurethane foams were produced using locally sourced castor oil at different ratios. The physio-mechanical and various mechanical test analyses were done on the sample foam produced, and they were also compared with polyurethane foams produced with 100 % polyether polyol.

Ogunfeyitimi et al. (2012), studied the use of castor oil as a reactive monomer in the synthesis of flexible polyurethane foam; he indicated that castor oil can be blended up to 25 % with polyether polyol in the flexible polyurethane formulation. He established that the products of this formulation can be used for all flexible application. He reported that 30% blend of castor oil with polyether showed a wide variations from the national standard recommended values with respect to density, porosity, compression and elongation test. Also, the cost benefit analysis done showed that the flexible polyurethane produced showed a significant decrease of about 10% when compared with foams produced with 100% polyol.

Dalen et al. (2014), also studied effects of low castor oil on mechanical properties of polyurethane foams, theyexplore and exploit alternative nonconventional or supplement local sources of raw materials such as castor oil for the commercial manufacture of polyurethane foams in our quest for local content development. He showed that castor oil properties compare reasonably with those of conventional and polymer polyols.

II. Materials And Methods

Foam preparation: The method described by (Ogunleye et al., 2008) was employed in foam preparation, based on the formulation for the various densities involved, mixing ratio of silicone oil and castor oil was included to a mixture containing laboratory mix formulation. The control experiment for each density was without castor oil. When homogeneity in the mixing was achieved with the use of a wooden stirrer, the mixture was quickly poured into the mould. After 5-10 mins, depending on how fast the rising time is, it was removed from the mould and the mould was then prepared for the next experiment.

Laboratory mixture: This was carried out by carefully formulating with respect to the different densities involved. Certain amount of polyol was measured into 5 L volume bowl. Other reagents such as water, amine, stannous octate, pigments, methylene chloride were also measured and added as needed. The mixture was stirred thoroughly with the aid of a wooden stirrer for about 30 s. TDI was then added and stirred more vigorously to ensure a homogeneous mixing. The mixture was then poured into a metal mould with paper lining and the mixture began to rise up. The rising time for the various experiments was noted.

After 10 mins, the box foam was removed from the mould and the paper lining was removed from the surface of the foam. The box foam was then left to cure for 24 hrs at normal room temperature (25 ^{o}C) after which a vertical cutter machine was used to cut the foam into various layers and shapes for physical tests to be carried out.

Density tests: The dimensions to the test-pieces were measured with the aid of a measuring tape. The values were in centimeter which was converted into meter. The weight of the test-pieces was also taken using a well calibrated weighing balance; the values were taken in grams and converted to kilograms. The sample weight was divided by its volume to give the density.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Indentation test: The foam sample was placed on an indentometer which is used to determine the hardness of the foam sample. The height of the foam sample was inputted into the machine. The hardness of the foam was the displayed after 10 minutes on the Read-out at 25 %, 40 % and 65 % hardness of the foam.

Compression test: A cubic shape of the foam sample was placed under a compression set instrument for 22hours, and when removed was allowed to stay for 30 minutes. The thickness of the foam was measured with the aid of a measuring tape before and after placing it in the compression set.

$$\text{Compression test} = \frac{(T_0 - T_1) \times 100}{T_0}$$

Where: T0 is the original thickness of the test sample

T1 is the thickness of the test sample after recovery.

This test, is used to check for the for the resilience i.e. the ability of the foam sample to return back to its initial height, thickness and form after a particular load is placed on it.

Tensile strength and elongation test: Foam samples were die-cut (dumb-bell shaped) with the aid of a dumb-bell machine. The thickness of the foam samples were determined by placing it in the grips of the testing machine. Care was taken to see that it was symmetrically positioned in order to ensure that tension was well distributed uniformly over the cross section. The machine was stated at this point and the tensile strength and the distance between the inside edges of the two reference lines was measured immediately prior to break of the foam to pieces.

III. Results And Discussion

Effect of castor oil on foam rising time: It was observed that from the formulations of the various densities, the rising time of the control experiment was higher than the subsequent ones that require substitution of castor oil with silicone oil at different percentages. It was also observed that when the quantity of castor oil exceeded that of silicone oil in 20 and 25 densities foam**,** the foam collapsed while carrying out the laboratory mix. At larger densities, of 30, 35, and 40 densities, the substitution exceeded 50 % to 75 %, 85 % and 66 % respectively. The decrease in rising time might be due to the fact that the mixture became too viscous.

Effect of castor oil on density: It was observed that the foams produced increases in density as the quantity of castor oil increases. Increase in the densities of foam samples can be with increase in castor oil, can be due to high viscosity caused by the presence of castor oil which improve homogeneity of the mixture because of its oleo chemical biding nature of castor oil, this improved emulsification and binding actions improves the foam's structure and linkages of foam cells and hence the increased densities.

Effect of castor oil on the index: It was observed that the hardness varied to a particular extent with increase in castor oil. Silicone oil aside the fact that it acts as an emulsifier, it also increase the hardness of foam.

