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Studies on Flame Retardants on Malaysian Coir Fiber

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***Abstract*— In this study to the effect of the utilization of urea and diammonium phosphate as fire retardant on Malaysian coir fiber was evaluated. Flammability and thermogravimetric analysis (TGA) tests were used to evaluate the fire retardancy. Weight loss and percentage of mass residue were used as a measure from the results of flammability and TGA, respectively. The results revealed the effectiveness of using urea and diammonium phosphate as fire retardant for Malaysian coir fiber. However, for the samples treated with retardant high concentration the weight loss is not significant with the time of dipping treatment. This indicates that the just dip application for the fire retardant of higher concentration is sufficient.**

***Keywords*— fire retardant, coir fiber, flammability, thermogravimetric analysis (TGA)**

I. INTRODUCTION

Coconut palms (*Cocos nucifera* L.) are abundantly growing in coastal areas of all tropical countries and its wide variety of products are being applied in food and non-food products. Its nutritious nuts represent a major form of livelihood for millions of people [1]. The coir fiber is extracted from the external portion of the fruit of the coconut palm, which is a by-product of the copra-extraction process and is generally considered a waste material. A better understanding of these fiber properties will help in the development of new products. Coir fiber is used in domestic (mats, carpets, rope), building (thermal insulation), and automotive (cushions, seat covers, etc.) applications. Coir consists of cellulose fibers with hemicellulose and lignin as the bonding material. Therefore, in a sense the coir fiber is itself a fibrous-composite material [2].

Since coir fiber is a lignocellulosic material, it catches fire and propagates very fast. Flammability is one of the major problems particularly for export market. Simple salts like zinc chloride and borax-boric acid retard fire but suffers from moisture absorption, migration to the surface and peeling off by mechanical action. Urea and phosphoramide Treatment using N-hydroxy methyldialkyl-phosphonoalkelamide, tetrakis hydroxyl methyl phosphoniumchloride and an oligometric vinyl phosphonate and another combination consisting of tri ethanolamine, 85% phosphoric acid and wetting agent can introduce good fire retardancy. But these treatments are very expensive [3]. Reference [4] discusses the role of boron in providing flame retardancy to wood. Different loading levels of borax-boric acid, ranging from O to 20 percent add-on by weight, were applied to Southern Pine. Two types of fire tests were used to evaluate flame retardancy. Reference [5] evaluated the fire retardant efficiency of diammonium phosphate, annonium sulphate and magnesium carbonate minerals on *Pistacia lentiscus* L. They found that AS (ammonium sulfate) and DAP (diammonium phosphate) seem to have a better performance. However, in terms of mass residue the DAP was more effective.

The aim of this paper is to evaluate the effectiveness of the utilization of urea and diammonium phosphate as fire retardant on Malaysian coir fiber using flammability and thermogravimetric analysis tests (TGA).

II. MATERIALS AND METHODS

A simple experiment was conducted before the application of the fire retardant test to optimize the suitable drying temperature using a drying oven. The experiments were conducted for 50ºC and 60ºC. Two samples having the same weight were used for the experiment. The weight is recorded after specific intervals until the change in weight is not significant.

Coir fibers of known weights are introduced into fire retardant solution of known concentration for just dip, 30 minutes and 60 minutes. The excess salt sticking on the fiber is removed and weighed again after drying at 60°C for 3 hours. Thus the percentage retention of the salt can be calculated.

Solutions of urea and diammonium hydrogen orthophosphate are prepared concentrations 30, 45 and 60 per cent were used for the experiment. In this paper C1, C2 and C3 will stand for 30, 45 and 60 per cent concentrations, while C0 will be used for the control (untreated sample).

Two experiments were conducted to test the effect of the fire retardant on the coir fiber. The main experiment was the flammability test and the other experiment was a confirmation for the effectiveness of the retardant.

For the flammability test the fire retardant behavior was evaluated using a modified vertical burning test column [6]. Ten samples were prepared including an untreated sample as a control. Each sample was made in the shape of a rope and hung vertically in the column (Fig. 1). A luminous Bunsen flame (4 cm length) was kept below the rope so that the flame is extended 2 cm into the rope. Each sample was fired for 12 seconds and the percentage weight loss has been determined.

