



## THE USE OF CASTOR OIL AS A FLAME RETARDANT IN POLYURETHANE FOAM

Salisu, A.A.\* and M. D. Said

Department of pure and Industrial Chemistry, Bayero University Kano

\*Corresponding Author: Email: [aasalisu@yahoo.com](mailto:aasalisu@yahoo.com) Tel. +2348065610456

### ABSTRACT

*Thirteen polyurethane foam samples were prepared with varying quantity of castor oil as a reactant with polyisocyanate and their flammability test was carried out using various flame test procedures. Physical properties of the foam samples were found to increase with the increasing in the quantity of castor oil. Results of flammability test shows that the flame propagation rate and the after-glow time are relatively reduced with the corresponding increase in the quantity of castor oil. The add-on test and the ignition time increases with increase in the quantity of castor oil as flame retardant. Foam with 8cm<sup>3</sup> and 10cm<sup>3</sup> quantity of castor oil as flame retardant seems to be perfect and required for good quality and quantity of polyurethane foam.*

**Keywords:** Castor oil, Polyurethane forms, Flame retardant. Polyol, Polyisocyanate

### INTRODUCTION

For many years polyurethane foam have been prepared from castor oil polyol and are characterized by their excellent stability, shock absorbance and electrical insulating properties (Mutaqqa, 2003). Hence, the possibility of halogenated compound serves as the bases for the flame retardant properties in polyurethane foams (Greyson 1980). Polyurethanes are prepared by the reaction of polyhydroxy containing materials such as castor oil with poly functional isocyanates. Urethanes prepared from castor oil based polyol are characterized by their excellent hydrolytic stability, shock absorbance and electrical insulating properties (Mutaqqa, 2003).

Castor oil and polyol derivatives have been found to be very useful in the preparation of rigid, semi-rigid and flexible urethane foams that are resistant to moisture and shock absorbing and have good low temperature flexible (Mutaqqa, 2003). Brominated castor oil has been investigated as a modifier for preparing flame retardant foam (Ward, 1955).

Generally, there are two types of flame retardants, reactive flame retardants, which are reactive components chemically built into a polymer molecule and additive flame retardants which are incorporated in to the polymer either prior to the formation of the polymer or on the process of polymerization (Ward, 1955). They are also classified by different types, including liquid, powder, reactive; nonreactive, radical scavengers, char-forming, non calorific additives and incorporation of more thermally stable linkages such as the isocyanurate linkage (Ashida, 2007).

An ideal flame retardant should be readily available and not dangerous to users. It should also have good penetrating power and should be colourless and odourless (Greyson, 1980). It also suppose to be positively active and of substantial stability (Desch, 1973). To limit the establishment of this combustion circle several techniques are available and among the techniques is the use of flame retardant. Flame retardant help to suppress the combustion process depending on the polymer and the fire safety test (Desch, 1973).

Flame retarding agent either cooled, the burning material below its ignition point or exclude air by forming a blanket of inert gas. It also interferes with one or several stages of the combustion process which include heating, decomposition, ignition, flame spread and smoke process (Garba and Madueke., 1997). Flame retardant can act chemically or physically in the condensed phase and in the gas phase. However, both of them occur during complex processes with many simultaneous reactions.

The first systematic study of the use and mechanism of the fire retardants was published by Gay-Lussac in 1921. Several workers made use of flame retardant in various kinds of materials such as wood, various plastics, polyurethane etc. Wyld (1935) and co-workers was the first to attempt applying flame retardant to cellulosic fabric for a fire retardant mixture consisting of alum ferrous sulphate and borax. Garba *et al.* (1995) ascertained flame retardancy in selected tropical construction materials. The thermal characteristics of the material were drastically reduced (Garba *et al.*, 1995). In 1994 Ahmed carried out flame retardant treatment using fire fighting clothing material. Also in 1995 Garba and co-workers made use of sodium bromide and ammonium hydrogen carbonate to retard fire on hard board. Also reactive flame retardants including halogen-containing alkylene oxide-based polyols were reported (Ashida, 2006). Good examples are trichlorobutylene oxide, phosphorous polyol and also hydroxyl-containing low-molecular-weight phosphates are available in the market.

