CHARACTERIZATION OF BANANA STEM FIBER AND EGG SHELL POWDER – NATURAL RUBBER COMPOSITES

Nyein Chan Aye[1], Nwe Nwe Aung[2], Nyo Nyo Myint[3], Thinzar Nu[4]

Abstract

This research work mainly concerned with the characterization of banana stem fiber(BSF) and egg shell powder(ESP)- natural rubber composites. Banana stem fiber and egg shell powder were used as fillers in the process of preparation of natural rubber composites. The banana stem fiber and egg shell powder-natural rubber composites were prepared by moulding method with various weight ratio (5 %, 10 %, 15 %, 20 %) of banana stem fiber and egg shell powder and were also characterized by modern technique such as SEM. The mechanical properties such as hardness, specific gravity, tensile strength, elongation at break and tear strength of banana stem fiber and egg shell powder- natural rubber composites were determined by standard rubber testing methods. From the experimental results, it was found that as the BSF and ESP loading increased, hardness and specific gravity also increased. Tensile strength of BSF and ESP composites decreased as BSF and ESP loading increased. Scanning electron micrograph results of both revealed that the distribution and adhesion interaction between the fillers and rubber matrix was good. It was generally observed that the egg shell powder presented better potentials for reinforcement than the banana stem fiber. These composites can be used as an alternative for various industrial applications.

Keywords: Natural rubber, banana stem fiber, egg shell powder, filler, mechanical properties

Introduction

Rubbers are widely used in various industrial applications, such as tires, seals and gaskets in automotive, aerospace, food and pharmaceutical industries, etc. credit to their highly non-linear elastic behaviour. Among all the rubbers available in the market, natural rubber which is obtained from the latex of the *Hevea brasiliensis* tree has good physical properties, such as high mechanical strength, low heat build-up and resistance to impact and tear.

1. PhD Student, Department of Chemistry, University of Yangon
2. Dr,Lecturer, Department of Chemistry, University of Yangon
3. Dr,Lecturer, Department of Chemistry, Mawlamyine University
4. Dr, Associate Professor, Department of Chemistry, University of Yangon

However, natural rubber has its drawback as well, such as low flame resistance, sensitivity to chemicals and solvents mainly due to its unsaturated hydrocarbon chain structure and its non-polar character, causing limitation in variety of applications. Hence, rubbers are reinforced by mixing with petroleum-based fillers, especially carbon black to enhance the mechanical properties of cross-linked rubbers. However, the petroleum reservoir is depleting due to its limited reserve and increasing demand from various industries. Furthermore, the world is facing environmental degradation due to excessive non-degradable waste rubber materials. Hence, developing alternative rubber composite materials which are cost effective, environmental friendly and biodegradable at the product end of life are amongst the most highly regarded research initiative. (Chai *et al*., 2016)

The advantage of composite material is that the high strength and stiffness of the filler can be incorporated into the soft, elastic rubber matrix. Among current biocomposites research works, food solid waste materials have been attractive bio-fillers for polymeric composites due to economic and environmental advantages. These bio-fillers are extracted from plants (e.g., oil palm, flax, jute, banana, hemp, etc.) and animals (e.g., eggshell, shellfish shell, shrimp shell, etc.) which are abundant and can be potentially used to replace the conventional reinforcing fillers. (Mohammed and Hadi, 2012)

Materials and Methods

Materials

Natural rubber (Grade 1) was obtained from Mudon Township, Mon State. The banana stems were collected from Mayangone Quarter, Mawlamyine Township, Mon State. To prepare eggshell powder used as the biofillers, chicken eggshell wastes were collected from various tea shops and home. The other compounding ingredients used were zinc oxide, stearic acid,N-cyclohexyl-2-dihydro-benzothiazolesulphonamide(CBS),2,6-di-tert-butyl-4-hydroxytoluene (BHT) and sulphur, which were supplied by Ministry of Agriculture, Livestock and Irrigation, Department of Agriculture, Rubber Research and Development Centre.

Preparation of Materials

Egg shell powder

The egg shell wastes (Figure 1) collected were washed thoroughly with water for several times. The egg shell membranes were removed and the egg shell pieces were dried under hot sun for three days (Figure 1). After the drying process, the egg shell pieces were grounded into powder form (Figure 2) by using domestic grinding machine.

Figure 1: Egg shell sample

Figure 2: Egg shell powder

Banana stem fiber

Banana stem was washed with water several times and dried under hot sun. And then, the dried stem was crushed and beaten by hand to obtain banana stem fiber. These fiber was ground by grinding machine (Figure 3).

