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The Impact of the Bark of Camel's Foot (*Piliostigmathonningii*) on the Physico-Mechanical Properties of Natural Rubber Vulcanizate

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Abstract: A study on the impact of the bark camel's foot "*Piliostigmathonningii*" on the physico-mechanical properties of natural rubber vulcanizate when used as filler has been carried out. Laboratory scale two roll mill was used to compound five different formulations of the natural rubber and the camel's foot bark filler according to the following ratios in grams: 100/0, 70/30, 60/40, 50/50, and 40/60 respectively. From the compounded formulations; test samples were prepared using the laboratory scale hydraulic press machine. Each prepared composite sample was tested for tensile-strength, elongation at break, hardness, abrasion and compression properties, and the result obtained showed that the tensile strength of the vulcanizate increased with increase in filler loading up till 50% of the natural rubber content but decreased when the filler is beyond that. The elongation at break decreased with the control sample having the highest elongation. The hardness of thevulcanizate increased with increase in filler loading. The abrasion resistance did not follow any consistent trend in particular. The compression-set was found to be decreasing with increase in filler loading.

Keywords: Bark of Camel's Foot, Piliostigmathonningii, Physico-Mechanical Properties, Natural Rubber Vulcanizate

1. Introduction

In natural rubber compounding, fillers are major additives. Incorporation of fillers into natural rubber matrix enhances properties such as tensile strength, modulus, tear strength, abrasion resistance, stiffness and processibility. Also significantly reduced by the addition of additives is the cost of the manufactured rubber products [1, 2]. The mechanism of elastomeric reinforcement by fillers has been reviewed byseveral workers [3]. One of the mechanisms by which particulate fillers reinforces elastomers is that reported by Beueche and Fleminert [4]. They considered that the effect of filler is to increase the number of chains, which shared the load of a broken polymer chain. Fillers used in rubber industries may be classified on the basis of sources, properties and colour. Those grouped on the basis of sources could be organic or inorganic fillers. Inorganic fillers are calcium carbonate, barites, silica etc. while that of theorganic fillers are phenolic resins, cyclised natural rubber etc. they are categorized either as reinforcing or non-reinforcing. While reinforcing filler on inclusion into a rubber mix increase the tensile strength, tear strength and abrasion resistance, the non-reinforcing only help to reduce the cost of product and act as diluents. Examples of reinforcing fillers are carbon black, silica etc. while examples of non-reinforcing fillers are mica powder, barium sulphate etc. [5]. In the rubber industry, fillers that are commonly in use are carbon black, calcium carbonate and china clay. Calcium carbonate ($CaCO_3$) had attracted considerable interest in recent years due to its availability and low cost [3]. For filled vulcanizates, the efficiency of reinforcement depends on a complex interaction of several filler related parameters. These include particle size, particle shape, particle dispersion, surface areas, surface reactivity, structure of the filler and the bonding quality between the fillers and the rubber matrix [6]. Again, reinforcing fillers shouldpossess a small particle size that is < 1000nm, a chemical active surface and a surface which is both porous and very irregular in shape to maximize surface contact between rubber and filler [7, 8].

Piliostigmathonningiiis a deciduous tree with a single stem. The tree is highly utilized by the local people. It flowers from December to February. An interesting feature of camel's foot is that the male and female flowers occur on different trees in most cases. If on the same tree, male flowers occur first and then female flowers later so that self-pollination is not possible. The flowers are not showy. Flowers are followed by large, thick, reddish brown, non-splitting pods about 30–70 mm long. The bark is dark brownish grey with a rough surface. A conspicuous feature of the tree is its large, simple, two-lobed, leathery leaves which resemble a camel's foot and account for the common name [9].

The use of agricultural by-products (maize cob, groundnut husk, cassava peel, cocoa pod husk, plantain peel, etc.) for producing vulcanisate materials that are competitive with synthetic composites has been gaining attention in the last decade because of availability of materials, easy processing, low cost, high volume applications and less abrasive to equipment. Agricultural residues as by-products and co-products of agriculture and processing of agricultural products represent a large feedstock of underutilized resources which can be used directly or converted by fairly simple chemical processes into higher value added materials.

2. Expeimental

2.1. Materials

Natural Rubber (NR), Bark of camel's foot (Piliostigmathonningii), Zinc oxide,Stearic Acid, Mercaptobenzothiazoldisulphide(MBTS), TrimethylQuinoline (TMQ), Sulphur.