In this paper a series of polyurethane foams were prepared using castor oil and polyol, and the efficiency of castor oil as a flame retardant in polyurethane foam was investigated.

### MATERIALS AND METHODS

#### Materials

Silicon oil (Acros), polyisocyanate (BDH), stannous octanoate (Fisher), methylene chloride (Fisher), Toluene (Acros) and Castor oil (Aldrich) were used directly as received without further purification.

**Preparation of polyurethane foam using Castor oil**

The application of castor oil in polyurethane foam involves a direct reaction between polyol, castor oil, and other reagents necessary for the formation of polyurethane foam as shown in Table 1. The blank foam (BK) was prepared without the castor oil while

F<sub>0.1</sub>, F<sub>0.2</sub>, F<sub>0.4</sub>....F<sub>10</sub> were the foams prepared from different quantity of castor oil as 0.00, 0.10, 0.20, 0.40, 0.60, 0.8, 1.0 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0cm<sup>3</sup> respectively. The volume of the reagent used is given in Table 1, below

**Table 1: Formulation for polyurethane foams (Volume in cm<sup>3</sup>)**

Foam	BK	F <sub>0.1</sub>	F <sub>0.2</sub>	F <sub>0.4</sub>	F <sub>0.6</sub>	F <sub>0.8</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	F <sub>4</sub>	F <sub>5</sub>	F <sub>6</sub>	F <sub>8</sub>	F <sub>10</sub>
Polyol	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Castor oil	0.00	0.10	0.20	0.40	0.60	0.80	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0
Silicon oil	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Stannuos octanoate	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
MethyleneChloride	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Toluene	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Water	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

**Testing for the flame retardancy****Determination of Ignition time**

Ignition time here simply means the time taken for the foam to catch fire. The foam sample (10cm length) was clamped vertically at a distance of 2.0cm from the lighter and the time taken for the foam to catch fire was recorded.

**Determination of Flame propagation rate**

The foam was cut into strip clamped vertically on a stand and then ignited at the base. The distance travelled by the flame from ignition to extinction is then timed and divided by the time taken for the flame propagation.

$$\text{Flame Propagation} = \frac{\text{Distance travelled by the flame (cm)}}{\text{Time taken (s)}}$$

**Determination of after glow time**

After glow time was determined by noting the time between the flame out and the last visually glow, time was recorded in seconds. All flammability procedures are in accordance with ASTM D-3014 as adopted by Garba (1995) and Ashida (2006).

**RESULTS AND DISCUSSION**

Physical test such as height, weight, texture, shrinkage, compression and colour of the foam samples were carried out on the effect of the flame retardant properties of castor oil in polyurethane foam. The height and the weight of the foam were found to increase with the increasing concentration of castor oil. In the shrinkage test, the blank sample F<sub>0.0</sub>, F<sub>0.6</sub>, and F<sub>2</sub> were observed to show less shrinkage in

