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UTILIZATION OF VIRGIN COCONUT OIL FILTER SEDIMENT WASTE AS A SUSTAINABLE PLASTICIZER ALTERNATIVE TO AROMATIC OIL IN RUBBER COMPOUNDING

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ABSTRACT: Plasticizers are non-volatile chemicals with low molecular weights that enhance the flexibility and processability of polymers. In the rubber sector, plasticizers are typically derived from petroleum or mineral oil derivatives. One major disadvantage of petroleum-based oils is that they are a non-renewable resource. Additionally, mineral oils with high aromatic concentrations may possess carcinogenic properties. The ban on the consumption of polyaromatic oils has posed challenges for the oil and rubber research sectors in developing sustainable alternatives. The extracted virgin coconut oil is filtered through ugh plate and filter press. When using gravity filters, sediment may still settle at the bottom of the container over time. This waste is frequently discarded into the environment, but it can also be utilized depending on its content. This study focuses on using filter sediment waste as a replacement for aromatic oil rubber compounding. The mixing process involved a two- roll mill followed by vulcanization using the compression moulding method. Collected sediment waste (Moisture content < 3%) was used to replace aromatic oil dosage in increments of 0 %, 25 %, 50 %,75% and 100 % by weight percentage. The results revealed that this replacement led to reduction in physio-mechanical properties such as tensile strength, specific gravity, and elongation at break. Simultaneously, hardness, abrasion resistance, 300% modulus and tear strength showed an increasing trend. Careful formulation is necessary to optimize the level of filter sediment waste used as a plasticizer to achieve the desired properties of rubber compound. The rubber composite with 25 % weight replacement of sediment waste for aromatic oil exhibit significantly better performance. This can be due to the inherent properties of sediment waste which promotes greater compatibility with polymer base and aromatic oil. The newly identified 25% replacement can be applied during manufacturing applications offering commercial benefits while contributing to the reduction of aromatic oil usage and ensuring environment sustainability through the utilization of waste material.

Keywords: aromatic oil, plasticizer, sustainable, rubber compounding, virgin coconut oil

1. INTRODUCTION

Plasticizers are non-volatile chemicals with low molecular weights that enhance polymer flexibility and processability. (Nandanan, 2007) Petroleum-based oils are widely utilized in rubber compositions. Plasticizers for the rubber sector generally employed petroleum or mineral oil derivatives. (Cherubini et al., 2021) One major disadvantage of petroleum-based oils is that they are a non-renewable resource. Mineral oils with high aromatic concentration may have carcinogenic properties. (Petrovic et al., 1998, pp. 233–249). The ban on polyaromatic oil consumption has posed hurdles for the oil and rubber research area to develop sustainable alternatives (Cherubini et al., 2021). There are recent developments in the use of bio-based oils in elastomers. Bio-based oil is a new oil source that could replace petroleum oil in elastomers as a plasticizer. It is a low-cost, renewable alternative to petroleum plasticizers with numerous benefits. Bio-based oils typically include several functional groups and can be processed, changed, or polymerized for various uses (Li et al., 2017). Bio based waste cooking oils have been incorporated in elastomeric compounds as a substitute for conventional mineral oils (Cherubini et al., 2021). Coconut oil was employed as a plasticizer in a natural rubber compound, and its mechanical and thermal properties were compared to those of a control compound with naphthenic oil. (Nandanan, 2007). The extracted VCO is filtered through plate and frame filter press (Dharmaratne et al., 2016) When filtering with gravity filters, feet may still settle on the bottom of the container after a lengthy period of time; simply decant the VCO to another container, leaving the feet behind. (Bawalan and Chapman, 2006). This waste is frequently discarded to environment, but it can also be utilized for other purposes depending on the content. The research focusing on use of virgin coconut oil filter sediment waste as a replacement for Aromatic oil where systematically changed in increments of virgin coconut oil filter sediment 0%, 25% ,50% ,75% and 100% by weight percentage in rubber compounding formula (Table 1).

Physiomechanical properties of rubber composite such as Hardness, Tensile Strength, Elongation at break, specific gravity, 300% Modulus, Tear strength, Abrasion Resistance were tested. The practicality of applying natural-based plasticizer filter sediment waste was determined by comparing its attributes to the application of aromatic oil. Although previous research has explored the use of different alternative oils including coconut oil, no studies have specifically investigated the use of coconut oil filter sediment as a material. The research aims to provide fresh and sustainable insights into natural based waste as plasticizers could substitute petroleum oil in NR-SBR rubber compounding.

