

Nigerian Journal of Polymer Science and Technology, 2020, Vol. 15, pp58-65

Received: 27/07/2020

Accepted: 30/09/2020

Utilization of Carbonized Cashew Nut Shell Powder (CNSP) Particles for the Reinforcement of Natural Rubber Filled Composite

¹Okele, A.I., ²Gimba C.E., ²Mamza, P.A.P., and ²Abba, H.

¹ Department of Polymer Technology, Nigerian Institute of Leather and Science Technology, Samaru-Zaria

² Department of Chemistry, Ahmadu Bello University, Zaria.

Corresponding Author: walislove4real@yahoo.com

Abstract

Natural rubber was reinforced with particles of cashew nut shell powder (CNSP) as filler. The filler was loaded in the compound from 0-50pphr of natural rubber. The cashew nut shell powder was carbonized and characterized for pH, moisture content, particle size, bulk density and ash content. The characterization results revealed 8.13 pH value, 0.58% moisture content, 276.4 d.nm at 69.2% and 404 d. nm at 30.8% particle size, 0.4032g/ml bulk density and 15.99% ash content. The mechanical analyses carried out were tensile strength, compression strength, hardness and abrasion resistance. The obtained results showed that as filler loading was increased from 0-50pphr, the tensile strength also increased from 0.30Mpa to 5.60Mpa which is a good indication of reinforcement of the filler. The compound filled with 10pphr gave the best percentage compression strength of 11.1% while that of 50pphr revealed 22.2%. The hardness values were not left out in the trend as the filler also increased, the hardness resistance also increased from 25-44 IRHD. The abrasion resistance increased as the filler loading was increased from 0-40pphr with abrasion values of 6.78, 0.84, 0.57, 0.35 and 0.21% respectively before it increased at 50pphr to 1.73%.

Key words: Ash content, Fillers, Moisture content, Natural rubber and Tensile strength

1.0 Introduction

The need to develop industrial products from renewable, environmental friendly and sustainable raw materials and processes is attracting global attention. Natural rubber is a gummy substance isolated from the white fluid of certain tree species called *Hevea Brasiliensis* with major chemical constituent of natural hydrocarbon polymer (polyisoprene) of 2-methyl-1,3 butadiene. It is the major feed stock to the rubber industries, however, in its raw state, natural rubber is not suitable for use in any given application because of their viscoelasticity

(tendency of both plastic and elastic behaviour)(Egwakhide et al; 2013).

Nanotechnology, technologies at nanoscale, is a new science that involves enhancing and engineering the material properties and technologies at the nanoscale. In comparison with the microtechnology, nanotechnology leads to extremely different phenomena and performances. The nanocomposite products contain reinforcing or fillers in nanoscale (less than 100 nm). Most of the mechanical properties can be improved using nanoscale fillers. Researchers have studied the current

and future prospective products within the nanoscience(Islam et al; 2013).

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 (oboh et al; 2008).

The mechanism of elastomeric reinforcement by fillers has been reviewed by several workers. One of the mechanisms by which particulate fillers reinforces elastomers is that reported by Bueche and Flemimert. 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(Egwakhide et al; 2013).

Composites are multifunctional materials of two or more distinct components. Macroscopically, they have identifiable distinct interface that separate them. Polymer composites basically have discontinuous phase (fillers) embedded in a continuous phase (polymer). They are termed hybrid composites when two or more discontinuous phases are incorporated into a continuous phase. Hybrid fillers reinforced composites have been reported to enhance the mechanical, thermal, damping properties compared to single filler reinforced composites(Oboh et al; 2018b). Extensive works have been going on in the search for possible substitutes for some grades of carbon black as filler for rubber products. For instance, by-products from agricultural sources have been used – maize cobs, rubber seed shell, ground nut husk, cassava peeling,

plantain peel, coconut fibre, rubber seed shell carbon (Aguele and Madufor, 2012)

2.0 Materials, Equipment and Methodology

Cashew nut shell was locally sourced from AuchCommunity of Edo State. Natural rubber was obtained from Rubber Research Institute of Nigeria, Iyanomo, Benin city, Edo State. All other compounding additives used (zinc oxides, stearic acid, trimethylquinoline, Sulphur and mercaptobenzothiazole disulphide) are of analytical grades and products of British Drug House (BDH), England.