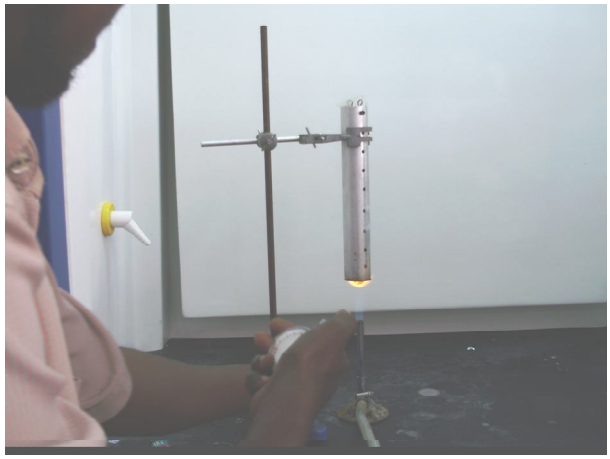

Fig. 1 Flamability test using the vertical burning column

The effect of the fire retardant was verified by conducting thermogravimetric analysis (TGA) using Mettler TGA apparatus supported with PC and software for control and data handling. Sample were weighed and put in an open type alumina sample holder. The experiments were conducted under non-isolated conditions (30ºC to 600ºC) with linear heating rate (10ºC/min) and in oxygen atmosphere (with rate flow 100 ml/min). Oxygen atmosphere was used in order to favour complete combustion conditions.

III. RESULTS AND DISCUSSION

The results of the drying experiments are shown in Fig. 2 and 3 for 50ºC and 60ºC, respectively. The suitable drying time was estimated from where the change in weight becomes not significant. The suitable drying time for the sample dried at 60ºC was found to be around 3 hours where as for 50ºC the drying time is more than 4 hours.

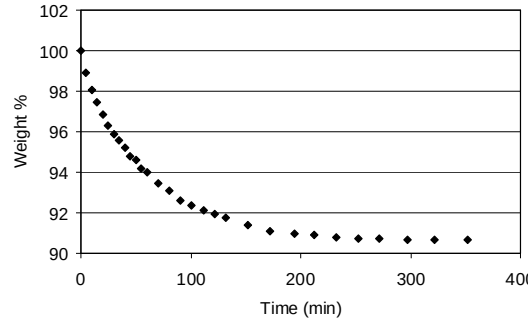

Fig. 2 Weight loss versus time for drying at 50ºC

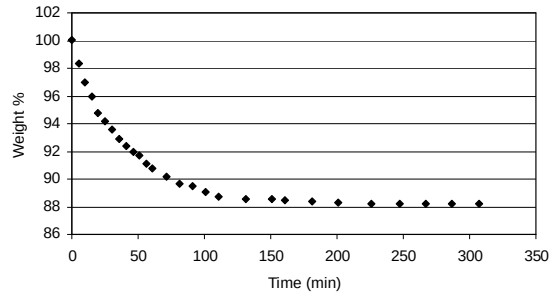

Fig. 3 Weight loss versus time for drying at 60ºC.

The results of the percentage retention of the fire retardant are shown in Table 1. The results show that the absorption rate increases as the concentration of the solution and the time of treatment increases.

TABLE 1
Percentage retention of the fire retardant chemical

Concentration	Just dip	30 minute	60 minutes
C1	8.33	10.48	14.88
C2	12.14	17.36	18.46
C3	21.54	23.21	28.46

Fig. 4 shows the results of the flammability test for the nine treated samples. The test revealed that the coir fiber shows good fire retardancy even after a just dip in the solution of lowest concentration (30%). The figure shows that the weight loss decreases as the concentration and the treatment time increases. The weight loss for the C0 sample was 96% which is very high compared with the maximum weight loss obtained for the treated samples (17.2%). However, for the samples of high concentration (C3) the weight loss is not significant with the time of dipping. This indicates that the just dip application for the fire retardant of higher concentration is sufficient.

