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A Study on the Tensile Behaviour of High Performance of Coconut Leaves treated with Methyl methacrylate

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ABSTRACT

The effects of electron beam irradiation on the mechanical properties of Coconut leaf fibre reinforced high impact Methyl methacrylate (MMA) were studied. In recent times efforts are being made to improve the quality of different plant materials. Agricultural or biodegradable materials have played a major role in human life. Kerala is the largest producers of Coconut palms. The coconut leaf has been used in different purposes. However the coconut leaves undergoes rapid deterioration and needs annual replacement. The purpose of the present investigation is to study the possibility of irradiation methods to reduce leaf deterioration of coconut palms. The collected leaves were categorized in to tender, mature and dried leaf bits. 20 samples from each of the samples were immersed in a beaker containing 150ml of unstabilized Methyl methacrylate (MMA) monomer for 180 hrs. The irradiation process was carried out using electron beams for inducing the polymerization of monomer infiltrated leaf bits. For electron beam irradiation, the samples were grouped in to three sets for giving radiation doses 5 kGy, 10 kGy and 15 kGy. 20cm long and 2cm wide specimens were used for tensile testing on an Instron testing machine. The mean value of the property measured was compared with the control samples without any monomer treatments. From these studies, assure that the monomer treated Coconut leaf samples cured by electron beam irradiation at particular doses made a change in their mechanical properties (tensile strength) thereby enhancing the durability and longevity of the samples. These converted leaf bits offers a big possibility of making high utility commercial products accessible to ordinary people.

Key words *Tensile Behaviour, High Performance Coconut Leaves, Methyl methacrylate*

The coconut palm (*Cocos nucifera* Linn.), a valuable tropical resource, supply food, energy and many economically viable products. In Kerala traditionally eco-friendly palm leaf woven houses, umbrella, baskets, separating screen etc are common. Natural fibres have some advantages over man made fibres, including low cost, light weight, renewable character, high specific strength and modulus and availability in a variety of forms throughout the world (Mohanti et al, 2000, Rajulu et al 2002)

Coconut leaf thatch is a cheap roofing material used widely in India (Kerala), Sri Lanka and in some Polynesian countries by millions of households. The leaves are available to extend of 5.6 million ton in Kerala whereas the worldwide production may exceed 42 million tons. The large availability of this renewable resource can contribute much in solving the housing problems in the developing world (Pillai, 1982). However the thatch made from coconut leaves undergoes rapid deterioration and needs annual replacement. A number of empirical studies have been reported on the prevention of deterioration (Pillai, et al 1981, Rama verma, 1957, Purushotham, et al 1953). Damage and deterioration to palm leaves are usually the result of insect damage, climatic factors (variations in humidity and temperature), staining, splitting and cleavage and mechanical damage. There is no systematic study of the properties of these palm fibers except for some brief reports regarding mechanical properties (Sathyanarayana et al, 1981) and details on the chemical characterization and structure (Venugopal et al, 1984). In view of these limited uses, a lot of this abundantly available resource is going waste. However, if diversified uses for these fibers can be thought of, it would not only increase the utilization of this abundant and renewable resource but also help in increasing employment opportunity in the rural sector since the fibre industry is a cottage industry.

Although a reduction in strength is observed during deterioration, it is interesting to note that there was an increase in strength of leaf when the green leaf was dried to a moisture content of 15 % (Pillai et al 1982).

The ability of high energy radiation like gamma and electrons to induce chemical and physical changes in materials in general and specially polymers and elastomers in particular, have been the basis for research since 1938 (Chapiro, A 1962). The effect of irradiation on mechanical, thermal and degradation properties of biodegradable polymer bionolle and its composites was studied by Mubarak and Idriss Ali, 1999. The enhanced tensile strength of bionolle was obtained when it was exposed under 20kGy radiation.

Although brief reports regarding the mechanical properties of palm fibres (Satyanarayana et al 1986) are available studies dealing with the mechanical property of Coconut palm leaf bits after treatment with monomer and radiation is almost nil. Hence to determine the durability of leaf bits a mechanical property study, tensile strength was undertaken.

MATERIALS AND METHODS

Fresh healthy leaf bits of coconut (*Cocos nucifera*) were collected from Taliparamba of Kannur district of Kerala. The collected leaves were categorised in to tender, mature and dried leaf bits. During sample preparation, leaf bits without midrib were prepared with length X breadth 20X2 cm. Thus prepared leaf bits were grouped separately.