2.1 Equipment

The equipment used are Endocott test sieve shaker, by Endocott test sieve Ltd., London, Ball Miller by Pascal Engineering Co. Ltd. Sussex, England, Furnace, soxhlet apparatus, beakers, stop watch and Two roll mill, Reliable Rubber and Plastics Machinery, model 5189, Advanced Material Testing Machine, Zwick/Roell, Hardness tester MuerFransisco, Munoz Irles, Abrader, Santra test equipment, and Wallace compression set machine.

2.2 Methodology

2.2.1 Preparation and Characterization of Filler

Cashew nut shell powder was winnowed to remove sand particles and other adhering foreign bodies and then washed. The washed Cashew nut shell powder was placed in the planetary mill with a spherical grinding media which consists of planetary balls (< 0.1mm diameter) made of hardened steel (0.24 to 0.95cm diameter). The Cashew nut shell powder and the grinding media were placed in a stationary tank followed by an agitation with an armed shaft rotating at 250rpm. The forces of shear and impact exerted by the grinding media on the Cashew nut shell powder reduced it to a

dispersion of fine powder. The resultant slurry formed was discharged, air-dried and further oven-dried. The cake was further extracted with N-hexane to discard off the oil in the Cashew nut shell powder and was carbonized at the temperature of 200°C, the residue was ball milled using the top-down technique (i.e. critical speed grinding under a continuous process of approximately 48hrs) to a fine particle size. Standard tests method was used to characterize the powder for moisture content (ASTM 1509) at 105°C, pH (ASTM 1512) and particle size [Ojinmah et al; 2017].

2.2.2 Compounding of the composites

The compounding of the rubber with other additives were done using a laboratory two roll mill in accordance with ASTM D3184-80 method at temperature of $70 \pm 5^\circ\text{C}$, followed by in-situ moulding and curing at 130°C with a hydraulic press machine.

2.2.3 Tensile Strength

These tests were conducted in accordance to ASTM D412. Tensile tests were carried out at room temperature using an Advance Material Testing machine model 3366 with a

load cell 1kN. Pre-moulded dumbbell shaped specimens with dimensions of 50 X 8 X 4 mm³ were used to perform the experiment at a loading speed of 200 mm/min (Islam et al; 2013)

2.2.4 Hardness test

The hardness test of a rubber is the relative resistance of the surface to indentation by an indenter of specified dimension under a specified load. Hardness of the vulcanisates was determined by standard dead load method (BS903 part A 26) [Egwakhide et al; 2007].

2.2.5 Abrasion resistance

Wallace Akron tester was used in accordance with BS method Abrasive resistance index = $(S) 1000 / T$ (1) [Egwakhide et al; 2007].

2.2.6 Compression set

Wallace compression set machine (Mode/Ref No (2, H250) was used to determine the compression set of the vulcanizates. Compression set % = $t_0 - t_r / t_0 \times 100$ (2) [Egwakhide et al; 2007].

Table 1: Formulation table

S/NO	Ingredients	PPhr
1	Natural rubber	100
2	Zinc oxide	5
3	Stearic acid	2
4	Trimethylquinoline (TMQ)	1.5
5	Mercaptobenzothiazole	3
6	Cashew shell powder	0,10,20,30,40,50
7	Processing oil	2
8	Sulphur	3

3.1 Results and Discussions

Table 2: Characterisation Results

S/NO	Characterisation	Results
1	Moisture content (%)	0.58
2	Bulk density (g/ml)	0.4032

3	Ph	8.13
4	Ash content (%)	15.99
5	Oil absorption number (ml/100g)	64,7
6	Iodine absorption number (cm ³ /100g)	109.94
7	Refractive index	1.586
8	% Loss on ignition at (950°C)	11

also influenced by the presence of volatile substances, the porosity of the surface and the presence of extractable (ASTM-D1510).

The result Cashew nut shell powder (CNSP) was characterized in terms of moisture content, pH, bulk density, particle size, ash content; oil absorption number, refractive index and iodine absorption number see Table 2. The above parameters were necessary because they play an important role in determining the distribution and dispersion of the fillers in natural rubber (Egwakhideet *al.*, 2017).

