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Studies on the Mechanical and Biodegradability properties of Guna Protein/Cellulose Based Biocomposites

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ABSRACT

In this study,Guna protein obtained from a yearly grown plant Guna (*Citrillus Vulgaris*) was blended with cellulose obtained from cotton fabrics after undergoing the processes of purification via direct physically mixing to produce various compositions of blends that is from ratio 90/10 blends of Guna protein/cellulose composites to 0/100 blends of the same materials or biodegradable composites. Plastic composites filled with Guna protein resin are materials that offer significant and credible alternative for using this botanical resource considering the production of low density materials with some specific properties. The mechanical properties and biogradability properties were obtained via Testometric Tester model 220D and the load extension properties were automatically read, The blends with the best mechanical properties in terms of load/extension was the blend composites ratios 70/30, 30/70, 40/60 and 50/50.Showed load /extension properties of 08.95Kgf/7.01, 08.23Kgf/12.56,11.06Kgf/8.06, and 11.75Kgf/8.76 respectively.

However, biodegradability studies showed that weight loss of composites buried in the soil, were biodegradable even at higher guna protein content in composites blends. The best blends of composites ratios 30/70,70/30, 40/60 and 50/50 were observed to have the best flexibility(biodegradability).

Keywords: Guna protein, Biodegreadability, Mechanical properties, Cellulose.

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INTRODUCTION

Synthetic polymeric materials have been used extensively globally due to their excellent chemical, physical and mechanical properties. However these properties on the other hand, have made them very resistant to micro-organism and other natural degradation forces. Therefore, they remain in the environment after disposal. This has led to serous environmental problems and in addition, problems of solid waste management [3]. Almost everywhere, plastics generated from synthetic means litter the environment more especially in everyday use materials e.g. packaging. These create increased cost on the collection and disposal of solid waste municipal wastes. Virtually all these disposal inadvertently end up in the landfills.

Recycling is seen as an alternative approach to solving this problem. However, not all plastics are recyclable and most of these will still end up in landfills.

The option of producing and use of biodegradable is considered as a possible route of producing materials with dependence on landfills in solving solid waste problems.

Attempts have been made in blending petroleum based polymers with natural polymers or biopolymers such as cellulose, starch, lignin, protein, chitosansetc. With improved properties and as a way of enhancing polymeric biodegradation [1, 5].

These natural biopolymers are abundant, cheap,reneweable and ecofriendly.The use of biopolymer as part of biocomposites or matrix phase offers the following benefits compared to mineral components [8, 11] lightweight, strong and rigid, environmentally friendly ,economical ,renewable and abundant resource.

Biopolymers have the merit of being degraded by moisture and also not suitable for elevated temperature applications and largely susceptible to fungal attack.

The purpose of this study therefore, was to produce environmentally friendly biocomposites of Guna protein and cellulose and to determine the effects of composite blend ratios that is 90/10 to 0/100 and fibre on mechanical properties of the formulated composites. In this regards, the biodegradation of the composites was evaluated for 80days through tensile property studies.

MATERIALS AND METHODS

Materials

A plain woven 100% cotton fabric of commercial quality was obtained from the market (Jimeta ultra-modern market). Guna obtained from farm lands in Jimeta.

Other materials used included distilled water, sieve and water bath.

Methods

Composite Formation

Fabrics were cut into 10cm x 10cm pieces. Fabrics pieces were slightly held under tension using masking tape. Guna protein resin (GPR) already prepared earlier will be poured over the fabric to impregnate it. Another layer of fabric will be put on top and more resin was poured on to the second layer of fabric. A total of four were used to make the composite. Then the resin coated fabrics were transferred to an air-circulating oven at 35^{o}c and were allowed to dry for approximately 36h for proper treatment. The samples were then cured. These were conditioned for three days (ASTMD 790-02) before further characterization.

Bioderadability Studies

GUNA protein resin/cellulose prepared biocomposites were subjected to biodegradability test. Various compositions of the guna protein/cellulose biocomposites that is 90/10, 80/20, 70/30, 60/40, 50/50, 40/50 30/70, 20/80, 10/90 and 100/0 respectively. Fabrics impregnated with protein at various proportions measuring 10cm by 2.5cm were cut and placed in an oven at 50^{0}c specified period of time, the fabric strips were removed from the soil, thoroughly washed or rinsed with tap water, following immersion in distilled water until it remained clear and drying in an air oven at 50^{0}c for 24h.Samples were allowed soil, thoroughly washed or rinsed with tap water, following immersion in distilled water until it remained clear and drying in an air oven at 50^{0}c for 24h.Samples were allowed to equilibrate to ambient temperature and humidity before further measurements. Biodegration of the fabric samples before and after degradation were followed by tensile strength, in which case testing was carried by Testometric tensile tester model 220D in accordance with method of [4, 10].

Mechanical Tests

Tensile tests were carried out using a testometric tensile tester model 220D according (ASTMD790-02) with sample obtained as described. The tensile properties were measured at room temperature at 10mm/min cross head speed and a gauge length of 5mm to obtain the breaking load and extension.