Effect of castor oil on the compression set: There is an indication of better ability of the foam to recover after compression with increase in castor oil in higher densities than the lower densities. This may be due to the fine structure nature of the foam cells formed as a result of the ole chemical activated of castor oil in the mixture. The void age fraction is reduced and hence the improved recovery ability.

Effect of castor oil on the tensile strength and elongation: it was gathered from the lab mix carried out that as the castor oil increases, the strength and elasticity of the foam samples under tension declined but still within the acceptable limit of standard. This trend can be attributed to the hardness index of the foam which ordinarily has an inverse relationship with the elongation and tensile strength.

IV. Conclusion

It was observed from the physical test carried out that castor oil can act best as a partial substitute for silicone oil at higher densities to an extent of 75 %. The tensile strength and elongation of foam samples, in some instances declined with increased castor oil, but however compared favorably with the control foam samples. Since the main aim of business is to make profit, the use of castor oil as an auxiliary stabilizer in the production of higher density foams such as 30 kgm^{-3}, 35 kgm^{-3} and 40 kgm^{-3} densities, since castor oil is renewable, biodegradable, hence its ecofriendly and readily available in the market at low cost compared to silicone oil which has to be imported into the country.

References

[1]. Aldrich Handbooks of Fine Chemicals and Laboratory Equipment, Sigma-Aldrich, "Castor", IENICA; 2003.

[2]. Dalen, M.B., Ibrahim, A.Q., and Adamu, H. M. (2014). Effects of Low Castor Oil on Mechanical Properties of Polyurethane Foams British Journal of Applied Science & Technology, 4(18): 2661-2683.

[3]. Food and Agricultural Organization of the United Nations, Economic and Social department (2008). Top ten Castor Oil seed producers.

[4]. Hill, W.J. (1992). Chemistry for changing Times, Sixth Edition, Macmillan publications Comb. New York. 541(551):615–625.

[5]. Materials Raw Research and Development Council Publication, 1990. 2nd Edition, Raw Materials Sourcing for Manufacturing in Nigeria, a Synthesis of Reports of Ten Techno-Economic Surveys of ten Industrial Sectors in Nigeria; 21-30.

[6]. Mohammed, S. (1981). Fatty Acids as Indigenous Resources for possible industrial applications, Pakistan Journal of Scientific and Industrial Researc; 24(1): 25–30.

[7]. Monts, L.T., Kohlkase, W.L. (1978). Selective hydrogenation of Soy bean oil: Effect of pressure on Copper Catalysis, Journal of America Oil Chemist Society; 55(4):402–403.

[8]. Morrison, T., Robert, B.N.R. (1991). Organic Chemistry 5th Edition Allyn and Bacon Inc., Newton, Massachusetts, U. S. A., 681–684.

[9]. Naughton, C.F. (1974). Production chemistry and commercial applications of various chemicals from castor oil. Journal of American Oil Chemist Society. 51(1):15-21.

[10]. NNPC Publication. (1995). History of Crude Oil Marketing in Nigeria.

[11]. Ogunfeyitimi, O.S., Okewale, A.O. and Igbokwe, P.K. (2012). The use of castor oil as a reactive monomer in synthesis of flexible polyurethane foam. International Journal of Multidisciplinary Sciences and Engineering. Vol. 3: 356-365**.**

[12]. Ogunleye, O.O., Oyawale, F.A. and Suru, E. (2008). Effect of castor oil on the physical properties of polyether based flexible polyurethane foam. Advances in Natural and Applied Sciences. Vol. 2 (1): 10-15.

[13]. Onugbu,T.U., Umoh, E.T. and Iwachukwu, I.E. (2012). Flame retardant effects on flexible polyurethane foam treated with potassium sulphate. ARPN Journal of Science and Technology. Vol. 2: 235-245.

[14]. Scott, A. (1985). Natural Resources Economics, Edited, Clarendon Press Oxford. 15(20):173–195.

[15]. Sutherland, J.P., Varnam, A.H. (1986). Evans MG. Food Quality Control; Wolfe Publication Limited London. Pp; 126–130.

[16]. Ulmanns, H. (2001). Encyclopedia of Industrial Chemistry, sixth edition, electronic release, Pergamon Press, London.