The pH of the filler slurry shows that the filler is alkaline in nature with alkaline value of 8.13 which in turns accelerates vulcanisation, moisture content of 0.58%, bulk density of 0.4032 g/ml, ash content of 15.99%.

The bulk density result which reveals 0.4032 g/ml is an indication of the material being light weight filler and its alkaline nature will help to accelerate vulcanization.

The low moisture content of 0.58% was as a result of the filler being carbonized at 200°C.

The iodine absorption number is the amount of iodine taken up by 100 g of the material. It is also a direct proportion to the surface area. The absorption number is in Table 2 shows that cashew nut shell powder has an iodine absorption number of 109.94cm³/100g, this implies that the higher the iodine absorption number the higher the

surface area and the better reinforcement the filler will be.

The oil absorption which is the amount of linseed oil required to exactly wet 100g of the pigment, depending on the surface, particle shape, surface type (morphology) of the pigment/extender will determine the quantity of oil to be absorbed (ASTM D281-95, 2007). The higher the oil absorption numbers of the pigment/extendors, the higher the materials surface area and the more binder it will require to bind it. The results obtained in Table 4.2 shows that CNSP has the lowest oil absorption number of 64.7ml, per 100g of the material. This in turn categorised CNSP as a medium oil absorption material materials.

The loss on ignition (LOI) is the mass loss from solid combustion residues upon heating in an air or oxygen atmosphere to a prescribed temperature. The mass loss can be due to loss of moisture, carbon, sulphur, and so forth from the decomposition or combustion of the residue (ASTM D7348-08).

The results obtain shows that CNSP has a loss on ignition of 11% at 950°C which signifies that the CNSP has higher volatile matters such as moisture, carbon and sulphur contents in it. The weight loss on ignition is a measure of carbon content lost during burning. The larger the non carbon element of the agricultural by-product, the lower reinforcing the fillers will be for elastomers (Ojinmah et al; 2017).

Refractive index is mostly used to identify a particular substance, confirm its purity or measures its concentration. It is used to measure the concentration of solutes in an aqueous solution.

and CB are 1.586 per 0.1g of the material dissolved in 50ml of methanol; these results were not far from that of Aguele et al; (2012) which reported R.I of carbonized coir to be 1.5191.

The results obtained from Table 2 showed that the refractive indices of CNSP, JSSP

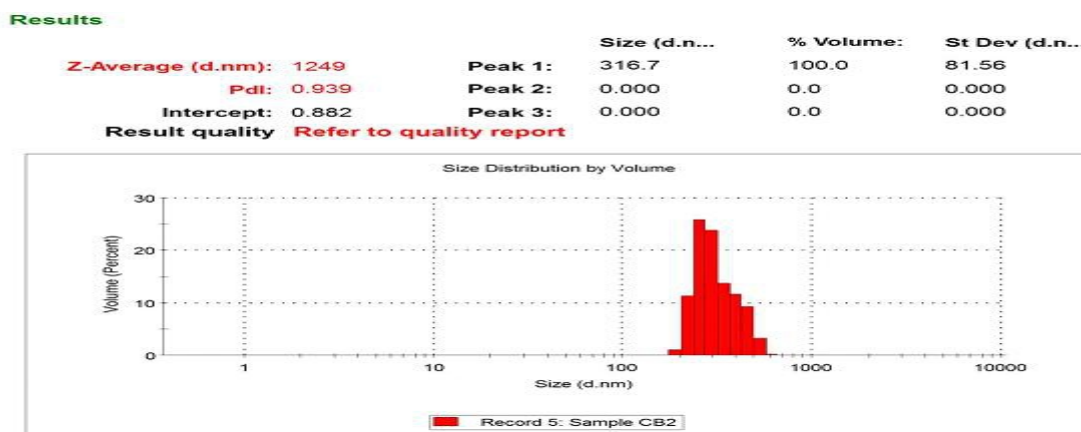


Figure 1: Dynamic light scattering of Cashew nut shell powder (CNSP)