RESULTS

Table 1 represents the results of tensile properties of guna protein /cellulose tensile blends

Polymeric blend ratios of Guna protein/ cellulose composites	Load(Kgf)	Extension
90/10	09.95	4.84
80/20	11.62	8.59
70/30	08.95	7.01
60/40	03.13	8.32
50/50	11.75	8.76
40/60	11.06	8.06
30/70	08.23	12.56
20/80	03.64	14.44
10/90	09.50	2.12
0/100	08.77	1.37

Table2: Results of Biodegradability studies of Guna protein/cellulose

Bends ratio/days	20days		40days		60days		80days	
Tensile properties	Load(Kgf)	E	L(Kgf)	E	L(Kgf)	E	L(Kgf)	E
90/10	02.40	14.10	08.24	9.19	10.99	8.73	10.41	14.35
80/20	08.45	4.40	02.61	4.73	11.64	6.89	03.59	08.72
70/30	03.50	14.47	11.78	7.60	10.54	11.94	03.69	10.92
60/40	10.11	7.59	04.84	10.25	05.51	7.01	04.07	10.81
50/50	08.09	7.51	10.93	8.42	06.49	10.32	07.93	7.59
40/60	09.75	7.24	11.14	7.47	10.45	8.00	04.56	8.30
30/70	09.32	8.19	04.81	9.72	09.07	7.86	05.24	12.64
20/80	08.80	8.64	08.61	9.03	09.47	7.60	07.43	7.60
10/90	04.20	9.29	03.90	11.87	08.55	7.06	01.90	9.98
0/100	05.64	12.88	07.88	8.89	08.95	7.22	06.21	15.06

DISCUSSIONS

Table 1 shows the mechanical properties of the composite blends of Guna protein/ cellulose composites of various ratios that is from blend composite ratios 90/10 to 0/100.

From the results, it can be seen that the tensile properties of the various blend ratios are observed to follow a regular pattern. Therefore for good mechanical properties to result, the load should be proportional to extension or elongation at break. Therefore, in this case the extension of composites materials increased with decrease in resin content and consequent increase in fibre(cellulose) content.

The materials that showed the best mechanical properties were composite ratios 70/30 and 30/70 showing both load and extension at break of (12.56, 8.26) and (7.01 and 8.95) respectively. These result therefore goes to show that in terms of mechanical properties the best tensile property were blend ratios 70/30 and 30/70.

Again, another set of blends that exhibited good material properties were Guna protein/cellulose ratio 40/60 showing an extension at break of 8.06 at a load of 11.06.This was closely followed by Guna protein/cellulose ratios 80/20 and 50/50 with extension and load of(8.59,11.62) and (8.76,11.75) .

The blend ratio 20/80 even though showed a high extension of 14.44 but a poor load of 3.34 showing so much flexibility which may have resulted from incoherent performances.

The worst of all the blends is the composite ratio 10/90 which though exhibited a load of 09.50 has a poor extension of of 2.12.

As a result, the composite ratio 10/90 has been observed to exhibit poor mechanical properties in relation to other compositions under the present study.

However, the flexibility, extension or mechanical properties of composite ratios 10/90 to 0/100 was observed to increase with increase in fibre ratio content and decrease with decrease in resin content.

More so, the inconsistency and fluctuations in tensile properties were observed which could be attributed to fibre agglomeration that localized from the uneven fibre distribution. This trend further reduces fibre –matrix interaction. In the end, it may create stress concentrations areas.

As pointed out [6], fibres have the tendency to agglomerate and this limits stress transfer from the matrix to the fibre.

The blend compositions 90/10,10/90 and20/80 have very poor mechanical properties which are worse than for pure materials.

The compositions blends 70/30 and 30/70 show almost same mechanical properties with the ratios of Guna protein/ cellulose 70/30 having higher extension of 12.56 at a load of 08.23Kgf.

This is so because; [12] interpreted the mechanical properties of polymers in terms of molecular motions. Thus the initial movement may be attributed to internal stress. At low applied force that is load in(Kgf), polymers exhibit high resistance to deformation owing to secondary bonds and the geometric interaction between the molecular chains which cannot more independently from their neighbours. Furthermore, the small motion of the chain segments caused by the applied stress (low force or load) in this range is attributed to the diffusion of short chain segments into the holes in the microstructure.

This may have accounted for the effects in blend compositions 70/30 with proportionate load/extension of 7.01 and 08.95 load, where as small stress of 08.95Kgf resulted in an extension of 12.56 in the case of composites blend composition 30/70.

One of the physical characteristics of immiscible blends is having weaker properties than pure polymers, even though there are methods of improving immiscible blends.
From the table, it was observed that blend composition 90/10, 10/90 and 60/40 are incompatible which may be attributed to the solidification of the matrix phase that is Guna protein before the cellulose phase may have resulted in bad adhesion between the two phases. Bad adhesion between two phases resulted in lower inter facial tension and hence lowering the internal stress.