Figure 3: (a) Banana stem (b) Banana stem fiber (c) Banana stem powder

Rubber composites

The formulation of the rubber is given in Table 1. The mixing of the rubber compounds were carried out by using a laboratory two roll open mixing millat Rubber Research and Development Centre. The nip gap, mill roll speed ratio, time, temperature of mixing, number of passes and sequence of addition of ingredients during mixing were kept under same conditions for all compounds. The amount of fillers (egg shell powder and banana stem fiber) were varied 5-20 % in each composites.

Table 1: Formulation of Rubber Compounds

Ingredients	Amount (g)
Stearic acid	1.0
Zinc oxide	5.0
CBS	0.5
BHT	1.0
Sulphur	2.5
Fillers (BSF or ESP)	5-20

BSF - banana stem fiber	B_1 = 5 % BSF	E_1 = 5 % ESP
ESP - egg shell powder	B_2 = 10 % BSF	E_2 = 10 % ESP
g - gram	B_3 = 15 % BSF	E_3 = 15 % ESP
	B_4 = 20 % BSF	E_4= 20 % ESP

Methods

Some mechanical properties of composite such as hardness, specific gravity, tensile strength, elongation at break and tear strength were carried out by appropriated standard methods.

Determination of hardness

Hardness is a measure of the resistance to a reversible deformation of the rubber by a rigid indentor and widely used as a quality control measure. The hardness was measured using a Wallace Shore Adurometer according to ASTM D2240.

Determination of specific gravity

Specific gravity is a measure of the ratio of mass of a given volume of materials at 23 °C to the same volume of deionized water. The specific gravity was measured using a Wallace test equipment according to ASTM D792.

Determination of tensile strength

The fabricated composite was sized to obtain the required dimension and were made ready for testing as per ASTM: D638 standards. A universal testing machine was used to carry out the experiment at room temperature.

The standard dimension of tensile strength specimen is of length 165mm, 19mm breadth and 7 mm thickness. Test involved mounting the specimen and subjecting it to tension until fractures happened. The tensile load was recorded with respect to increase in gauge length. Each of 8 specimens namely B_1, B_2, B_3, B_4, E_1, E_2, E_3 and E_4 were prepared and experiment was repeated to obtain average values.

$$T_s = \frac{F}{W \times t}$$

T_s = tensile strength in Mega Pascal (MPa)
F = the maximum force recorded in Newton (N)
W = width of the narrow portion of the die in mm
T = thickness of the test length in mm

Study of surface morphology by scanning electron microscopy

The fracture behaviour of the specimens were observed using scanning electron microscope (Model - JOEL JSM- 5610) after sputter coating the samples with platinum for 45 seconds in a JOEL – JFC 1600 fine coater at a voltage of 12 kV. Photographs were taken at various magnifications.

Results and Discussion

Mechanical Properties

Hardness

Figure 4 shows that the hardness of composites increased as BSF and ESP % increased from 5 to 20 %. This is due to increasing the surface area of BSF and ESP in contact with rubber. The explanation of such behaviour agrees with the results of elasticity because hardness gives indication to modulus of elasticity for rubber under simple strain condition.

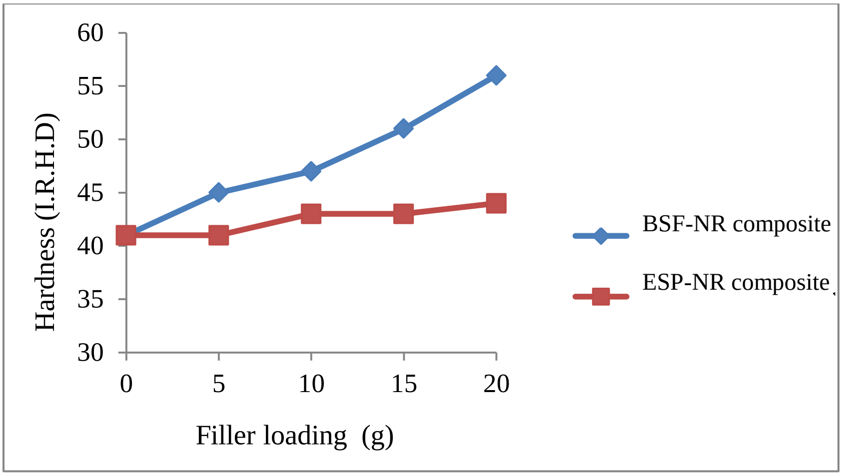


Figure 4: Hardness of prepared banana stem fiber-natural rubber composites and egg shell powder-natural rubber composites

Specific gravity

Figure 5 shows increasing of specific gravity of composites with increasing loading BSF and ESP %. This can be explained as follows that the particles interfere between rubber chains and make it denser per unit volume.