The dynamic light scattering was use to analyse the particle size of the filler, the results obtained revealed that 100% of the particle size of the carbonized cashew nut shell powder falls in 316.7 d.nm, which falls

above the 0 to 100 nm range to be classified as nano filler, rather can be categorized as semi-nano filler

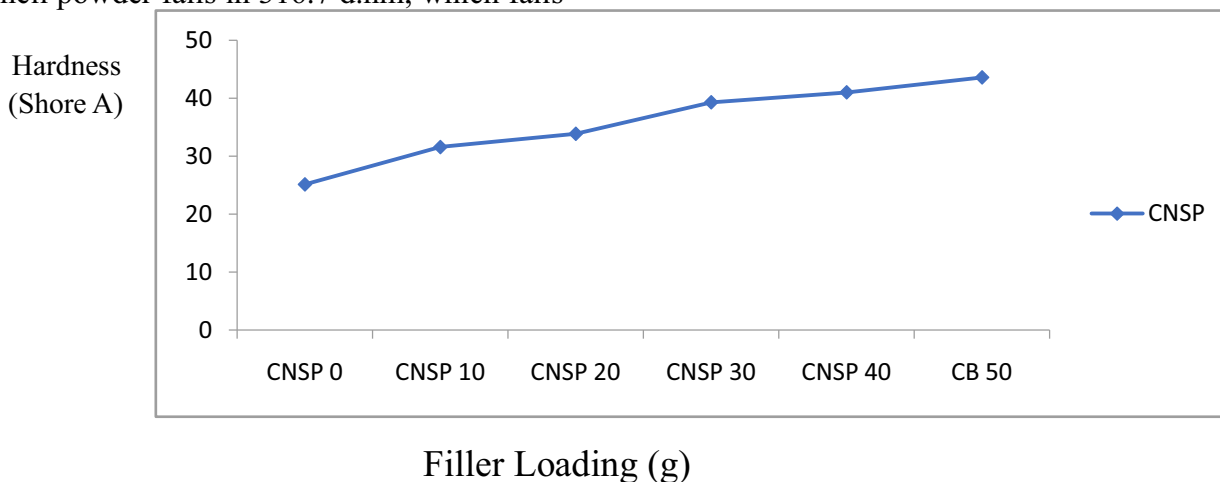


Figure 2: Effect of filler loading on Hardness

The mechanical properties of the compound showed that hardness values increased as the filler content increased from 0-50pphr. See

Figure 2. With the blank compound showing hardness value of 25 IRHD and that of 10pphr of CNSP showed a hardness value of 32 IRHD. The result further increased to

that reinforced with 50pphr with a hardness value of 44 IRHD.

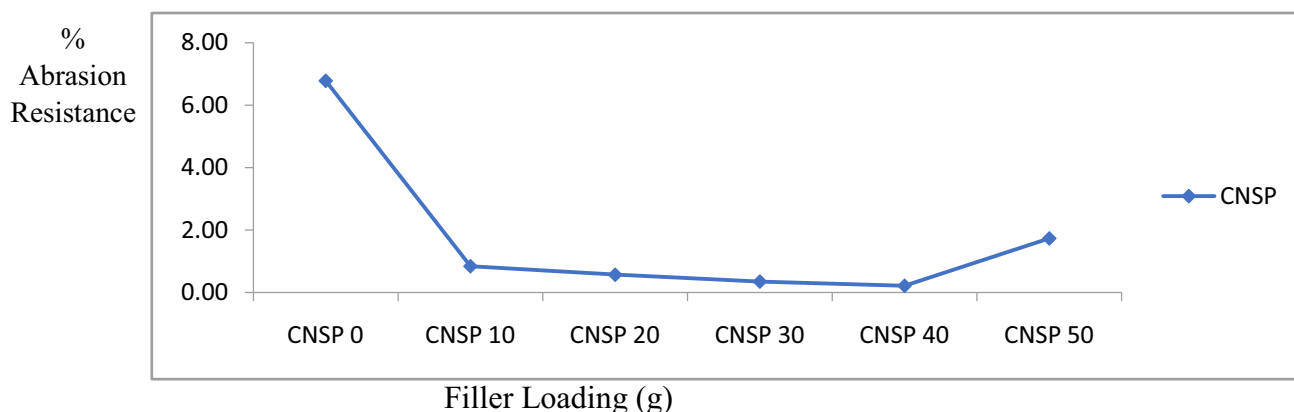


Figure 3: Effect of filler loading on Abrasion resistance

Figure 3 shows the results for percentage abrasion resistance which reveals reinforcement of filler with respect to the utilization was particulate nature. The compound without filler showed the poorest abrasion resistance percentage with value of 6.78% wear and the result became better as the filler loading increased from 10-40pphr with abrasion values of 0.84, 0.57, 0.35 and 0.21% respectively. And it later increased to