2.2. Sample Preparation

The bark of the camel's foot (*Piliotigmathonningii*) was collected and was identified as *Piliostigmathonningii*. After collection, the bark was washed with water to remove the dirt. It was then cut into smaller pieces for easier drying and grinding. It was left in an open space for drying. After that it was grinded with a grinding mill machine (Thomas-Wiley laboratory mill, model 4 with mesh size 2mm) into a fine powder. It was then sieved to obtain a finer powder, using a 400μm standard sieve. Compounding with natural rubber was carried out in a laboratory scale two roll mill (Model No: 5183). The natural rubber was first masticated for about five minutes to ease incorporation of the additives during compounding. It was followed by the sequential addition of the rest of the materials as presented in table 1 after the formation of bank. It was thoroughly mixed throughout the compounding by cross-mixing with a knife for even mixture. The nip of the rolls was adjusted whenever the need arises. The temperature of the rolls was kept at 80°C.

Table 1. *Formulation Table.*

Ingredients	**Pphr**				
Samples	A	B	C	D	E
Natural Rubber (NR)	100	70	60	50	40
Zinc Oxide (ZnO)	5	5	5	5	5
Stearic Acid	2	2	2	2	2
Tri-methyl Quinoline (TMQ)	1.5	1.5	1.5	1.5	1.5
*Piliotigmathonningii*bark (Filler)	0	30	40	50	60
Mercaptobenzothiazoldisulphide (MBTS)	3	3	3	3	3
Sulphur	2.5	2.5	2.5	2.5	2.5

After compounding, the samples were cured into flat square sheets using hydraulic pressing machine (carver, model 385-0) at temperature of 150°C for about 15-20 minutes. Samples for testing were cut out from the cured square sheets.

2.3. Tensile Test

The tensile test of each dumb-bell shaped test piece measuring 6 by 2 cm with a gauge length of 2 cm was carried out using the material testing machine (Type BDO-FBO.5th).

2.4. Hardness Test

Hardness of the vulcanisates was determined by a hardness testing machine (Durometer, model 5019). Each piece of the samples was placed on the surface below the indenter. The meter of the hardness tester was set at the zero mark and then the reading was taken after the indenter was pressed against the test piece using the handle of the machine. The procedure was carried out three times at different points and the average value was taken.

2.5. Abrasion Test

Each sample was measured to a uniform weight of 12.2 g, and was pressed against a sand paper attached to an electrical motor for a period of time of about 12 seconds each. Afterwards, each sample was reweighed. The weight loss (in percentage) for each sample was obtained using the following expression:

$$weightloss = \frac{\text{initial } wieght - finalweight}{\text{initial } weight} \text{X100} \quad (1)$$

2.6. Compression Set Test

From each cured sample a test piece was cut to an equal size of 4 by 4 cm. The thickness of each test-piece was measured using a Vernier caliper. Afterwards, each test-piece was compressed using a hydraulic press (carver, model 385-0) under the pressure of 1600 metric tons for a period of 24hrs. And after that, it was removed and the final thickness was measured.

2.7. Water Absorption Test

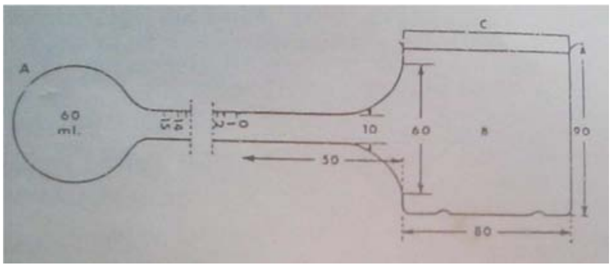

Fig. 1. *Kubelka Apparatus (Dimensions in millimeters).*

The water absorption test was carried out using the kubelka apparatus (Figure 1). The interior surfaces of the apparatus were wet with distilled water, and the water was poured away. The apparatus was placed with the bulb "A" directly below the cylinder "B". The apparatus was filled approximately to the zero mark with distilled water by running into it75ml at 20±2°C. The specimen was weighed and then was placed in the cylinder "B" and water was run into this part of the apparatus to immerse the specimen. The cylinder was closed with a rubber stopper "C" to prevent evaporation losses. After 24hrs, the apparatus was turned so that the liquid drains into the bulb "A". The volume of the liquid absorbed was measured after one minute of drainage. The volume of water absorbed by each specimen was measuredusing the following formula:

$$P = \frac{v}{V} \text{ x } 100 \quad (2)$$

Where P = water absorbed in ml of water per 100 of specimen, v = volume of water absorbed (ml), and V = volume of the specimen.