shape. Samples F<sub>0.1</sub>, F<sub>0.2</sub>, F<sub>0.4</sub>, F<sub>0.8</sub>, F<sub>1</sub>, F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub>, F<sub>8</sub> and F<sub>10</sub> exhibit no shrinkage in shape while, F<sub>6</sub> exhibited maximum shrinkage in shape. In the compression test, the blank sample F<sub>0.0</sub> and F<sub>6</sub> were found to be less compressible. Sample F<sub>0.1</sub>, F<sub>0.2</sub>, F<sub>0.4</sub>, F<sub>0.8</sub>, F<sub>2</sub>, F<sub>3</sub>, F<sub>4</sub>, F<sub>5</sub> and F<sub>8</sub> were compressible, and F<sub>0.6</sub>, F<sub>0.8</sub> and F<sub>10</sub> were highly compressible. Textures of the samples F<sub>0.0</sub>, F<sub>0.1</sub>, F<sub>4</sub> and F<sub>5</sub> were found to be soft. Samples F<sub>0.2</sub>, F<sub>0.4</sub>, F<sub>3</sub> and F<sub>10</sub> are slightly soft in texture. F<sub>0.8</sub>, F<sub>2</sub> and F<sub>6</sub> are rigid and smooth while, F<sub>0.6</sub>, F<sub>1</sub>, F<sub>2</sub> and F<sub>8</sub> are rigid in texture. All the samples F<sub>0.0</sub> to F<sub>10</sub> were white in colour.

Result of the effect of add-on shows that the weight of the foam increases with the corresponding weight of the castor oil added in the foam (Fig 1). This test involves the addition of castor oil as a flame retardant chemical while producing the foam. To determine the percentage add-on test: The weight of the form with castor oil was subtracted from the weight of the foam without castor oil (blank foam) and the percentage add-on test was determined.

$$\text{Add on \%} = \frac{w_a - w_b}{w_b} \times 100$$

Where W<sub>a</sub> = Weight of the foam containing castor oil

W<sub>b</sub> = weight of the foam without castor oil

From Fig 2 above it is evident the ignition time or the time taken for the foam to catch fire (Ignition time) increases due to the increase in the quantity of castor oil as a flame retardant in accordance with Carr, 2005.

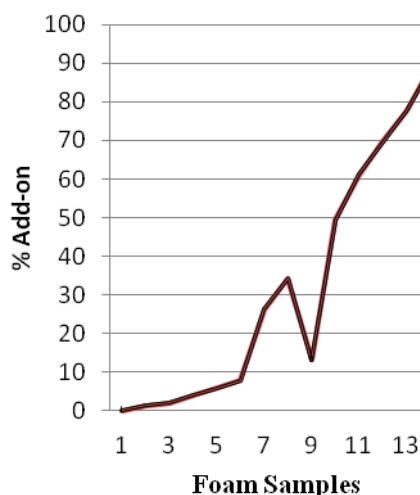


Fig 1: Effect of flame retardant on add-on test

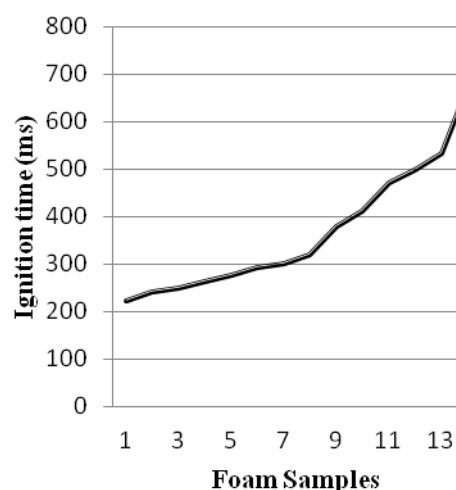


Fig 2: Effect of flame retardant on ignition time

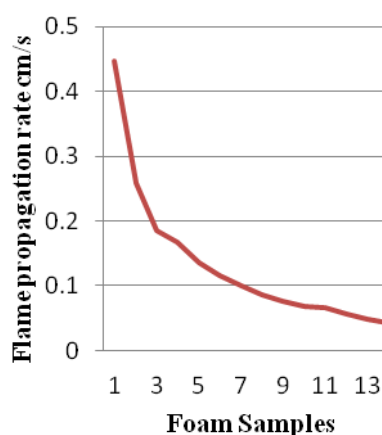


Fig 3: Flame Propagation (cm/s)

