

Original Research Article**The Effect of *Sterculia setigera* Bark Extract on the Flammability of Flexible Polyurethane Foam****ABSTRACT**

Due to the health and environmental problems caused by conventional flame retardants the search for alternative flame retardants cannot be overemphasized. This led to the selection of the bark of *Sterculia setigera* for their flame retardant properties on flexible polyurethane foam based on hausa folklore tradition and other research conducted which revealed that modification of the flammability characteristics of the treated flexible polyurethane foam was achieved based on add on % which ranged from 9-20 %, Ignition time from 3-7 seconds, flame propagation rate from 0.70-0.60cm/s, after glow time from 6-2 seconds and char formation which ranged from 36-39 %.

Keywords: Flame retardants, Polyurethane, Add on, Ignition time, Flame propagation rate, After glow, Char

INTRODUCTION

Humans have always been plagued by unwanted fires, therefore it is not surprising that considerable efforts had been expended to investigate what makes objects burn, as well as how the flammability of materials could be controlled¹. The method by which the flammability of polymers can be reduced by chemical means is of long-standing importance and has engaged the minds of scientists since the time of alchemy and the Roman era². At the siege of Piraeus in 83 BC, for example, the wooden storming towers used, were fire-retarded by treatment with alum. The ancient Egyptians also extensively practiced fire

retardancy of cotton fabrics. The early scientists tried a variety of concoctions with the result that by the 19th century, enough knowledge had accumulated to enable Gay Lussac to make a systematic study of the phenomenon and to formulate theories². These theories have since been widely accepted as laying the foundation for the understanding of the mechanism of flame retardancy in polymers. The first recorded effort at applying flame retardants to cellulose was in 1735 when a British patent was granted to Jonnathan Wyld for a flame retardant mixture consisting of borax, alum and sulphates^{3,4}. Since then so much has been known that the burning behaviour of certain textile materials, papers, plastics and even timbers have been extensively investigated and documented. Nonetheless, it is necessary to state here that it is impossible to make such polymers as celluloses and the plastics completely flame-proof and still retain their advantageous qualities. In fact, for all polymers, it may require an exceptional ingenuity on the part of chemists to obtain the desired safety level and at the same time maintain the fundamental properties of the parent polymer. In most cases, flame retardant treatments aim at a compromise between safety and functional performance. In this article the effect of treating some flexible polyurethane foam materials with the extract of the bark of *Sterculia setigera* as flame retardant formulation is presented.

Sterculia setigera is a savanna tree. It is wide spread in the savanna area of tropical Africa, often characteristic of stony hills. It is deciduous, grows up to 12m high and 15m in girth. The bark is pale purplish, smooth with scales which when peeled off expose yellowish patches, exuding gummy sap. The 3-lobed leaves, 6-20 cm are broad and long, broadly ovate and densely pubescent on both surfaces. Flowers are borne in small inflorescence in the previous years shoots. The fruits are composed of 4 or 5 boat shaped carpels, which split to reveal about 12 slate coloured seeds, 10-15mm long⁵. It is used in the treatment of asthma, bronchitis, cough, wound, boils, fever, cancer and dysentery. It is also

54 used as a flame retardant⁶. It is used in the treatment of diarrhoea⁷. According to
 55 Hausa folklore tradition it is used as a flame retardant.

56 The aim of this study is to develop novel plant based fire retardant for flexible
 57 polyurethane foam that is free from the shortcomings of the conventional flame
 58 retardants.

59 **EXPERIMENTAL**

60 **Materials:**

61 **Sample Collection and Identification**

62 Representative samples were obtained from the bulk sample. The bark of
 63 *Sterculia setigera* were procured from Sokoto market. The samples were
 64 transported to Chemistry laboratory at Usmanu Danfodiyo University, Sokoto in
 65 large paper bags. The samples were identified and authenticated at the
 66 Herbarium of the Botany unit, Usmanu Danfodiyo University, Sokoto, Nigeria.

67 The polyurethane foam materials which comprised of Polyol, Toluene
 68 diisocyanate (TDI), Methylene Chloride, Dimethylethylamine, Tin (II) Isooctoate
 69 and Silicon Oil were obtained from Concord Foam and Allied Chemicals
 70 Ltd opposite Sa'ad Petrol Station along western bye pass and Latex Foam
 71 Company in Rinjin Sambo industrial layout, all in Sokoto.

