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EFFECTS OF MIXED ORGANIC MATERIALS AS FILLER ON THE PHYSICO-MECHANICAL PROPERTIES OF FLEXIBLE POLYETHER FOAM

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ABSTRACT
This work investigated the effects of some organic materials (rice husk and spear grass) as fillers in flexible polyether foam. The mixture of rice husk and spear grass pulverised into particle sizes of 100µm respectively were obtained in the ratio of 50:50. Varying loads of the mixed fillers ranging from 10%, 20%, 30% to 40% were mixed with polyether recipes in the appropriate foam formulations. The physico-mechanical tests carried out on the samples showed variations in the properties such as density, compression set, elongation at break, hardness, tensile strength and thermal conductivity as compared with the unfilled foam. The results showed that the densities, compression set, hardness of the samples increased with increase in filler load. The result of the tensile strength showed a better reinforcing property when compared with the unfilled sample, though, the values decreased as the filler load increased with 10% filler load having the highest value and 40% the least value. In all, the 30% and 40% filler load of the foam samples showed better reinforcing properties than the unfilled used as standard. It was observed from the result of the thermal conductivity that there was a decrease in its value as the filler load increased, which means a reduction in the flammability property of polyurethane foam, thus, can serve as fire retardant. These fillers can be used in the production of polyurethane foams since they are organic materials, thus they can enhance the mechanical properties and biodegradability of polyurethane products and be used also as flame retardants. The use of these fillers in polymer composites will help to sanitizing the environment by reducing landfills and producing eco-friendly wastes.

KEYWORDS: *Mechanical properties, biodegradability, thermal conductivity, filler, polyether foam*

INTRODUCTION
The versatility of polyurethane chemistry permits the production of a great variety of materials such depending on the initial ingredients used in the synthesis. Flexible polyurethane foams are one of the most important classes of cellular plastic and can be applied in the fabrication of a wide range of materials for different uses such as foam mattresses, pillows, furniture, cushioning materials for automobiles, packing, recreation, shoes, etc. [15]. They are major consumer plastic materials with an annual production capacity of nearly 12 million tons [3]. The distribution of various polyurethanes used was as follows: 29% rigid foams, 37% flexible foams, 12% elastomers, 12% coatings [13] and 10% polyurethane fibers used for lightweight foundation garments, swimsuits, shoulder pads [5].

In general, industries that produce flexible polyurethane foams use fillers such as calcium trioxocarbonate (IV), kaolin and talc to modify the material's properties in some way, such as: dimensional stability, retraction from the mould and density [12, 4]. The effect of filler on the properties of the foam depends on the factors such as surface area, porosity, bulkiness and surface chemistry. Filler makes an impact from the materials that are added to polymer formulation to lower the cost or to improve its properties [11].

In principle, any material can be used as filler. However, some aspects must be considered when selecting the material for this purpose. These include size, in that the particles must be small and able to easily disperse in the polymer matrix, chemical purity, to avoid undesired reactions; and abrasiveness, which can cause excessive deterioration to the mixing equipment and increase costs [7].

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Thus, this study harnessed the use of some organic materials as fillers and their effects on the physico-mechanical properties of flexible polyether polyurethane foam.

MATERIALS AND METHODS

Sample Collection

The foam recipes used for the production of the foam samples were obtained from Vita Foam Nigeria Plc (RC -3094), Ikeja, Lagos State, while the fillers (rice husks and spear grass) were sourced from two different places. The rice husk was sourced locally from the Eziulo Rice Mill, Abakaliki, Ebonyi State, and the spear grass was obtained from Ibeagwa Express, Abakpa Nike, Enugu, Enugu State, Nigeria.

Preparation of Materials

The fillers which were collected in different axes were washed and sundried. The dried samples were pulverised using electrical grinder into soft powder. Then was sieved using hand sieve with mesh number equivalent to 100μm rice husk and spear grass respectively and stored in polyethene bags.

Foam Formulation

This simply refers to the list of chemicals/materials and their relative quantity to be used in the preparation of foam. This is obtained based on the chosen density and other properties of the desired foam. The table 1 shows the formulation of various chemicals/materials used in this work.

Table 1: Foam Formulation

Materials	Pph	S1	S2	S3	S4	S5	S6
Polyol	300	600	600	600	600	600	600
TD1	165	330	330	330	330	330	330
Amine	1	2	2	2	2	2	2
Stannous	0.5	2	1	1	1	1	1
Silicone oil	2.5	5	5	5	5	5	5
Water	14	28	28	28	28	28	28
Filler%	Varies	0	10	20	30	40	50

Note: Pph = Part per hundred, S1-S6 = Samples 1, 2, 3, 4, 5 and 6.

Preparation of Flexible Polyether Foam

Polyether polyol and the mixed fillers were placed in a plastic container, and the mixture was stirred until complete homogenization. Then, amine, surfactant and water were added. The mixture was subjected to mechanical stirring for one minute. Shortly, after the catalyst was added; the mixture was stirred again for 30 seconds. After introducing toluene diisocyanate, TDI, the mixture was subjected to ten seconds of stirring and then poured into a cubical cardboard box (8 x 8x 8 cm). The foams were left to cure for three days before testing. The measurements of these materials were all based on parts per hundred of polyol [8].

Characterization of the Foam Samples

The following mechanical properties of the foam samples were determined using standard methods: density,[6], while tensile strength, elongation at break, compression strength and hardness test were measured according to the ASTM-D standard specifications [2].