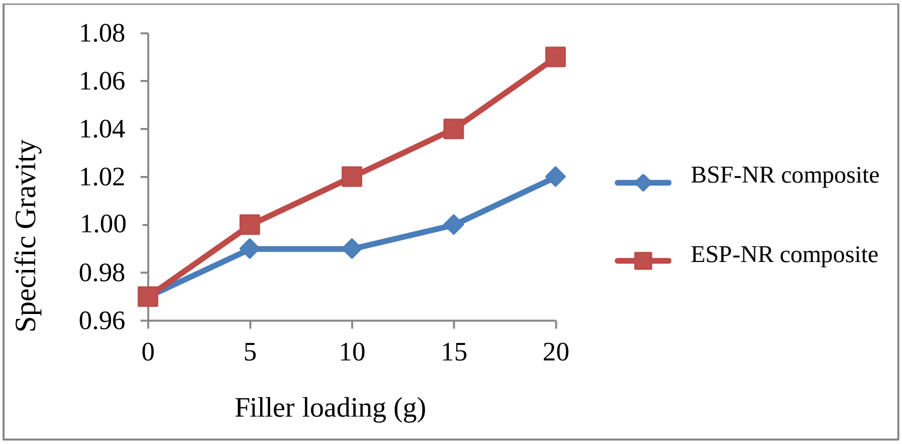


Figure 5: Specific gravity of prepared banana stem fiber-natural rubber composites and egg shell powder-natural rubber composites

Tensile strength

Figure 6 shows that the tensile strength of composites decreased as BSF and ESP % increased. The strength of particulate- filled polymer composites depends, to a great extent, on the interfacial adhesion between the matrix and the filler which will facilitate the transfer of a small section of stress to the filler particle during deformation. In this study, no coupling agent has been added into the BSF-NR and ESP-NR. In the absence of any coupling agent, the interfacial adhesion between the NR matrix and the BSF and ESP have obviously not been improved. Without the chemical modification, there is simply adhesion of the polymer to the filler through weak bonding, i.e., Vander Waals or induction interaction.

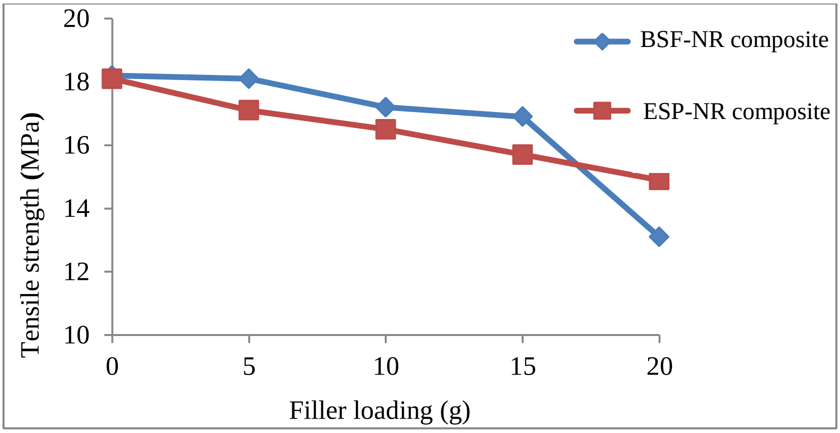


Figure 6: Tensile strength of prepared banana stem fiber-natural rubber composites and egg shell powder-natural rubber composites

Elongation at break

In Figure 7, it could be seen that the elongation at the break of composites decreased with increasing filler loading. Increased filler loading in the (NR) matrix resulted in the stiffening and hardening of the composite and the recipe take away from ductile.