C1T1 – Coconut tender leaf bits

C1T2 – Coconut mature leaf bits

C1T3 – Coconut dried leaf bits

In order to minimize variations in the properties, the following procedure was followed during sample collection. Leaf bits at the bottom most part of the crown of mature palms was taken. Then specimen samples of required size were cut out from the leaflet at a desired distance of approximately 0.2m from the petiole end of the leaflet and the rest of the leaflet rejected.

20 samples each from the above mentioned samples were immersed in beaker containing 150ml of unstabilized methyl methacrylate monomer for 180 hrs. After monomer infiltration for 180 hours, they were taken out and air dried for about 2 to 4 hours in order to evaporate excess monomer. The air dried and monomer infiltrated samples were covered in zip lock polythene bags separately.

In the present study, the irradiation process was carried out using electron beams for inducing the polymerization of monomer infiltrated leaf bits. For electron beam irradiation, the samples were grouped in to three sets for giving radiation doses 5kGy, 10kGy and 15kGy. The process was carried out in 200mev accelerator machine, Electron beam centre, Kharghar, Mumbai for enhancing longevity and durability of samples.

20cm long and 2cm wide specimens were used for tensile testing on an Instron testing machine. The leaf specimens could be readily gripped and were breaking almost at the middle of the specimen. The ultimate tensile strength is the load at break per unit area of the specimen. A guage length of 5cm was employed for tensile testing. All experiments were repeated with 5 samples and the average taken. The measurements were tabulated. $UTS = \frac{B/L}{area}$

Here B/L is the breaking load.

RESULTS AND DISCUSSIONS

The Coconut leaf bits immersed in monomer and treated with electron beam at different doses showed a great increase in tensile strength as compared with the control samples without any treatments.

In the control leaf samples of Coconut without any treatments, the tensile strength is found as 23.72MPa, 22.19MPa and 31.92 MPa in tender, matured and dried leaf bits respectively. (Table 4)

The tensile strength of Coconut leafbits immersed in monomer and cured under 5 kGy electron beams is measured as 49.04 MPa, 42.19 MPa and 40.83 MPa respectively in tender, matured and dried leaf bits.(Table 1)

The tensile strength of Coconut leaf samples immersed in monomer and cured under 10kGy electron beams are 37.55 MPa, 42.02 MPa and 42.30 MPa in tender, matured and dried leaf bits respectively.(Table 2)

The 15kGy treated leaf bits of Coconut samples showed tensile strengths 52.21 MPa, 51.99 MPa and 47.98 MPa respectively in tender, matured and dried leaf bits.(Table 3)

When electron beam radiation passes through matter, its energy is transferred to the molecules of absorbing medium by various mechanisms. The primary reactions for the ionization or the excitation of molecule take place at certain rates in the radiated matter. The ability of high energy radiation like gamma and electrons to induce chemical and physical changes in materials in general and specially polymers and elastomers in particular, have been the basis for research since 1938 (Chapiro, A 1962). In the subsequent reaction steps, stable molecules or free

Table 1. Table showing the Tensile strength of *5KgY samples*

Samples	Thickness (mm)	Width (mm)	Maximum force (N)	Tensile strength (MPa) MEAN & SD
EC1T1	0.176	19.6	157.2	49.04±1.64
EC1T2	0.256	19.6	250	42.19±0.93
EC1T3	0.292	20.2	220.5	40.83±0.83

Table 2. Table showing the Tensile strength of *10KgY samples*

Samples	Thickness (mm)	Width (mm)	Maximum force (N)	Tensile strength (MPa) MEAN & SD
EC1T1	0.196	21.2	155.2	37.55±0.73
EC1T2	0.204	22.2	185.8	42.02±0.54
EC1T3	0.284	21	300.0	42.30±1.14

Table 3. Table showing the Tensile strength of *15KgY samples*

Samples	Thickness (mm)	Width (mm)	Maximum force (N)	Tensile strength (MPa) MEAN & SD
EC1T1	0.164	19.6	147.5	52.206±0.57
EC1T2	0.172	20.8	190.8	51.99±1.4
EC1T3	0.256	18.8	228	47.98±0.64