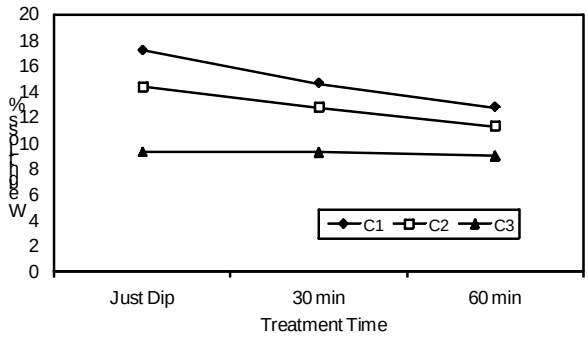

Fig. 4 Flammability results for different fire retardant concentrations at different dip time

Fig. 5 and 6 represent samples of the TGA results for the control and C3 sample of 60 minutes dipping time, respectively. The figures show how the residue is formed at the end of the test. The amount of char residue formed form the TGA test is a measure of its flame resistance. The results show that percentage mass residue increases with the concentration and the dip time (Table 2). The control sample reveals the lowest percentage mass residue. The TGA results show that the maximum temperature (600ºC) used was not sufficient for complete combustion of the control sample which is due to the limitation of the device used. However, the general trend shows that the residue is getting lower for the control sample compared with the samples treated with the fire retardant. The results show the effectiveness of the fire retardant.

The flammability and the TGA experiments confirmed the effectiveness of the using the urea and diammonium phosphate as a fire retardants for the coir fiber. The resuls show same trend of the effect of the fire retardant on Indian coir fiber obtained by [3]. However, the obtained results for the Malaysian coir fiber show better effect.

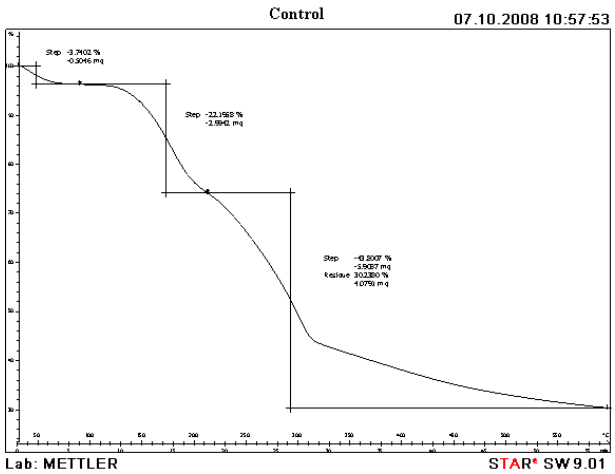

Fig. 5 Thermogravimetric analysis curve for the control sample

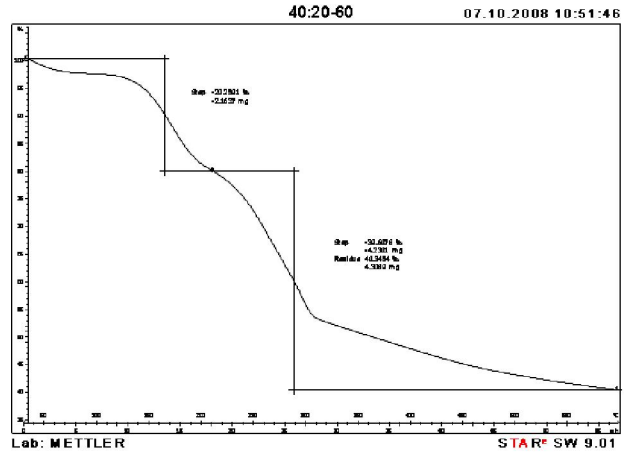

Fig. 6 Thermogravimetric analysis curve for the C3 sample of 60 minutes dipping time

TABLE 2
Percentage of the mass residue for the treated samples using TGA

Concentration	Just dip	30 minute	60 minutes
C1	37.6	31.9	33.8
C2	37.7	37.5	37.5
C3	37.6	39.3	41.0

IV. CONCLUSIONS

Flammability test supported by and TGA test methods used this paper revealed the effectiveness of using urea and diammonium phosphate as fire retardant for Malaysian coir fiber. However, for the samples of high concentration the weight loss is not significant with the time of dipping treatment. This indicates that the just dip application for the fire retardant of higher concentration is sufficient.

NOMENCLATURE

TGA Thermogravimetric analysis
DAP Diammonium Phosphate

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