Table 1: Density Formulation

RAW MATERIALS	QUANTITITY (g)				
	20D	**25D**	**30D**	**35D**	**40D**
Polyol	600.0	700.0	600.0	660.0	660.0
TDI	300.0	349.0	227.0	235.0	229.0
Water	25.0	29.0	18.0	18.0	16.0
Amine	2.0	2.0	2.0	2.0	2.0
Methylene chloride	20.0	-	-	-	-
Silicone oil	5.0	4.0	5.0	4.0	4.0
Tin	-	1.3	0.8	0.83	0.7
Pigment	-	Yellow, 15.0	Black, 15.0	Blue, 15.0	Pink, 15.0

Table 2: Variation of Silicone Oil with Castor Oil

Set up	Ctrl	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5	Exp 6	Exp 7	Exp 8	Exp 9
Wt of silicone (g) @20 D	5.00	4.50	4.00	3.50	3.00	2.50	2.00 ~~C~~	1.50	1.00	0.50
Wt of castor oil (g)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
Wt of Silicone oil (g) @ 25D	4.00	3.50	3.00	2.50	2.00	1.50	1.00 ~~C~~	0.50	0.00	-
Wt of Castor oil (g)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	-
Wt of Silicone oil (g) @ 30D	5.00	4.50	4.00	3.50	3.00	2.50	2.00	1.50	1.00 ~~C~~	0.50
Wt of Castor oil (g)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
Wt of silicone oil (g) @ 35D	4.00	3.50	3.00	2.50	2.00	1.50	1.00	0.50 ~~C~~	0.00	-
Wt of Castor oil (g)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	-
Wt of Silicone oil (g) @ 40D	4.00	3.50	3.00	2.50	2.00	1.50	1.00 ~~C~~	0.50	0.00	-
Wt of Castor oil (g)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	-

Exp= Experiment
Ctrl = control
Wt= weight

Table 3: Result of Analysis

Physical test	**Control**	**Exp.1**	**Exp.2**	**Exp.3**	**Exp.4**	**Exp.5**	**Exp.6**	**Exp.7**	**Exp.8**	**Exp.9**	**Exp.10**
Rising time (sec) @											
20 D	66.0	65.0	65.3	63.0	55.0	50.0	ID	ID	ID	ID	ID
25D	60.0	57.2	57.4	64.0	56.0	ID	ID	ID	ID	ID	ID
30D	88.5	72.0	106.0	87.2	81.5	60.0	58.0	105.0	ID	ID	ID
35D	107.0	101.0	82.0	80.0	101.0	81.1	92.0	ID	ID	ID	ID
40D	115.0	110.0	105.0	103.0	92.5	90.0	ID	ID	ID	ID	ID
Aver. Density											
(kgm^{-3}) 20D	20.8	19.6	20.4	20.7	20.3	23.9	ID	ID	ID	ID	ID
25D	22.3	22.5	23.1	24.4	25.0	ID	ID	ID	ID	ID	ID
30D	31.2	28.9	30.3	29.9	30.7	30.4	29.4	31.8	ID	ID	ID
35D	34.2	31.9	30.6	31.3	36.4	36.0	37.0	ID	ID	ID	ID
40D	35.1	35.2	35.7	35.6	37.3	40.9	ID	ID	ID	ID	ID
Hardness (KN)											
20D	174.5	105.7	125.7	134.6	108.3	88.3	ID	ID	ID	ID	ID
25D	138.5	103.5	120.3	131.0	125.0	ID	ID	ID	ID	ID	ID
30D	142.1	117.2	128.2	120.6	120.7	105.3	111.9	145.7	ID	ID	ID
35D	163.7	125.4	121.7	117.9	153.2	177.4	154.0	ID	ID	ID	ID
40D	4.0	6.9	3.7	3.9	8.3	4.2	ID	ID	ID	ID	ID
Compression (%)											
20D	16.6	19.2	16.7	12.5	20.8	16.0	ID	ID	ID	ID	ID
25D	12.5	16.0	20.0	4.0	19.2	ID	ID	ID	ID	ID	ID
30D	8.0	12.0	11.6	8.0	8.0	4.3	4.0	4.0	ID	ID	ID
35D	8.7	9.0	8.0	8.0	4.4	4.0	8.0	ID	ID	ID	ID
40D	162.5	156.7	169.4	195.8	166.6	248.8	ID	ID	ID	ID	ID
Tensile strength											
(KNm^{-3}) 20D											
25D	98.6	169.5	131.6	135.9	124.5	160.4	ID	ID	ID	ID	ID
30D	146.8	92.4	94.9	84.03	84.03	ID	ID	ID	ID	ID	ID
35D	97.2	127.3	168.7	134.9	115.3	120.3	97.92	113.9	ID	ID	ID
40D	134.9	103.2	170.6	117.8	171.8	98.7	161.7	ID	ID	ID	ID
	162.5	150.7	169.4	195.8	166.6	284.4	ID	ID	ID	ID	ID
Elongation (%)											
20D	218.5	216.8	173.6	180	204.3	228.4	ID	ID	ID	ID	ID
25D	267.9	84.6	88.9	146.7	135.1	ID	ID	ID	ID	ID	ID
30D	184.7	252.4	188.9	191.9	228.5	240.3	269.1	254.3	ID	ID	ID
35D	226.1	138.9	190.4	227.4	331.8	169.8	230.8	ID	ID	ID	ID
40D	262.4	249.6	277.7	301.1	200.7	129.5	ID	ID	ID	ID	ID

ID= Indeterminate, Exp= Experiment