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Study on effect of euphorbia coagulum on physico-mechanical and fire retardant properties of polyester-banana fiber composite

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Abstract

Present study is focused on the utilization of coagulum of euphorbia as binder in polyester banana fiber composite. Euphorbia coagulum (dried latex) is rich in resinous mass (60-80%), which are terpenes and polyisoprene (10-20%). Effect of varying percentage of coagulum content on various physico-mechanical and fire properties of polyester-banana fiber composites has been studied. Since banana fiber is sensitive to water due to presence of polar group, banana composite undergoes delamination and deterioration under humid condition. Alkali treated banana fiber in the polyester banana fiber composite results in improvement in overall mechanical properties and reduction in water absorption. The best physico-mechanical properties have been achieved on replacing 40% of polyester resin by coagulum. An increase of 50% in bending strength, 30% bending modulus and 45% impact strength as well as 68% decrease in water absorption was observed. Incorporation of coagulum in polyester banana fiber composite enhanced limiting oxygen index from 18 to 21% with the reduction of smoke density. The developed composite material can be utilized for the partition board, particle board etc. This study presents the possibility of utilization of renewable materials for environmental friendly composite development as well as to find out alternative feedstock for petroleum products.

Keywords: Euphorbia latex, coagulam, banana fiber, polyester resin, natural binder.

Introduction

The concept of using renewable material for the production of chemicals and new plastics for construction applications has been recorded since the beginning of our civilization. In recent years, the growing interest on renewable resources use in the research and industrial communities throughout the world is the outcome of growing environmental concern and legislative regulation on disposal and use of non biodegradable petrochemical based products. Continued research efforts have been made since 1990's to exploit the natural renewable resources as alternative feedstock for petroleum products in various applications. Resin and fibers obtained from renewable resources (Mohanty & Misra, 1995; Mohanty *et al.,* 2000; Sebe *et al.,* 2000) can provide the desired alternatives that would reduce the dependence on petroleum feedstock. In this direction, extensive research studies have been conducted on variety of natural fibers (Scott, 2000; Joshi *et al.,* 2004; Averous, 2004) with significant out come for their industrial uses especially in construction application. The present study emphasizes on utilization of coagulum of euphorbia latex as substitute for polyester resin in different proportions for the development of banana fiber reinforced composites based on euphorbia coagulum modified polyester resin. Developed composites however are prone to fire hazard and an enhanced resistance to fire is therefore desired to protect it in case of fire where it will use. One of the major considerations in the manufacturing of flame retardant composite is to maintain the necessary physical and mechanical properties upon incorporation of flame retardant additives.

Banana fiber is a natural ligno-cellulosic fiber with certain advantageous features such as low density, high specific strength and low abrasion besides the ease with which it can be processed and handled. Like other natural fibers (Herrmann *et al.,* 1998; Luo & Netravali, 1999; Mohanty *et al.,* 2000; Cunha *et al.,* 2001) presence of polar groups in banana fiber presents a challenge for banana fiber composites along with hydrophobic polymers, which resulted in weak interfacial adhesion, especially under humid conditions. Thus, it is imperative to modify functional moieties of banana fiber for better wettability and improved interfacial adhesion with synthetic polymers. Natural latex from different wild plants can be the renewable resource used compatible for composite development. In fact, if latex from plants of *Euphorbiaceae* family such as *Euphorbia royleana, E. nerifolia and E. caducifolia* etc. along with *Hevea brasiliensis* are properly utilized for industrial applications, India can easily be a leading source of latex for exploitation (Dabholkar *et al.,* 1986). The main constituents of *Euphorbia* latex is resinous mass (65-80%), protein (10-20%) and isoprene rubber (5-10%) (Diwan *et al.,* 1991). The resinous mass present in *Euphorbia* latex is mainly tetracyclic triterpenoid having empirical formula $C_{30}H_{50}O$ (Diwan *et al.,* 1991).

The present papers is focused on incorporation of euphorbia coagulum in banana fiber reinforced polyester composites and study the effect of varying concentration

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of coagulum on the various physico-mechanical and fire property of the developed composites.