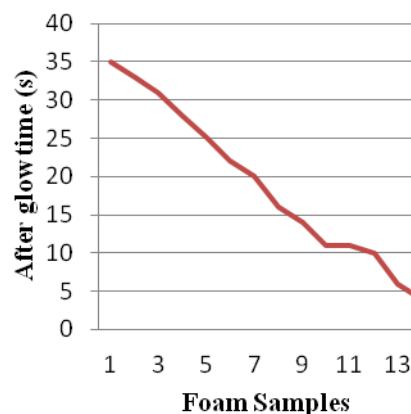


Fig 4: Effect of flame retardant on after glow time

The flame propagation rate shown in Fig 3 and its strongly proved the efficiency of castor oil as flame retardant by moderately reducing the distance travelled by the flame from ignition to extinction. This shows a property of good flame retardant chemical (Wyld, 1947). Flame propagation rate means the distance travelled by the flame from the ignition to extinction. Fig 4 shows that the amount of castor oil used as flame retardant reduces the after-glow time for the foam experimented. Glow is a heterogeneous oxidative surface reaction which depends on 'Burn' material and oxygen available (Williams and Emmanuel, 1973). To provide a very good and qualitative product it can be deduced from the analysis conducted that foam samples with 2cm<sup>3</sup>, 3cm<sup>3</sup>, 4cm<sup>3</sup> and 5cm<sup>3</sup> quantity of castor oil as a flame retardant have moderate effect on the polyurethane foam and

foam with 8cm<sup>3</sup> and 10cm<sup>3</sup> quantity of castor oil as flame retardant seems to be perfect and required for good quality and quantity of polyurethane foam.

#### CONCLUSION

Castor oil can be use in the industries as a flame retardant and even performed better than the commonly used flame retardant. Incorporation of castor oil into polyurethane foam shows that the flame propagation rate and the after-glow time are relatively reduced with the corresponding increase in the quantity of castor oil. On the other hand, the add-on test and the ignition time increases with increase in the quantity of castor oil as flame retardant. The thermal properties of polyurethane foam can be modified and controlled by the castor oil as flame retardant.

#### REFERENCES

Ashida K. (2007): Polyurethanes and related foams: Chemistry and Technology, *Taylor and Frances*, 1, 43-46.

Carr, M. (2005): Chemistry of the textiles industry Edited by, *Blackie academic professionals* 2, 115.

- Desch, H. E. (1973): Timber; Its structure, properties and utilization, *MacMillan Press London* **2**, 295-300.
- Garba B., Abdulrahman F. W. and Obaseki M. E. (1996): Effect of sodium hydrogen carbonate and sodium bromide on the flammability of hard board, *Fire and Materials* **20**, 297-298
- Garba B., Abdulrahman F. W. and Obaseki M. E. (1995): Effect of some halogenated flame retardant on the thermal characteristics of some selected tropical construction materials, *Intern. Poly. Mat.* **19**, 19.
- Garba, B. and Madueke, A. A. (1997): Mechanistic study of sodium tetraborate decahydrate as flame suppressant for wool and cellulose, *Intern. Poly. Mater.* **21**. 1-5
- Greyson, M. (1980): Kirth-Othmer encyclopedia of chemical technology **10**, 3<sup>rd</sup> Edn. *Wiley and Sons, New York*, **10**, 242-256.
- <http://www.inchem.org/document/ehc/192.htm>, flame retardants (ECH192, 1997) Browsed date on 8/3/2010.
- Muttaqa (2003): Effect of flame retardant on polymeric materials, *J. Flame retard Mat.* **2**, 235-246
- Ward F. (1955): Textile research Journal of Soc. Dyes & Colourist, [www.rsc.org/delivery/article](http://www.rsc.org/delivery/article) browsed date on 8/3/2010
- William D. H. and Emmanuel F. (1973): Collter Encyclopeadia, Macmillan, *New York, Voller Inc London* **9**, 746.
- Wyld B. (1947): Reactive flame retardant for polyererthane forms, *J. flame retard. Commer.* **23**, (3), 551