3. Resultand Discussion

3.1. Tensile Strength

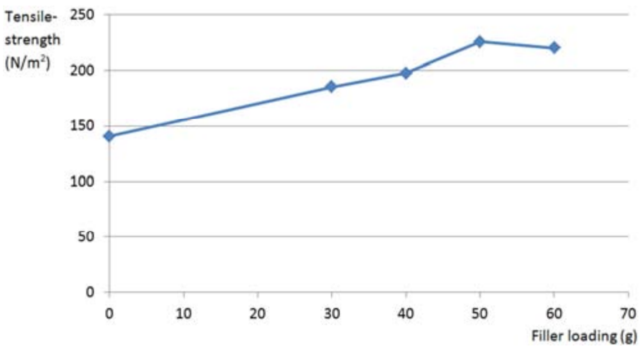

Fig. 2. *Effect of Piliostigmathonningii Loading on Tensile Strength of Natural Rubber Vulcanizate.*

The result of the tensile strength test of the samples is shown in figure 2. From the figure, it can be seen that the tensile strength of the vulcanisates increased steadily from 140 N/m^2 to a maximum value of 225 N/m^2 as the filler content of the vulcanisates was increased from 0 g to 50 g respectively. This can be attributed to the reinforcing effect of the filler (Piliostigmathonningii) which manifests itself to rise in stiffness, leading among other things, to greater tensile strength [10]. However, beyond the 50 g filler content, that is at 60 g filler content the corresponding tensile strength decreased slightly from 225 N/m^2 to 223 N/m^2 respectively. This altercation in the original trend can be attributed to the dispersion of the filler in the matrix which of course has become obvious as the quantity of the filler was increased. It will therefore be permissible to conclude at this point that for maximum reinforcement to be obtained the filler content in the matrix should not exceed 50 g. Several workers [11, 12] had reported that significant reinforcement is only attainable when the particle size of thefiller is of the order of 0.02-0.05 µm. Parkinson [6], foundthat decreasing the particle size of carbon black filler generally enhanced mechanical properties such as tensile and tears strength. The tensile strength at 50 wt% is the highest and also greater than the strength of unfilled natural rubber.

3.2. Elongation at Break

The result of the elongation at break is shown in figure 3. From the graphical illustration it can be seen that the elongation at break of the control sample (i.e 0 g of the filler) is the highest, which then decreases as the filler content of the samples were increased. Decreased elongation at break with increasing filler content may be due to the stiffening of the polymer chain and hence resistance to stretch when strain is applied [13, 14].

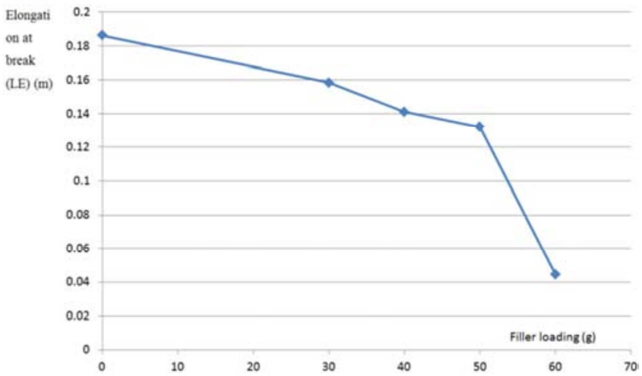

Fig. 3. *Effect of Filler Loading on Elongation at Break of Natural Rubber Vulcanizate.*

3.3. Hardness

Figure 4 shows the result of the hardness of natural rubber vulcanisates and the hardness is being affected by the addition of the filler (Piliostigmathonningiibark). The graphical illustration has shown that the hardness of the vulcanisates increased with the addition of the filler, and as more filler is added the hardness also increases in that order. It is expected because as more filler particles get into the rubber, the elasticity of the rubber chain is reduced, resulting in more rigid vulcanizates. The hardness enhancement can be attributed to better wetting and dispersion of the fillers which happen to be a biomaterial.