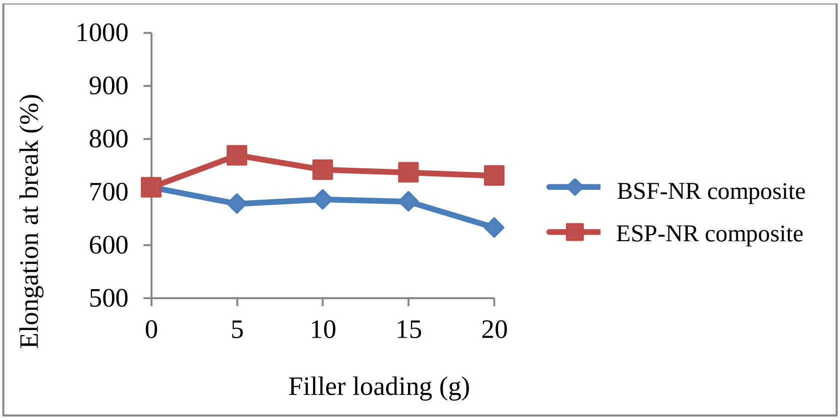


Figure 7: Elongation at break (%) of prepared banana stem fiber-natural rubber composites and egg shell powder-natural rubber composites

Tear strength

According to Figure 8, the tear strength results for ESP-NR composites decreased with increasing filler loading. On the other hand, the tear strength results for BSF-NR composites were fluctuated.

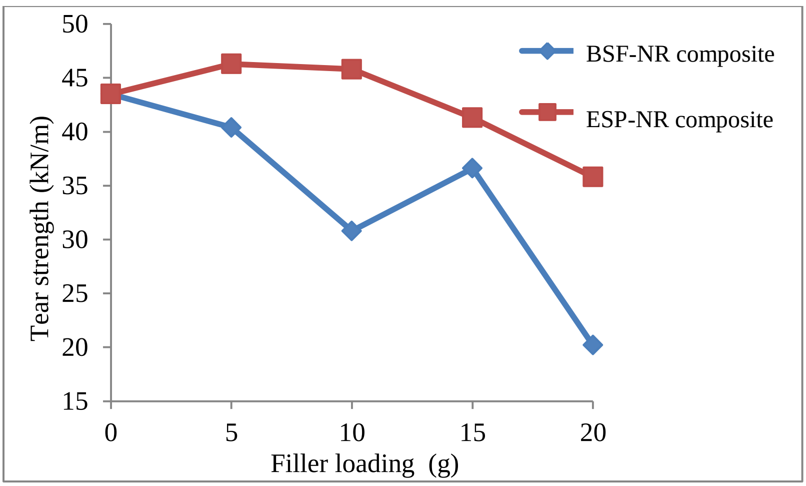
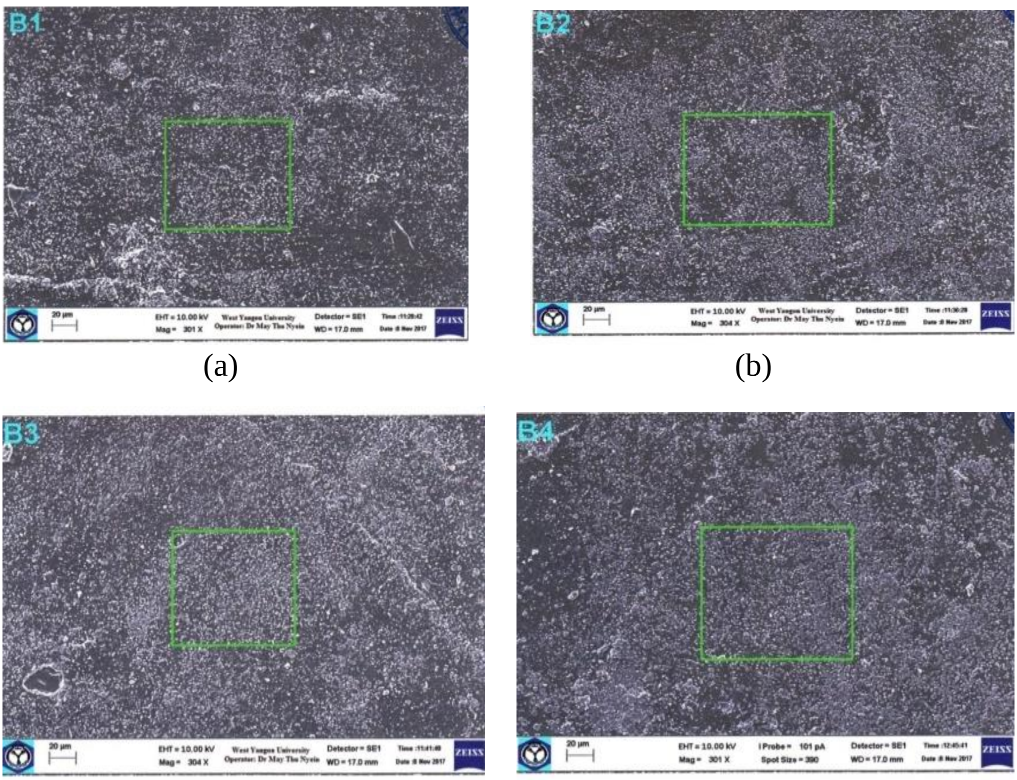