72

73 **METHOD**

74 **Preliminary Sample Treatment**

75 One (1) kg of the plant material was thoroughly washed with clean water, dried at
 76 room temperature and then powdered using a grinder. A sample (200g) of the

powdered plant material was soaked in water(200ml) for 48 hours.At the end of the extraction the extract was filtered using Whatman filter paper.The filtrate was concentrated to dryness in an oven at 70⁰C and stored until further use^{6,7}

Sample Preparation

(a) Preliminary Screening of Fire Retardant Plants

Preliminary screening of the plant bark extract for flame retardancy was done by soaking the extract of this plant in commercial polyurethane foam obtained from Latex Foam Factory and it's efficacy tested. Flame retardant activity was observed which prompted the final selection of this extract as a flame retardant in flexible polyurethane foam

(b) Flexible Polyurethane Foam Preparation

Flexible polyurethane foam was produced by mixing the TDI (2.5ml) with the mixture of the polyol(12ml), tin(II) isooctaoate(0.1ml),silicon oil(0.2ml),distilled water(0.5ml) and dimethylethanalamine(0.1ml).The mixture was thoroughly mixed with a glass stirrer to get a good dispersion of the reagents so as to get a foam which will be used as a blank sample in the experiment⁴.

(c) Incorporation of the Plant Extract in the Foam Production

Five series of different concentration (0.2, 0.4, 0.6, 0.8,1.0 g) of the plant extract (dried) were measured and incorporated into the above formulation as a monomer.The resultant foams produced were left to cure for 48 hours in order to get a foam of good cell structure.

Analysis

(a) Addon %

100 The method adopted was the one in which the flexible polyurethane foams
101 produced after inoculation with the flame retardant was weighed and the one
102 without flame retardant was also weighed and the difference divided by the
103 weight of the untreated foam multiplied by 100. The same dimension was used for
104 all the samples, that is, $2\text{cm} \times 2\text{cm} \times 5\text{cm}$ ^{3,8}

105 (b) **AfterGlowTime**

106 The after glow times were calculated using a stop watch to find out the time in
107 seconds between the time the flame extinguished and the time the material
108 stopped glowing^{3,8}.

109 (c) **Flame Propagation Rate**

110 The time in seconds it takes the fire after being ignited to travel across the
111 substrate were recorded and the flame propagation rate were calculated by
112 dividing the the distance which was 5cm by the time obtained using a stop watch
113 clock^{3,8}.

114 (d) **IgnitionTime**

115 The methodology adopted to find out the ignition time was achieved by recording
116 the time in seconds after the Bunsen burner flame stroke the sample surface to
117 the time when the sample caught fire^{3,8}.

118

119 (e) **CharFormation**

120 The methodology below was adopted to ascertain the amount of char formed
121 This was done by first crushing the sample in a crucible and weighing the
122 content. It was then put in an electrically heated muffle furnace at 700°C for 20

minutes and weighing the samples. It was calculated by dividing the weight of the material after burning by the weight of the material before burning multiplied by 100^{3,8}.

RESULTS AND DISCUSSION

Result

The results of the various tests conducted are shown below from figure 1 to 5. These are add on %, ignition time, flame propagation rate, after glow time and char formation.

Discussion

The incorporation of flame retardant into a flexible polyurethane foam formulation can result to some extent in combustion modified urethane foams⁹. Addition of a flame retardant may also alter the rise time of the flexible polyurethane foam depending on the flame retardant type and the amount of the flame retardant used⁹. Furthermore, concentration of *Sterculia setigera* bark extracts does not affect the rise time of the foams.

From Figure 1 *Sterculia setigera* bark extract showed a moderate add on %. The lowest add on was 9% and the highest was 20%. It was observed that add on depended on the dope concentration of the flame retardant material and the specific gravity of the material. It is the amount of the flame retardant material imbibed by the substrate⁸. The result showed that add on % increases as the concentration of the dope increases in all the foams. This is in agreement with the cited literature⁴ because they follow the same pattern despite the fact

145 that the result varies⁸ which could be due to the difference in the dope
146 concentration of the flame retardants used in both cases.