2. METHODOLOGY

Virgin coconut oil filter sediment waste were collected which are generated as result of filtration process during the virgin coconut oil production from Real oil mills (PVT) LTD. Collected fully homogenized Virgin coconut oil filter sediment waste were tested (at 105°C for 20 minutes) for the moisture content weight percentage whose value was <3% were used for compounding. A laboratory scale ban bury mixer (Protech industrial eng.co ltd CHSM 2.3,2.5HP) and two-roll mill (Protech industrial eng.co ltd CHSM 2.8,7.5HP) were used for blending the compounds. Rubber masticated for 4 minutes ~ 80°C in the Banbury mixture. Next fillers including plasticizers were added and mixed for 3-4 minutes. Finally, stearic acid, zinc oxide was added, and mixing was carried out for 6 minutes also temperature inside of the mixer indicated as 148°C at the end. After compound getting back to the room temperature compound mixture put into the open two roll mill. Accelerators, Vulcanizing agents were added to the compound. The compound was being mixed another 10 minutes approximately doing 5-8 mill passing. During this compounding process to get the uniform compounding and appropriate dispersion of the ingredients in the rubbery matrix proper nip cap and cuts were maintained Following that, the compositions were compressed moulded for 15 minutes at 150 °C. To ensure complete curing (100% cure), the cure time was set significantly higher than t95 (time to 95% cure). The t95 value was determined by measuring the increase in torque values of none-vulcanized rubber compounds and identify the time point where 95% of the maximum torque is reached. Mooney viscometer was used to measure the viscosity of rubber compounds at 100°C. Different test specimens were obtained after curing as moulded products all tests were conducted at 25°C.

Table 1. Sample formulation

Properties	**Unit**	**Test method**	**A [Control] (0%)**	**B (25%)**	**C (50%)**	**D (75%)**	**E (100%)**
HARDNESS	Shoe A	ISO - 868	49	50	51	51	52
SPECIFIC GRAVITY	---	---	1.163	1.17	1.185	1.183	1.18
TENSILE STRENGTH	MPa	ISO 37-2005	14.3	15	15.5	14.2	13.6
ELONGATION @ BREAK	%	ISO 37-2005	734	698	661	650	633
300% MODULUS	MPa	ISO 37-2005	1.8	2.2	2.4	2.5	2.7
TEAR STRENGTH [METHOD B]	N / mm	ISO 34-1 2010	36.1	32.3	29	28	31
ABRASION RESISTANCE	mm^3	DIN 53516	245	286	320	345	367

3. RESULTS AND DISCUSSION

After 4 phr of coconut oil loading, the mechanical characteristics showed a significant improvement, resulting in good tensile strength of 18.26 MPa and elongation at break of 1859.05%. A crosslink density of 3.15×10^{-4} gm/mol/cm^3 was recorded (Othman and Ismail, 2020). The combination of the plasticizing effect and improved Carbon Black -Standard Malaysian Rubber 20 interaction influenced the Crude Palm Oil formulations' tensile characteristics, tear strength, hardness, and abrasion resistance (Abbas and Ong, 2009). Increasement of sediment waste can alter the distribution or efficacy of fillers, hence influencing hardness. The Fig. 1(a) shows the variation of hardness due to the replacement of Aromatic oil by sediment waste. It shows increasing trend of hardness in compounds with respect to the compound having 0% of sediment waste. The connection between hardness and plasticizer content in rubber compounds is usually inverse as plasticizer level increases, hardness decreases. This effect is critical for tailoring the mechanical characteristics of rubber to specific application requirements. The Fig. 1(b) shows the variation of specific gravity due to the replacement of Aromatic oil by sediment waste. It shows decreasing trend of hardness in compounds with respect to the compound having 0% of sediment waste. Sediment waste softens the rubber compound, increasing the free volume and decreasing the tight packing of polymer molecules. This greater free volume may reduce the overall density of the material, resulting in a lower specific gravity

Table 2. Test results

Material	A (0%)	B (25%)	C (50%)	D (75%)	E (100%)
NR	75	75	75	75	75
SBR	25	25	25	25	25
Aromatic Oil	5	5	5	5	5
Virgin oil filter sediment	-	1.25	2.5	3.75	5
clay	50	50	50	50	50
Stearic acid	1	1	1	1	1
Zinc Oxide	2.5	2.5	2.5	2.5	2.5
PEG 4000	1	1	1	1	1
TBBS	0.2	0.2	0.2	0.2	0.2
DPG	1.5	1.5	1.5	1.5	1.5
Sulfur	5	5	5	5	5

As per the Fig. 1(c) sediment can increase tensile strength, excessive amounts can reduce tensile characteristics. This is because excessive sediment waste can disrupt the polymer network, lowering the overall structural integrity of the material and resulting in a mushy and weak composite. This produces a softer, more ductile material that can stretch further but may fail under lesser stress. Graphical representation of Test results as shown in the Fig. 1(e), increased sediment waste in rubber compounds diminishes elongation at break by disrupting the polymer network, lowering cohesion, and weakening the material. Excess plasticizer causes softness, phase separation, and structural weakening rather than increasing flexibility. According to the Fig. 1(f), increasement of sediment waste may raise modulus by 300%. This is especially true when the sediment waste improves filler dispersion, increases polymer-filler interactions, or optimizes crosslink density. However, as sediment waste is a solid it may contribute for the rigidity of compound. The Fig, 1(g) shows the variation of tear tearing strength due to the replacement of Aromatic oil by sediment waste. Increased sediment waste content in rubber compounds diminishes tear strength because it weakens the polymer network by increasing chain mobility and resulting in a softer material.