RESULTS AND DISCUSSION

The results of the physico-mechanical properties of the foam samples were observed. The particle size of filler has a dominating effect on tensile strength and other properties. Fillers become increasingly reinforcing as their particle size decreases in order to enable a large surface area for the polymer matrix-filler interaction.

Density

The densities of the foam samples produced were obtained by cutting the foam samples into specific measurement of sizes and weighed individually.

Table 2: Effect of filler load on density of the foam samples

Filler (%)	Filler Load (g)	Vol (Lx BxH) (m^3)	Weight (kg)	Density (kg/m^3)
0	0	0.181 x 0.18 x 0.066	0.04786	22.26
10	40	0.181 x 0.18 x 0.066	0.04699	21.86
20	80	0.181 x 0.18 x 0.066	0.05827	27.10
30	120	0.181 x 0.18 x 0.066	0.06749	31.39
40	160	0.181 x 0.18 x 0.066	0.06871	31.96

It was observed from Table 2 that the density increases as the filler load increases. From the 20% filled foam sample, the density increased steadily with increasing filler load as when compared to the unfilled foam. The higher values could be attributed to the fibrous nature of the fillers and hence a good reinforcing property. This is in agreement with some other researchers [12,13].

Compression Set

The result of the compression set revealed that as the filler load increased, the compression set also increased, as shown in Table 3. This means that the foam sample would easily reagain its original height after a large weight is lifted from the foam. This is one of the qualities of good and durable foams. This could be attributed to the improved mechanical property displayed by the fillers. The fillers are all cellulosic materials and their reinforcing ability is therefore the load-carrying component in the produced foam samples. This also agrees with other authors [14].

Table 3: Effect of filler load on the compression set of the foam samples

Filler (%)	Filler load (g)	Compression set (%)
0	0	3.8
10	40	8.0
20	80	12.0
30	120	30.8
40	160	48.0

Tensile Strength

The results of the effect of the fillers on the tensile strength of the flexible polyether foam sample are as shown in Table 4. The fillers exhibited its reinforcing properties by showing high values from 10% to 30% filler load than the unfilled foam. Rather it was observed that the tensile strength decreases as the filler load increases, but this decrease is higher than the unfilled foam except at 40% filler load where a sharp decrease was seen. This implies that the load bearing capacity of the foam is higher for the test filler than that of unfilled foam sample.

Table 4: Effect of filler load on tensile strength of the foam samples

Filler (%)	Filler load (g)	Tensile strength (MPa)
0	0	121.86
10	40	152.13
20	80	141.26
30	120	133.16
40	160	119.63

Elongation at Break

The fillers showed a remarkable increase in the elongation at break. Though, the increment was seen to decrease as the filler load increased but in all it was far above the value for the unfilled foam sample. This could be attributed to good filler-polymer interaction. This is as shown in the Table 5.

Table 5: Effect of filler load on elongation at break of the foam samples

Filler (%)	Filler load (g)	Elongation at break
0	0	164.20
10	40	220.72
20	80	203.21
30	120	192.86
40	160	179.86

Hardness Test (Indentation Force Deflection)

It was observed from the Table 6 below that an increase in the filler ratio, leads to an increase in the hardness of the foam sample. This means that the filler impacted a hard effect on the foam and would carry a lot of weight over a long period of time without collapsing immediately. Hence, the fillers have improved the hardness of the foam due to their fibrous nature.

The 65% IFD is indicative of the foam hardness and characterizes the foam support to a seated adult. Table 6 shows that the 65% IFD is influenced both by the main effects of volume fraction and particle size as well as the interactions between these variations [13].

Table 6: Effect of filler load on IDF of the foam samples

Filler (%)	Filler (g)	25%	40%	65%	Support factor 65/25 IFD
0	0	134.6	153.1	212.3	1.6
10	40	85.6	97.6	145.8	1.0
20	80	85.1	113.9	214.7	2.5
30	120	94.5	128.3	207.1	2.2
40	160	80.6	104.5	241.9	3.0

Thermal Conductivity

The result of the thermal conductivity revealed that as the percentage of the filler load increased, the thermal conductivity decreased as seen in Table 7. The implication of the decreasing thermal conductivity of the produced foam is that, the fillers will help to reduce the flammability of the foam, that is, the fillers seemed to have some extinguishing fire properties; and can be used as flame retardants in polyurethane production.

Table 7: Effect of filler load on thermal conductivity of the foam samples

Filler (%)	Filler load (g)	Thermal conductivity ($Jcm^{-1}S^{-1}K^{-1}$
0	0	150
10	40	120
20	80	112
30	120	103
40	160	92

CONCLUSION

The results of the effects of the mixture of rice husk and spear grass on the flexible polyether foam samples showed the reinforcing effects of these fillers. The particle size of 100μm was used in the production and the smallness of the particle size provides a larger surface area and hence a large filler-polymer matrix- interaction that the improved mechanical properties of the foam produced

The study showed that 20% test foam sample compared favorably with the control filler used in commercial foam, while 20-30% filler produced foam showed better qualities than that used as standard. This is mostly achieved when it is used in a low concentration.

Thus, the use of rice husks and spear grass as fillers other than inorganic fillers such as calcium trioxocarbonate (IV), $CaCO_3$, in polyether foam can be encouraged as it improves the mechanical properties of foam and reduced the flammability of the produced foam. Thermal conductivity also showed a decrease in its value as the filler increase that means it can serve as a fire retardant. All these properties were compared to a controlled sample.

These materials are completely available, cheap, organic, renewable, eco-friendly and biodegradable; thus can help to reducing the cost of production of polyurethane products and sanitising the environment by eliminating landfills caused by polymer materials.

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