147 Figure 2 depicted the ignition time of the extract. It had low ignition time yet it is
148 higher than the blank sample. The lowest ignition time recorded in the series was
149 3 seconds and the highest was 7 seconds while that of the blank sample was 1
150 second. According to Ashida (2007) among the isocyanate based foams,
151 polyurethane both flexible and rigid are more inherently flammable, thus,
152 increasing the ignition time, that is, the time before the foam is ignited is
153 important. Moreover, the ignition time increases as the dope concentration
154 increases in the subsequent concentrations. This is in concert with Ike, (2011).

155 Figure 3 showed the flame propagation rate of the sample analysed. It had low
156 flame propagation rate. The highest flame propagation rate recorded was 0.60
157 cm/s and the lowest was 0.70 cm/s while that of the blank sample was 0.98 cm/s
158 indicating some flame retarding activity. There was also a decrease in the
159 flammability resistance then an increase, finally decreasing as shown in the
160 graph above. The spread of a flame along a substrate takes place in the
161 following manner; piloted or radiant heat raises the temperature of the
162 material to pyrolysis level. The resultant volatile and combustible pyrolysates
163 ignite at the right air or oxygen concentration. Some of the exothermic heat of
164 combustion is lost to the surrounding while some parts are re-channelled back
165 for further pyrolysis of the substrate, hence, combustion is sustained. The rate
166 of this pyrolysis or combustion scheme along the substrate determines the rate of
167 flame propagation⁸.

168 The flame propagation rate is inversely proportional to flammability resistance of
 169 foams. If the flame propagation rate is increasing the flammability resistance is
 170 decreasing and vice versa. This assertion is true for the extract as the flame
 171 propagation rate decreases as the dope concentration increases along the
 172 series despite the fact that it burns vigorously with scattering of the burning
 173 material. The blank sample burn while dripping the burning portion continuously.
 174 Figure 4 showed the after glow times for the extract analysed. *Sterculia setigera*
 175 bark extract had an excellent after glow time. The lowest after glow time was 2
 176 seconds and the highest was 6 seconds while the blank sample took 30 seconds
 177 before the glowing stopped Glow is a heterogeneous oxidative surface reaction
 178 and depends on the amount of burnt material and oxygen available^{3,8}.
 179 Therefore, it can be seen that the treatment decreases the after glow time as you
 180 go up the series. For all the materials investigated, there are definite after glow
 181 times.

182 Finally, figure 5 showed the char % of *Sterculia setigera* bark extract. It has a
 183 good char forming ability. The lowest char formation was 36% and the highest
 184 was 39%. The char formed by the blank sample was 10%. The char percentage
 185 increase initially as you go up the series then decrease and increasing again as
 186 you go along the series. Char formation is the formation of an impervious
 187 layer between the burning and the unburned part turning the material into a
 188 carboneaceous char. The formation of an insulating barrier between these
 189 parts is brought about by dehydrating agents or char forming agents which
 190 hinder heat transfer to unburned parts thereby reducing the reaction rate.

The difference in char percentage between the cited literature⁴ and the present work is significant although it is higher than the blank sample which may indicate that the sample analysed has char forming ability.

CONCLUSION

The thermal properties of flexible polyurethane foam were modified by the controlled addition of *Sterculia setigera* bark extract. Therefore, it is envisaged that the devastation caused by fire on flexible polyurethane foam treated with *Sterculia setigera* bark extract could be reduced. From figure 1 to 5, the result showed the effect of this treatment was more pronounced in after glow and char formation which may indicate condensed phase mechanism.

Flame suppressant treatment is aimed at delaying the spontaneous spread of the fire when it does occur, such that reasonable lives and properties may be saved.