Materials and methods

Euphorbia latex: Latex of *Euphorbia royleana* was collected from foothills of Himalayas around the regions of Sahastradhara, Dehradun, India. Banana fber was procured from local market. Unsaturated polyester resin (Grade, C-451) was collected from crystic resin (P) ltd., New Delhi. Methyl ethyl ketone peroxide (MEKP) of industrial grade was procured from G. S. chemicals testing and allied industries, Mumbai, India and used as an initiator. Cobalt naphthenate of industrial grade, toluene (sulphur free) and tannic acid, AR grade were procured from S. D. fine chemicals (P) ltd., Mumbai, India and was used as an accelerator, solvent and coagulating agent for latex respectively. All the chemicals were used as such without further processing.

Coagulation of euphorbia latex

Latex collected from *Euphorbia royleana* was coagulated by 5% aqueous solution of tannic acid. The coagulated latex was washed several times with water to remove tannic acid and dried at 60^0C in an oven. Details of the method for extraction and analysis of coagulum from latex is done by the method of Diwan *et al.* (1991).

Alkali treatment of banana fiber

Banana fiber was treated with 4% by wt. aqueous sodium hydroxide solution for 4 h to delignify and to remove hemicellulose and then dried at 105°C by hot air for one hour and hot pressed to minimize shrinkage.

Process for composite preparation

Powdered coagulum was mixed homogeneously with polyester resin in different ratio along with MEKP initiator (1.5% by wt.) and cobalt naphthenate accelerator (0.5% by wt.). Hand lay up technique was used for sheet preparation using toluene as diluent and Banana fibers were treated with resin for wetting. The fibers were placed in the mould of 150 mm x 150 mm x 3 mm dimension and dried at ambient temperature for 30 minutes and placed in compression molding machine (Sentec, New Delhi, India). The mould was pressed for 30 min at 120°C and 5 MPa pressure raised gradually for 5 min. The molded sheets cooled under pressure were then released from the mould. In all the sheets, banana fiber content was kept at 40% by weight and quantity polyester resin and coagulum were varied.

Characterization of composites

Flexural test: Test specimens were cut from molded sheet. The dimension of the test specimens was 127 mm x 12.7 mm x 3.4 mm. Flexural strength and flexural modulus of coagulum modified polyester banana fiber composites specimens were tested on universal tensile machine (Instron, 4302 model, UK) at the crosshead speed of 5 mm/min and at a span length of 96 mm. Temperature was maintained at 23±2°C as per the guidelines of ASTM D-790.

Izod impact strength: Notched specimens were cut from the compression molded sheet for izod impact strength test as per ASTM D-256 -93a. The dimension of test specimens was 60 mm x 10 mm x 3.4 mm. Hammer of 2.75 J was used during testing with dissipation energy of 0.011 J. Izod impact tester model no.6545/000 from Ceast, UK was used for impact strength.

Water absorption test: The water absorption test was carried out as per of ASTM D-570.

Limiting oxygen index (LOI): LOI was determined for each specimen of the size 6 mm x 25 mm as per ASTM D-2863.

Smoke density: It was determined as per ASTM 2843.

Results and discussion

Effect of alkali treatment on banana fiber

The main purpose of alkali treatment of banana fibers is to improve the interfacial properties of fiber and resin by removal of hemicellulose and lignin. On alkali treatment, surface area of banana fiber is expected to increase which further enhances the resin penetration into the fiber.

Effect of coagulum content on polyester banana fiber composite

Banana fiber composites have been prepared by replacing polyester resin with euphorbia coagulum up to 50% by wt. and its effect on various physico-mechanical properties and fire retardant properties have been investigated.

Effect on water absorption

Banana fiber is hygroscopic due to presence of polar groups resulted in poor wettability of fiber by resin and dimensional deformation under moist condition. The water absorption values of different compositions of coagulum-polyester banana fiber composites having treated and untreated fiber has been shown in Fig. 1. The results revealed that water absorption reduced considerably with increasing percentage of coagulum content into polyester resin in banana fiber composites. Results further revealed that increase in coagulum content alongwith alkali treated fiber has been more effective in reducing water absorption. This might be attributed to good wettability of the banana fiber by

Fig. 1. Effect of incorporation of coagulum and fiber treatment on water absorption of polyester banana fiber composite.