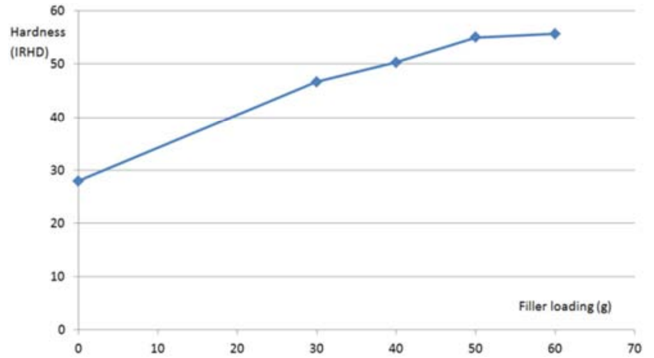

***Fig. 4.** The Effect of Filler Loading on Hardness of Natural Rubber Vulcanisate.*

3.4. Abrasion

Figure 5, shows the effect of the filler content on the abrasion resistance of the vulcanisates. The abrasion resistance of the control sample has been reduced by the addition of the filler. As more filler is added, the abrasion resistance of the filled vulcanisates was reduced gradually except for the 60 g filler content where there is a sharp rise in the abrasion resistant but still below that of the control sample and 30 g filler content respectively. The observation may therefore be attributed to the degree of dispersion of the fillers.

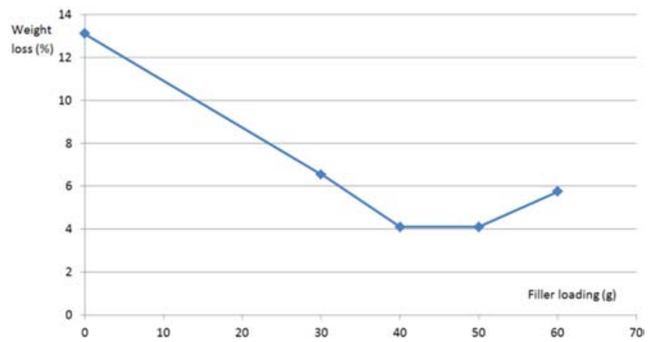

***Fig. 5.** The Effect of Filler Loading on Abrasion Resistant of Natural Rubber vulcanizate.*

3.5. Compression-Set

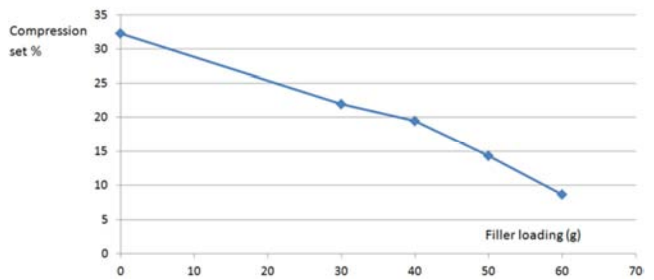

***Fig. 6.** Effect of Filler Loading on Compression Set of Natural Rubber Vulcanisate.*

Figure 6, which is the compression set result, showed that the unfilled system had the largest compression. Compression decreases with increase in filler loading. The observation can be attributed to the amount of filler incorporated into the matrix, the degree of dispersion of the fillers and its particles size.

3.6. Water Absorption

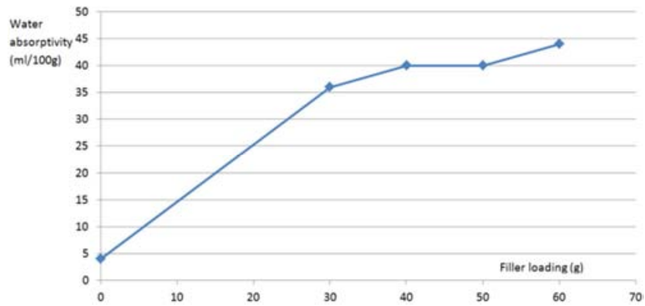

***Fig. 7.** Effect of Filler Loading on Water Absorption of Natural Rubber Vulcanisate.*

Figure 7 shows the effect of the filler content on the water absorption ability of natural rubber vulcanisate. The control sample has the least water absorption property, and as the filler content was increased the water absorptivity of the resulting vulcanisatesalso increases.

4. Conclusion

The impact of the bark of camel's foot (Piliostigmathonningii) on the physico-mechanical properties of natural rubber vulcanisates has been studied. The addition of the filler has some effect on some of the physico-mechanical properties of the vulcanisates that were tested. Properties such as the tensile strength, hardness, and water absorptivity are enhanced by the addition of the filler; they also increase as the filler content are increased. This implies therefore that the bark of camel's foot can serve as reinforcing filler for natural rubber vulcanisate. However, some properties such as the elongation at break, abrasion resistant, and compression set were reduced as the fillers were added.

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