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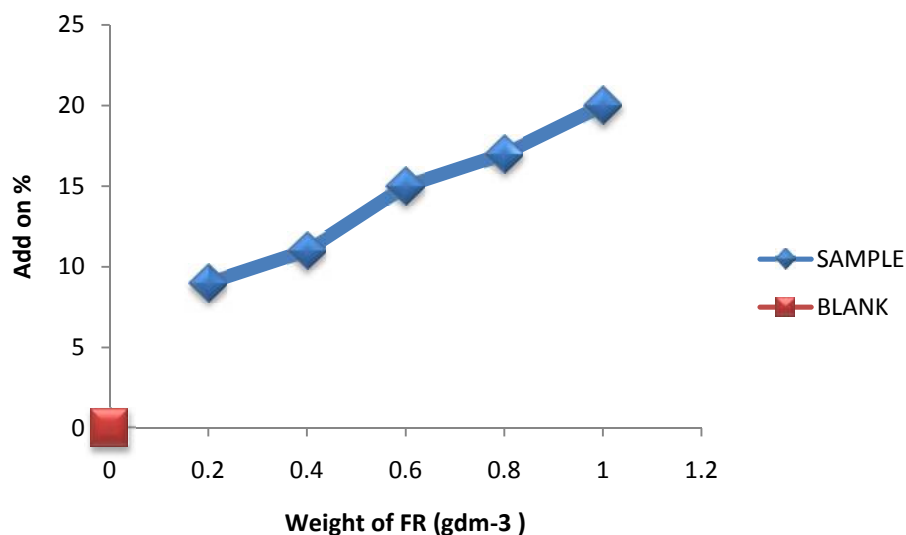
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231 **Figure 1: Effect of Concentration on Add on.**

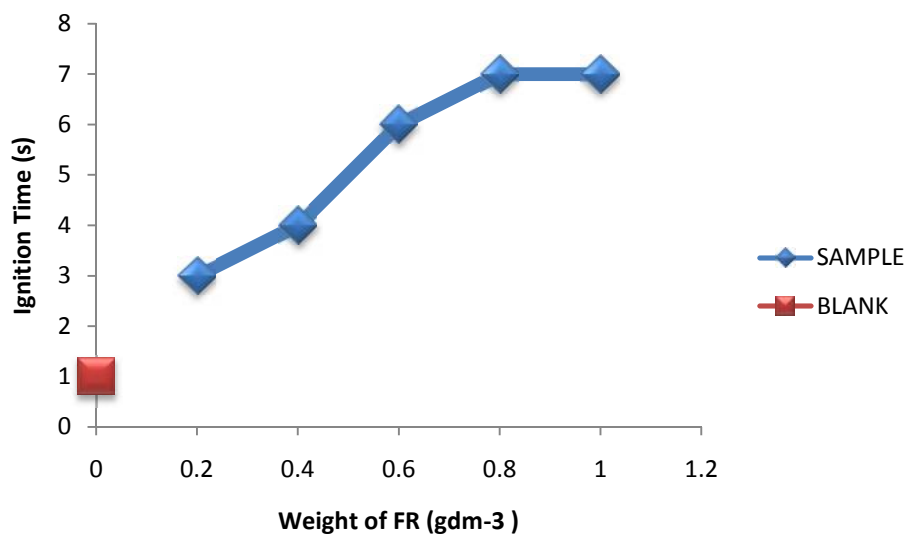


Figure 2: Effect of Concentration on Ignition Time.