Table 4. Table showing the Tensile strength of *CONTROL samples*

Samples	Thickness (mm)	Width (mm)	Maximum force (N)	Tensile strength (MPa) MEAN & SD
CC1T1*	0.26	16.4	28.7	23.72±0.65
CC1T2*	0.22	18.8	98.3	22.19±0.71
CC1T3*	0.16	18.8	98.5	31.92±0.69

EC1T1 – Electron beam treated Coconut tender leafbits

EC1T2 – Electron beam treated Coconut matured leafbits

EC1T3 – Electron beam treated Coconut dried leafbits

* - Control Samples

radicals and ions formed. In further reactions with certain systems, this brings about chemical chain reaction that is capable of producing new chemical structure. The irradiated matter then exhibits changed physical and chemical properties. A good deal of work has been reported on the employment of gamma radiation as a polymerization initiator. Investigation of the alteration of the properties of wood in which graft co.polymerization had been initiated by gamma irradiation of wood impregnated with a suitable monomer styrene. There are other ionizing radiations- notably electron beams which will be equally effective in initiating graft co. Polymerization, and which are more convenient radiation source for experimental work in this field (Ramalingam, et al, 1968). Radiation induced polymerization techniques suggests a possible preservation method for the preservation of Botanical specimens (Merwin L Brown and R.W.Funsch, 1970). Polymerization of methyl methacrylate and methyl, ethyl and N-butyl acrylates was carried out in a wide range of dose rated, 10 - 10^6 rad/s by gamma ray and electron beam irradiation (Kanae Hayashi et al 1987). Biodegradable polymers constitute a family of polymers that are designed to degrade through action of living organisms or like that. They offer a possible alternative to traditional non-biodegradable polymers where recycling is unpractical or un economical. The other method to tackle this problem is to use natural fibers as the reinforcement in polymers (Rozman HD et al 2001, Countinho FMB et al, 2000, Harikumar KR, 1999).

The electron beam (EB) irradiation technique is being increasingly utilized to modify the surfaces of various polymer materials like fibers, textiles and films. Cotton fabrics have been coated with pigment colours using EB to improve colour fastness, tensile mechanical resistance (El Naggar AM et al 2005). A novel non coloured and colourless polymer of gum Arabic can be produced by radiation induced polymerization techniques. Chemical and physical changes in gum Arabic were induced by treatment with ionizing radiations with up to 100kGy doses. Polymerized gum Arabic can be obtained by irradiations at high solute concentrations (Tsuyoshi Katayama et al, 2005). Natural fibers that have been studied as a substitute for glass and other non – biodegradable composite components are included hemp, flax, jute, banana, kenaf etc (Baiardo, M et al 2004). Other advantages of using the natural fiber are also due to its low density, high toughness, comparable specific strength properties, ease of separation and reduction in tool wear (Bessadok et al, 2009). Chemical modification and electron beam irradiation proved to be important to improve the fibre matrix adhesion so as to produce composite materials with superior strength (Zimpaloni, M et al 2007).

The increase of dose irradiation has increased the tensile strength of Pine apple leaf fibre composites. It can be seen that the tensile strength of PALF composites without irradiation is about 21.10 MPa. Meanwhile by using higher dose irradiation (100kGy), the composite has brought improvement of tensile strength value up to 40.25 MPa. The increase in dose may be a result of crosslinking reaction and interaction of free radicals produced in irradiated matrix (Ratnam,CT et al 2007).

However, no such studies have been carried out so far to enhance the utilization of Coconut palm leaves by treating them with a monomer and polymerize it through electron beam induced polymerization techniques. Tensile strength of leaf bits after treatments was compared with the control. Durability of polymerized leaf bits are tested by biological degradation assessment of the treated polymerized samples, hence the novelty and importance of the study.

From the results it is evident that there is a steady increase in the tensile strength of all the monomer immersed samples irradiated with electron beams under different doses and the increase in tensile strength is almost double the tensile strength of the control samples without any treatments. The tensile strength of 15kGy treated Coconut palm leaf bits are higher as compared to the 5kGy and 10kGy electron beam treated samples. From this studies assure that the monomer treated Coconut leaf samples cured by electron beams at particular doses made a change in their mechanical properties (tensile strength) thereby enhancing the durability and longevity of the samples.

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