1.73% at 50pphr. This could be as a result of too much filler dosage and the NR matrix was no longer sufficient to wet the filler which can as well give rise to inhomogeneous compound mix.

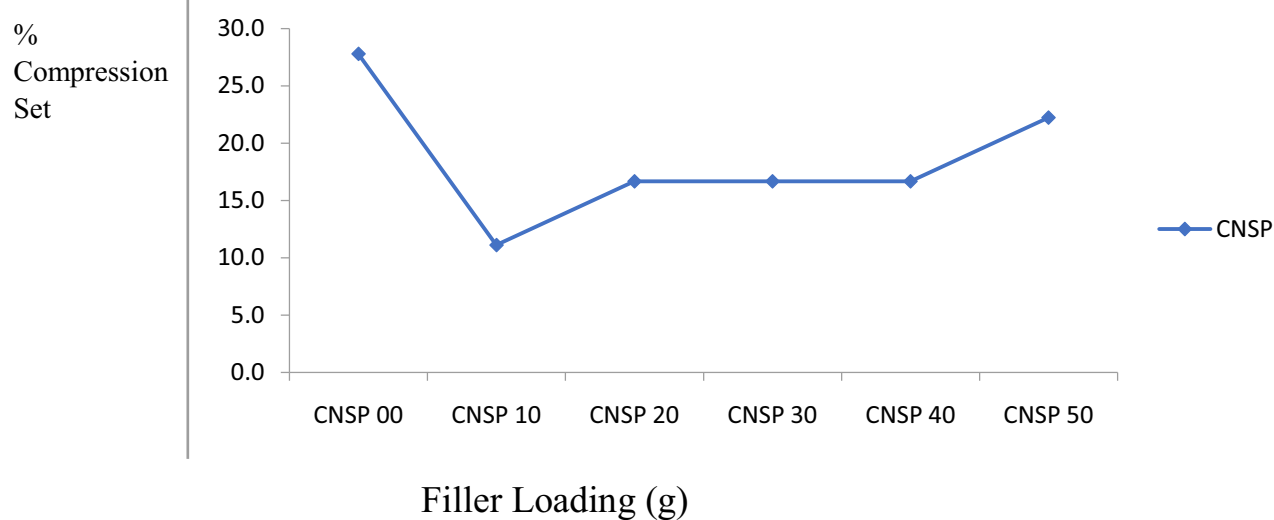


Figure 4: Effect of filler loading on Compression set

Figure 4 shows that the percentage compression set was not left out as it increased with increase in filler loading from 0-10pphr as 11.1% compression which revealed the best percentage compression set

compound amongst all and there was a slight increased from 20-40pphr with percentage compression as 16.7% across board and further decreased to 22.2% at 50pphr.