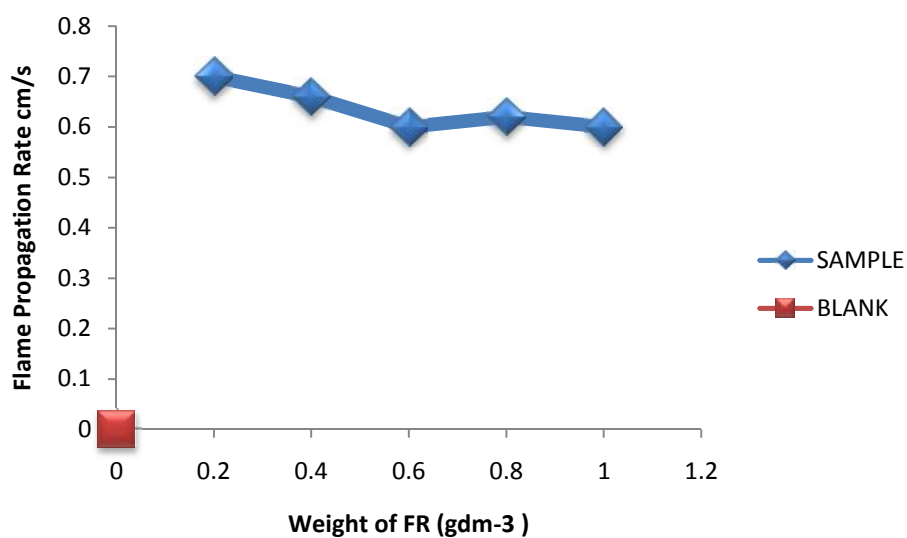
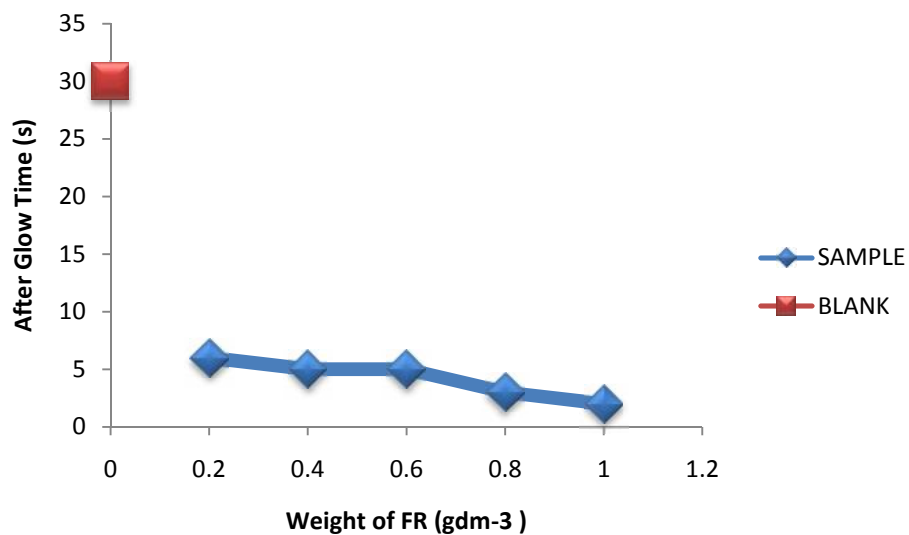
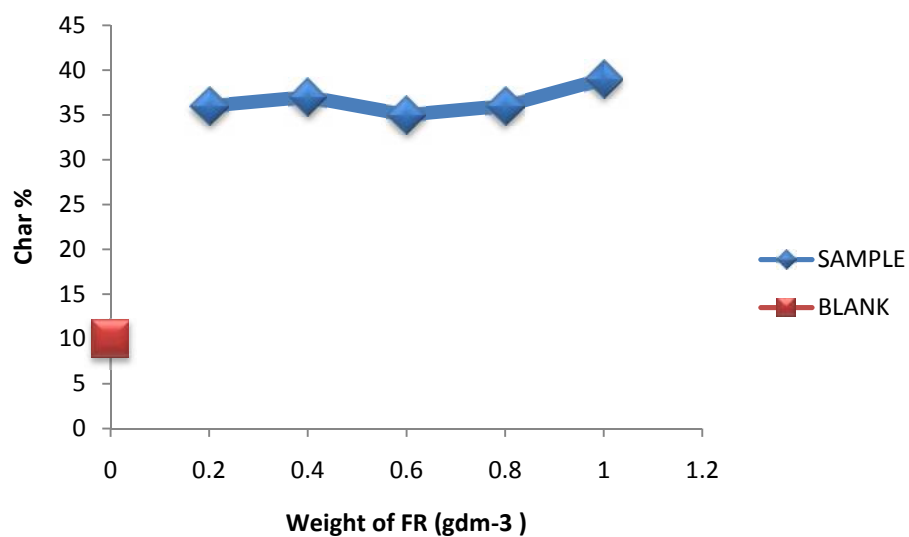


Figure 3: Effect of Concentration on Flame Propagation Rate



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239 **Figure 4: Effect of Concentration on After Glow Time**



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241 **Figure 5: Effect of Concentration on Char %**

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