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THE EFFECTS OF ANIMAL WASTES ON THE TENSILE STRENGTH, ELONGATION-AT-BREAK AND HARDNESS OF FLEXIBLE POLYETHER FOAM

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Abstract : This work studies the effects of animal bones on the tensile strength, elongation at break and hardness of flexible polyether foam. Cow and chicken bone powders were characterized, different loads of these powders incorporated in the foam recipes and their properties examined. Particle size distribution of the filler showed 320μm, 180μm, 87μm and 63μm while 63μm was used. AAS and qualitative analyses of the bone samples indicated the presence of Ca^{2+}, Na^{+}, Mg^{2+}, K^{+}, Fe^{2+}, Zn^{2+}, Mn^{2+}, Cu^{2+}, PO_4^{2+} and CO_3^{2+} with cow bone having higher concentrations in the two bone samples, The results of the tensile strength and hardness vary while that of elongation at break decreases with increase in filler load. This work therefore recommends the use of 5% and 10% of cow and chicken bones as good substitutes for 10% $CaCO_3$ used as conventional filler.

Introduction

The conversion of agricultural wastes to industrial raw materials has received great attention. It is only during the last few years that the significance of eco-friendly materials has been realized all over the world to a greater extent [1-3]. There is a continuing need to improve the texture and at the same time lower the prices of flexible polyether foams by the incorporation of a variety of fillers in the foam recipes. The recipes for the production of flexible polyether foams are mostly liquid reagents and chemicals obtained from petrochemicals and agro products [4]. The recipes are polyol, polyisocyanate, blowing agents, surfactants, catalysts and additives such as fillers, antistatic agents etc.

Additive used in this work is filler. Filler, as used in plastic and rubber industries is a finely divided solid material which is added to the liquid, semi-liquid or solid composition to modify the physical properties of the composition and to reduce cost [5]. The common fillers used for

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plastic include clays, silica, diatomaceous earth, asbestos, wood flour, kaolinite as well as various fibres and nut shells [6]. Fillers can be organic such as wood flour, cotton, paper pulp, carbon black while the inorganic fillers asbestos, oxide, lead, copper and alum which are in powdered form [7]. The effect of fillers on the properties of the foam depends on the properties of the fillers such as porosity, surface area bulkiness, surface chemistry etc [8]. Reinforcing fillers are those fillers added to increase the mechanical strength [9,10]. The qualities of reinforced plastics make them useful in spacecraft design and in boat hulls, which are required to withstand marine salt water. Recently, several authors [9,10] have investigated the suitability of agricultural waste as replacement filler for calcium carbonate in the polyurethane industries. The vast applications of foam in virtually all aspect of human activity show the overwhelming importance of the foam samples and its growth in synthetic polymer technology. Today, a number of foam materials are known and are around us in our daily lives, in our homes, vehicles, schools and businesses. The present study is an attempt to provide additional information on the effects of animal wastes on the tensile strength, elongation 'at break and hardness of flexible polyether foam samples.

Experimental

Materials

The fresh cow and chicken bones were obtained from abattoir and Citi Exotic Fast Food Company, No. 39 Afipko Road, all in Abakiliki, Ebonyi State, Nigeria, while the raw materials used for the production of foam were obtained from Winco Foam Nigeria LTD, Awka, Anambra State, Nigeria.

Methods

19.95kg of the cow bone samples were oven dried at 100°C for 24hrs in order to remove the water content. 11.10kg of the bone recovered was crushed in mortar and milled with a manually operated Corona lever Machine, Landers and YCIA S.A. model and sieved. 10.50kg of the oven dried chicken bone was also milled using the same procedure.

Characterization of the filler samples

1. Sieve Analysis

The size distributions of the two bone samples were determined using Gilson Automatic Sieve Tester, SS-15 model attached to the following mesh sizes 320μm, 180μm, 87μm and 63μm.

2. Specific gravity

Specific gravities of the bone samples were measured with air comparison pycnometer method using ASTM D2842.

3. Charring temperature

1.0g of each of the bone samples was placed inside an ignition tube attached to a thermometer (0-360°C). The combustion tube was then clamped on a heating mantle and the char temperature was recorded.

4. Metallic ion analysis

The metallic ion present were analyzed using Buck Scientific AAS 205 model Air acetylene flame type at a flame temperature of 2000°K and flame height of 6mm [11].

5. Anion contents were determined by usual qualitative analysis.

Foam formulation.

Table-1 **:** Cow and chicken bones as filler in foam formulation

Raw Materials	Pph(%)	$CaCO_3$ (g)	Ab_0 (g)	Ab_1 (g)	Ab_2 (g)	Ab_3 (g)	Ab_4 (g)	Ab_5 (g)
Polyol	100	200	200	200	200	200	200	200
Water	4	8	8	8	8	8	8	8
TDI	54.4	108.8	108.8	108.8	108.8	108.8	108.8	108.8
Silicone	0.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Stannous octoate	0.15	0.3	0.3	0.3	0.3	0.3	0.3	0.3
DMEA	0.14	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Mthylene chloride	3.8	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Filler(Cow/ Chicken bone)	Percentage varied	10%	0%	5%	10%	15%	20%	25%

Note: Pph= part per hundred, Ab = Animal bone

Preparation of flexible polyether foam

Cow and chicken bone powder used in the production of foam samples varied from 0%, 5%, 10%, 15%, 20%, and 25% while 10% calcium carbonate used in industry was used as control. Flexible polyether foam samples were produced by batch process as described in a number of articles [12,13].