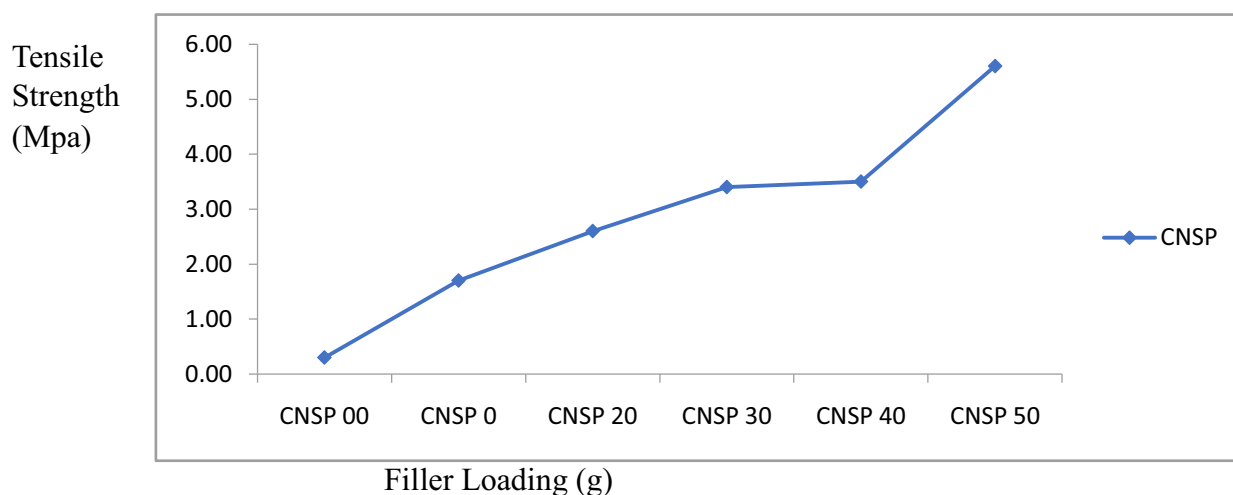


Figure 5: Effect of filler loading on Tensile strength

Figure 5 shows the result for tensile strength and it is an indication of filler reinforcement. The result of natural rubber filler cashew nut shell powder show a considerably increase in the tensile strength as the filler content was increased from 0-50pphr with the unreinforced compound having the least tensile strength result of 0.30 Mpa, and then a continual increase from 10-50 pphr with tensile strength values of 1.7, 2.6, 3.4, 3.5 and 5.60 Mpa respectively.

Conclusion

The utilization of cashew nut shell powder as filler was characterized for bulk density, moisture content, pH, ash content and particle size distribution. Also analysed were the mechanical tests such as hardness, abrasion resistance, tensile strength and compression strength. The preliminary characterization revealed that the filler is a light weight material and it is alkaline in nature, hence can promote vulcanization.

The tensile strength and hardness resistance were increasing as the filler loading were increased from 0-50pphr. This has proved that carbonized cashew nut shell powder is a potential reinforcing agro waste filler to be utilized in rubber compounding in order to reduce the cost of production or rubber

articles as increase in filler loadings tends to increase the mechanical properties of the rubber compounds.

References

- Aguele, F.O and Madufor, C.I. (2012) "effects of Carbonised Coir on physical of Natural Rubber Composites" *American Journal of Polymer Science*, 2(3): 28-34.
- Egwaikhide, A. P., Okieimen, F. E. and Lawal, U. (2013). Rheological and Mechanical Properties of Natural Rubber Compounds Filled with Carbonized Palm Kernel Husk and Carbon Black (N330). *Science Journal of Chemistry*, 1(5), 50. <https://doi.org/10.11648/j.sjc.20130105.11>
- Islam, M. S., Masoodi, R., & Rostami, H. (2013). The Effect of Nanoparticles Percentage on Mechanical Behavior of Silica-Epoxy Nanocomposites. *Journal of Nanoscience*, 2013, 1–10. <https://doi.org/10.1155/2013/275037>
- Oboh, J. . O., Ibrahim, A. . M., Patrick, B. T., & Okele, I. . A. (2018). Reinforcement of Natural Rubber with Sisal / Sugarcane Hybrid Nanofiller. *Journal of Polymer & Composites*,

6(3), 35–42.

Oboh, J. O., Okafor, J. O., Kovo, A. S.,
Abdulrahman, A. S., & Okele, A. I.
(2018). Isolation of Cellulosic
Nanoparticles from Coir Fibre for the
Preparation of Natural Rubber
Composites. *Journal of Polymer &
Composites*, 6(1), 9–16. Retrieved from
www.stmjournals.com

Ojinmah N, Uchechukwu T.O, Ezech V.O
and Ogbobe, O. (2017) "Studies on the
Effect of Rice Husk SemiNano Filler
on the Mechanical Properties of
Epoxidized Natural Rubber Composite"
*European Journal of Advances in
Engineering and Technology*, 2017, 4
(3): 164-171.