The composition 70/30, 30/70 and 50/50 of Guna protein/cellulose blends have good mechanical properties. For composite blend 50/50 ratio ofGuna protein/cellulose, the two polymers are roughly in equal amounts, they form two core continuous phases. This means both phases will bear the load if any stress is applied on the composite material, thereby making it stronger. The increasing amount of the core polymer protein enhances cohesion in the long run.

More so, the good adhesion of 30/70 and 70/30 blend components showed the highest values of extension which means with better adhesion, the two phases resulted in greater inter facial tension and higher internal stress which resulted in lower extendibility in the case of blend component 30/70.

Consequently, it was observed that strength improvement depends partly on fiber content. Elongation and break decreases with the addition of fibers.
Table 2 represent the results 0f biodegradability studies carried out on the composite blends of 10/90 t00/100 blends.

For good mechanical properties to result, there must be control of morphology as pointed in the studies carried out Sun etal, 2001.Thus the control of morphology is very important in Guna protein/cellulose blends and other related polymer blends.

Biodegradability studies were carried out on polymer blends of Guna protein/cellulose ranging from the ratios 90/10 to 0/100.This is to advance an understanding of the suitable and the right mix and thus providing broad spectrum information on the biodegrading ability especially through the study of their mechanical properties.

From the table, the results of biodegradability studies through the study of mechanical properties polymer blends showed that, except for polymer blends 90/10 and 70/30 with load/ extension properties of 3.40Kgf/14.10 and 3.50Kgf/14.47 respectively which have load extension properties slightly similar to those of pure materials(composites),all other composite blend ratios showed slightly lower than pure composite materials .This disparity may be attributed to the inherent properties of the composite blends.

Furthermore, the results from Table2, also indicated that, for most of the ratios of the guna protein/cellulose ratios, real degradation onset was mostly observed in the subsequent days of studies. This was evident in the decrease in material stiffness as the number of days of burial progressed gradually from 20days to 80days.

Except for little fluctuations in terms of extension values which may be attributed to fibre agglomerations due to inherent material properties as pointed out in the studies of Jacob et al 1999).

However, it was observed that blend ratio of Guna protein/cellulose 30/70exhibited excellent biodegrading with load /extension properties of 05.24Kgf/12.64 in relation to pure blend ratio 0/100 composite with load/extension property of06.21Kgf/15.06 respectively. For good mechanical properties to result, the load /extension values usually show proportionality.

In the same light, the load /extension properties of the composite blend 70/30 were 03.69Kgf/10.92,indicaing a tremendous decline in material stiffness. Is may have resulted from increased the increase fibre content and diffusivity of water, causing swelling and enhanced biodegradation.

The compositions 60/40 and 40/60, even though having an almost equal loads of 4.86Kgf 4.07Kgf respectively still differ in their extensions of 8.30 and 10.81 respectively. This may have resulted from increased fibre content as pointed out in the studies of [2, 9].

In the same vein, the increased fibre content may have provided the needed surface area for action by micro-organisms. This may have accounted for the increased flexibility or loss of stiffness occasioned by the increased biodegrading of composite blends.

Comparatively, the compositions 90/10 and 10/90 blends represent two extreme cases of the composite Guna protein/cellulose blends. These are characterized by load/extension properties of 10.41Kgf/14.35 and 01.90Kgf/9.98 respectively.

Therefore, as pointed out [2], fibre length and content contributes to extendibility of composite materials whereas load distribution in response to an applied force is attributable to the matrix phase. These all contribute to either increasing or decreasing the extension of composite materials.

Furthermore, the ratios 90/10 results from an increased internal force leading to an increased flexibility of the material. The 10/90 composition blend on the other hand, has higher fibre content and reduced stress transfer. This effect may have translated in the reduction in internal stress and reduced extension.

All these effects and factors contributed to the reduction in material stiffness over the study period of 80days.This are shown in table 2

In the same light, the compositions 20/80, 80/20 and 50/50 showed some interesting flexibility properties.

For the 50/50 blend of Guna protein/cellulose composites, as a result of the formation of two co-continuous phases. The two continuous phases actually too part in the load bearing activity resulting in the observed load /extension property of7.43Kgf/7.60,making it stronger. Same applies to the composition blends 80/20 and 20/80 with the 80/20 blend composition having a slightly higher load (internal stress) of 03.69Kgf as against 01.90Kgf of 20/80 blend composition.

Consequently, the compositions 30/70, 70/30 and 60/40 degraded fester and are comparable to the degradation values of pure materials.

CONCLUSION

Guna protein was extracted using distilled water and dried at room temperature. It was observed that it was plausible to use this biopolymer (Guna protein) as low cost material ,in view of the properties obtained from the blends of various composition.

The composite stiffness was observed to have increased with increased fibre content decreased protein content.

However, the guna protein showed reasonably good degradation in almost all the composite blends.

Finally, product utilization of guna protein in packaging appears feasible and promising.

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