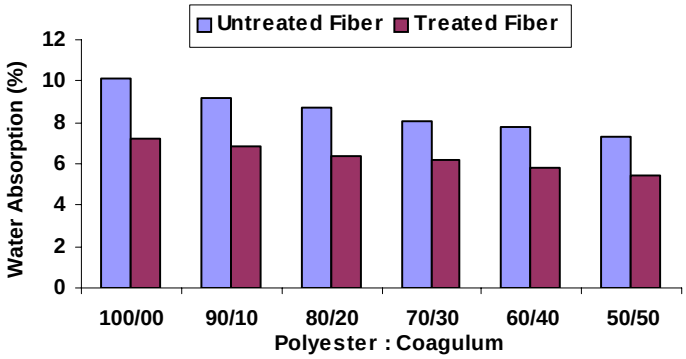

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Fig. 2. Effect of incorporation of coagulum & fiber treatment on flexural modulus of polyester banana fiber composite.

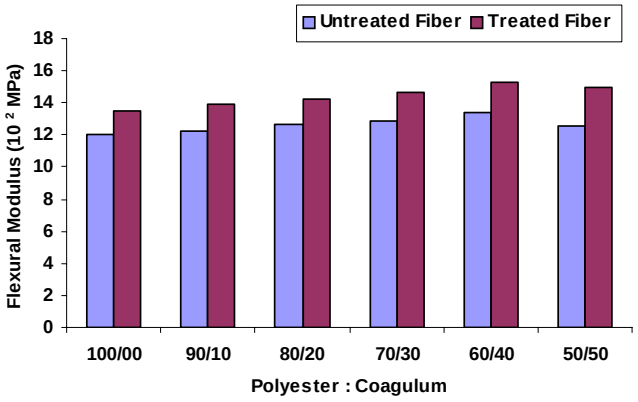


Fig.3. Effect of incorporation of coagulum & fiber treatment on Flexural Strength of polyester banana fiber composite.

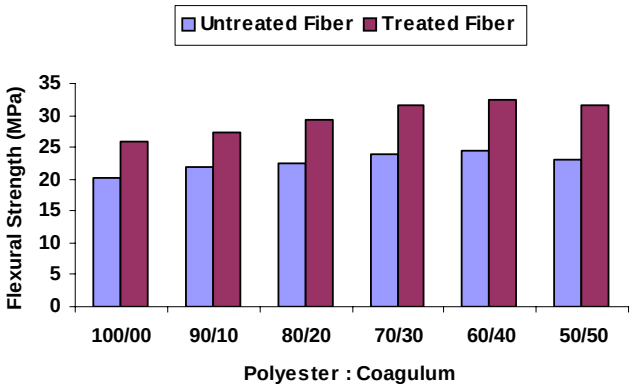
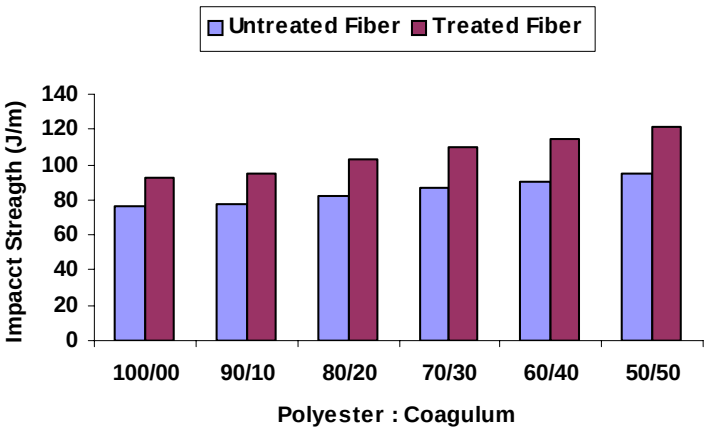


Fig. 4. Effect of incorporation of coagulum & fiber treatment on Impact Strength of polyester banana fiber composite.



coagulum-polyester resin.