Figure 8: Tear strength of prepared banana stem fiber-natural rubber composites and egg shell powder-natural rubber composites

Morphological characteristics

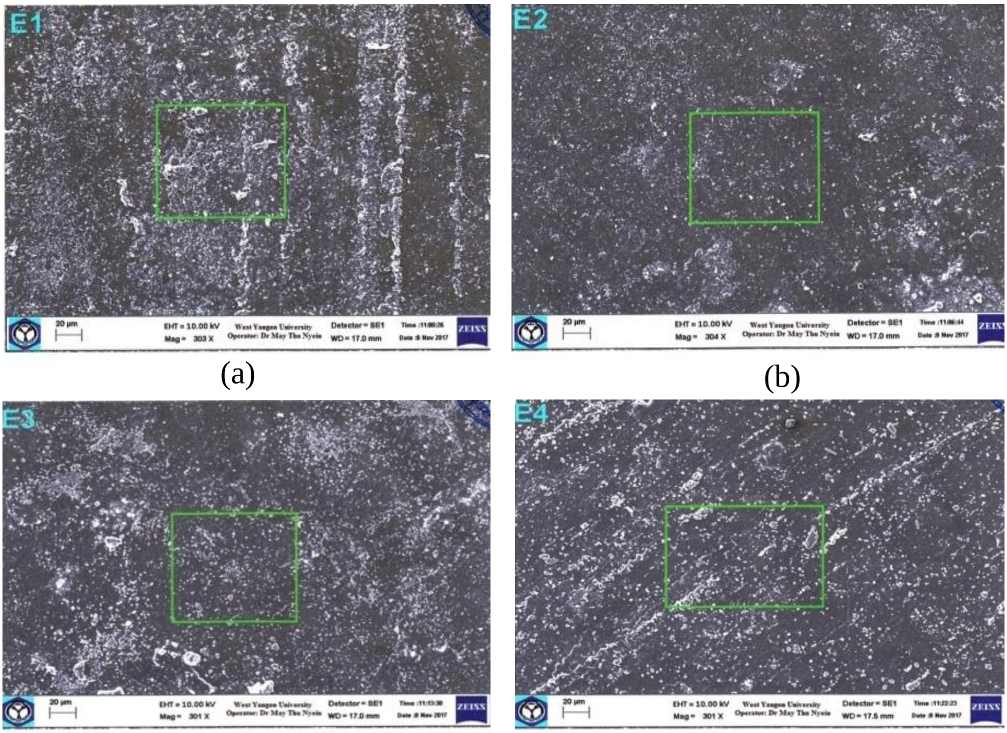
Morphological characteristics of rubber composites obtained from banana stem fiber filled and egg shell powder filled natural rubber (Grade 1) with various fillers loading were investigated. Figures 9 (a), (b), (c) and (d) show the micrographs of B_1, B_2, B_3, B_4 composites. Among them, Figure 9 (c) shows the surface image of B_3 composite and it has uniform matrix with smooth interface having perfect regular shape of homogenous phase materials. Figures 10 (a), (b), (c) and (d) show the micrographs of E_1, E_2, E_3, E_4 composites. Among them, Figure 10 (b) indicated the surface image of E_2 composite which was more smoothand homogenously distributed through the particles on the composite, so the quality of it may be better than others.



(a) (b)

(c) (d)

Figure 9: Scanning electron micrograph of B_1, B_2, B_3, B_4 composites



(a) (b) (c) (d)

Figure 10: Scanning electron micrograph of E_1, E_2, E_3, E_4 composites

Conclusion

Banana stem fiber (BSF) and egg shell powder (ESP) were incorporated as biofillers in natural rubber composites. The mechanical properties and morphological properties of banana stem fiber and egg shell powder reinforced natural rubber composites have been investigated. As for the mechanical properties, it was concluded that as BSF and ESP loading increased, the hardness and specific gravity also increased. However, the tensile strength decreased as the filler content increased resulting in a poor dispersion of the filler on rubber matrix. The elongation at break and tear strength results for ESP-NR composites were decreased with increased filler percent in the rubber. The tear strength result for BSF-NR composites was fluctuated nature. The characteristics of composites were studied using scanning electron microscope. The results of this study was opened the possibility to replace the use of existing fillers and decreased the cost of the products.

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