Characterization of the foam samples

Tensile strength was measured according to the standard specifications and methods as reported earlier [14,15]. Samples for tensile strength tests were cut with a dumb-bell cutter according to BS 903 Part A2 1956D. Instron testing Machine ILAO TIEH Model 4501 was used for measurement of the tensile properties. In measuring the tensile properties of the foam samples, a known length of the foam sample was cut at about 150cm and was marked at 2 points, 50cm apart known as test lines. Both ends of the samples were placed in the grips of the Instron machine and firmly tightened. The Instron was set at zero point and the start button punched. The elongation-at- break also was tested using standard specifications [14] while hardness was studied using standard method [16] and Eseway hardness tester DVRB-M.

Results and Discussion

The results of the particle size determination of the bones indicated that the size distributions are 320μm, 180μm, 87μm and 63μm, while 63μm was used for the production. The particle size of the filler a filler has a dominating effect on a tensile strength and other properties. The smaller the particle sizes the larger the surface area and the more the filler polymer interaction. The physical properties of cow and chicken bone samples are shown in Table-2.

Table-2 : Physical properties of cow and chicken bone samples

Properties	Cow bone	Chicken bone
pH value	6	5
pH colour	yellow	Deep yellow
Specific gravity	0.88	0.79
Charring temperature(°C)	200-216	190-200
Colour	milky	Brown

The cow and chicken bone filler have pH values of 6 and 5 with pH colour of yellow and deep yellow respectively. The results showed that the two bone samples have specific gravity of 0.88 and 0.79 respectively. The charring temperature of the cow bone filler lies between 200-216°C while that of the chicken bone filler lies at the range of 190-200°C which indicated the resistance of the two filler samples to thermal degradation. The cow bone filler has milky colour while the chicken bone filler has light brown, while the mixture of both fillers was light brown in colour which implies that the two bones samples would impact colour on any composite into which they are incorporated. The results of compositions of the ions in the bone samples are shown in Table-3.

Table-3 : Compositions of ions in cow and chicken bone samples

Ion	Cow bone g/dm^3	Chicken bone g/dm^3
Ca^{2+}	80.654	78.039
Mg^{2+}	7.302	7.304
K^+	2.434	1.495
Na^+	9.804	7.833
Fe^{2+}	0.30930	0.38499
Zn^{2+}	0.15025	0.28608
Mn^{2+}	0.09188	0.06688
Cu^{2+}	0.00926	0.00707
PO_4^{3-}	0.0005	0.00035
CO_3^{2-}	0.36720	0.408

From the results of the cation composition above, the cow bone filler has the highest concentration of Ca^{2+} followed Na^+, K^+, Mn^{2+} and Cu^{2+} while the chicken bone has the highest concentration of Mg^{2+} followed by Fe^{2+} and Zn^{2+}. The presence of these cations creates a chance for the surface adhesion between the polymer and the filler. The Ca^{2+} and Mg^{2+} serve as the binding agent in the polyurethane foam as well as a hardener. Na^+ and K enhance porosity, Mg^{2+}, Cu^{2+} and Zn^{2+} act as a catalyst while Fe^{2+} help in structure maintenance and rigidity. The results of the anion composition show that the cow bone has the highest composition of PO_4^{2-} while the chicken bone has the highest composition of the CO_3^{2-}. The presence of phosphate will help as a buffering agent as well as retardant while the carbonate, CO_3^{2-} in combination with calcium will serve as extender.

Generally, the use of two novel fillers in the production of flexible polyether foam was so advantageous over the conventional filler, $CaCO_3$, used in the industries. Mechanical properties such as tensile strength, elongation-at-break and hardness on flexible polyether foam reinforced with animal bones were evaluated to asses the prospects of using as a new environmentally friendly material in flexible poly ether foam.

Table 4 shows the effects of tensile strength, elongation-at-break and hardness on flexible polyether foam.

Table-4 : Rheological properties of the foam samples

Percentage filler load	Tensile strength N/mm^2	Elongation-at-break	Hardness value
0%	4.5	86	226
10%$CaCO_3$	9.68	62	711
5% cow bone	10.06	75	352
10% cow bone	10.68	69	761
15% cow bone	8.81	56	653
20% cow bone	8.62	53	572
25% cow bone	6.12	47	329
5% chicken bone	8.93	83	300
10% chicken bone	9.12	76	741
15% chicken bone	7.56	59	572
20% chicken bone	6.93	43	361
25% chicken bone	5.93	40	249

Tensile strength is the maximum load that a material can sustain without fracture when being stretched divided by the original cross-sectional area of the material, when testing metals, indentation hardness correlates linearly with tensile strength. From the table, it can be seen that tensile strength decreases with increase in the two bone samples from 15% to 25% when compared with the $CaCO_3$ The increase in tensile strength of the composite containing 5% and 10% of the two bone samples is attributable to improved adhesion between filler surface and foam recipes. However, there is a remarkable increase in the tensile strength of all the foam samples produced when compared with the unfilled ones.. Hardness value was slightly increased from 0% to 5% (226 to 350 for cow bone and 226 to 300 for chicken bone). When compared to 10% $CaCO_3$ filled sample 10% of both bone samples performed better. The hardness values start to decrease with increasing filler loads.

Conclusion

10% cow and chicken bones enhanced the tensile strength, elongation-at-break and hardness when compared to samples filled with 10% $CaCO_3$. Again when compared to filled foam, tensile strength and hardness values were improved while the elongation-at-break has lower values. From the general results, it could be seen that 10% cow bone filled foam showed superiority over 10% $CaCO_3$ unfilled foam and other filler loads. From the observation it may be concluded that 5% and 10%'of the two bone samples were good substitutes for 10% $CaCO_3$ used in the industries which serves a control without detrimental effects on the properties.

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