Effect on flexural properties

The effect of coagulum on flexural strength and flexural modulus with increasing coagulum content (0-50 % by wt.) in polyester banana fiber composites having treated and untreated fiber are given in Fig. 2 and 3. It was observed that maximum flexural properties were achieved at 40% replacement of polyester resin by coagulum in the banana fiber composite. However on further increase in coagulum content, a decline in flexural properties was noticed. This decline in flexural properties might be due to presence of rubber content of the coagulum, which makes it flexible. Results shows that increase in coagulum content is more effective with alkali treated fiber, which might be due to good wettability of the banana fiber by coagulum-polyester resin.

Effect on Impact strength

The effect of coagulum on impact strength with increasing coagulum content (10-50% by wt.) in polyester banana fiber composites are given in Fig. 4. Impact strength increases as coagulum content increases from 0% to 50% in the polyester banana fiber composites. This might be attributed due to the ability of coagulum to absorb impact or shock energy by incorporation of increased amount of isoprene rubber present in coagulum.

Effect on limiting oxygen index (LOI)

In the present study, the effects of coagulum on LOI of polyester-banana fiber composites were studied. The effect of coagulum on LOI with increasing coagulum content (10 to 50% by wt.) in polyester banana fiber composites are given in Table 1. It was observed that with the increase of the coagulum content in the polyester banana composites from 0% to 50%, an increase in LOI value up to 16% was observed due to excess nitrogen generated in the system due to presence of 15% protein in the coagulum.

Effect on smoke density

During the burning process of reinforced polymeric materials, smoke generation is a cause of concern, as it will affect not only visibility during rescue operation but also pollute surrounding environment. Incorporation of coagulum in polymeric formulations C-1, C-2, C-3, C-4, C-5 and C-6 shows varying degrees of smoke generation. An appreciable reduction in the smoke density was observed when polyester resin was replaced by the *euphorbia* coagulum (Fig. 5). The reduction in smoke generation might be due to presence of nitrogen in proteinous mass of coagulum, which prevents the composite from the burning.

Conclusion

In the present work, an attempt has been made to replace polyester resin with naturally occurring euphorbia latex of *Euphorbia royleana* successfully in order to develop eco-friendly composite. It has been observed that the increasing coagulum content leads to decrease in water absorption and increase in impact strength of the composites. Maximum flexural properties were obtained at 40% replacement of polyester resin by coagulum. Incorporation of coagulum in the composites

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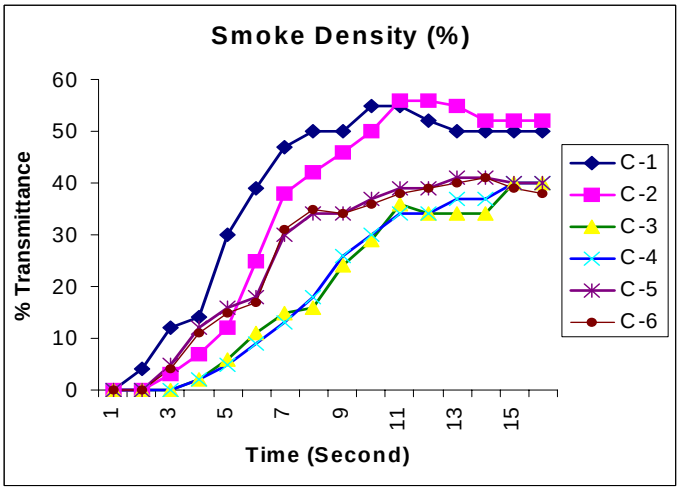
Table 1. Effect of coagulum on limiting oxygen index (LOI) of polyester banana fiber composites.

Coagulum: Polyester ratio	Sample code with coagulum	(LOI)
0:100	C1	18.0
10:90	C2	19.1
20:80	C3	19.8
30:70	C4	20.3
40:60	C5	20.6
50:50	C6	21.0

Fig. 5. Smoke density of polyester banana fiber composites modified with varying percentage of Euphorbia coagulum.



reduces smoke density appreciably along with improvement in LOI value to the extent of 16% due to the presence of nitrogen present in protein of coagulum. Such composites will have great potential for application in different sectors especially in hardboard.

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