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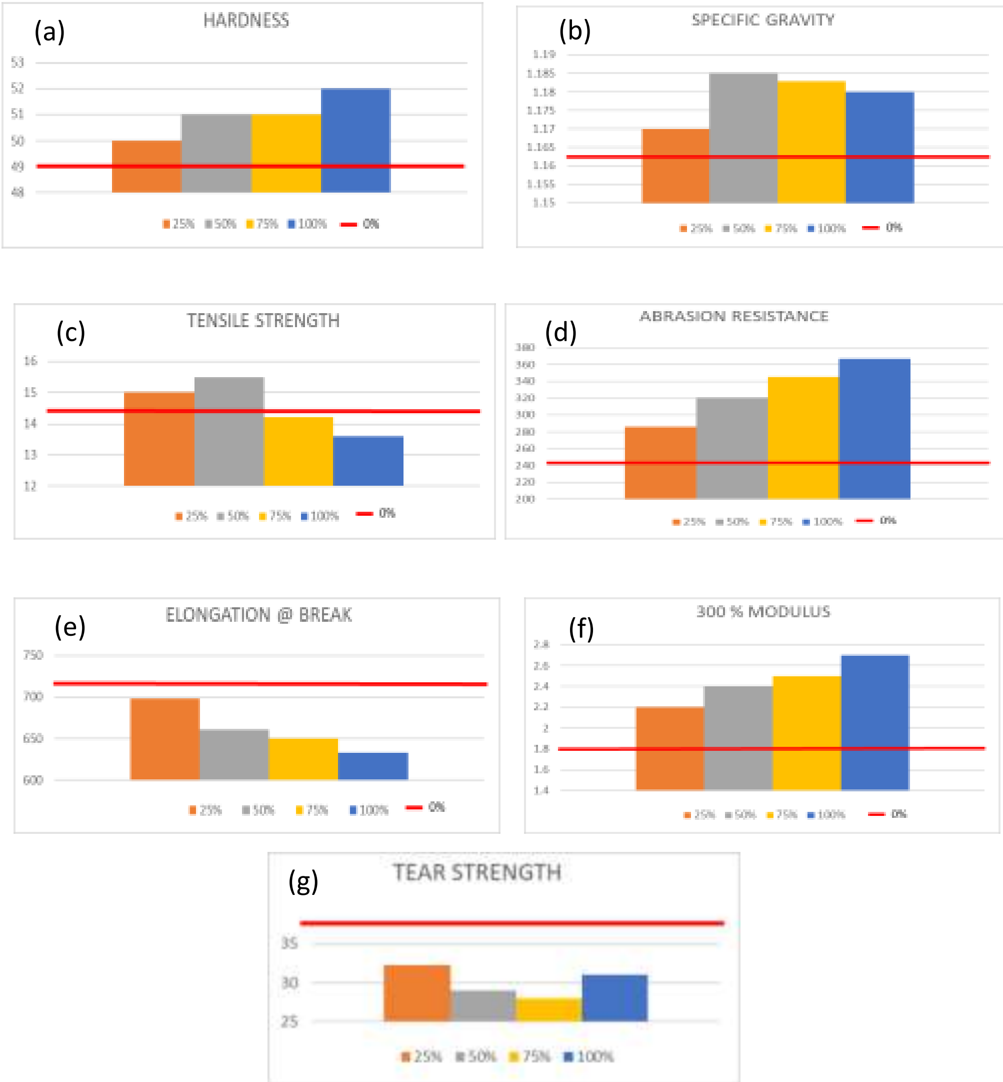

Fig. 1. Graphical representation of Test Results

This allows cracks or tears to spread more easily into the rubber, resulting in lesser tearing resistance. As shown in the image 4.0 Increasing sediment waste content can improve abrasion resistance by increasing the flexibility allowing the material to withstand wear. Increased filler dispersion and smoother surface characteristics lead to improved performance. Replacement of Aromatic oil by Sediment waste has shown growth of abrasion resistance of rubber compound.

4. CONCLUSION

When use of Coconut Oil as Plasticiser in Natural Rubber Compounds they outperformed the compounds based on naphthenic oil in terms of tensile strength, rip strength, resilience, and abrasion resistance. The crosslink density of the coconut oil mixtures was similar to that of the reference substance. The crosslink density of the coconut oil mixtures was similar to that of the reference substance (Sunil, 2017). When its considered the overall performances of rubber composites which is included filter sediment waste as a plasticizer shows higher values and increasing trend than that of aromatic oil as plasticizer in properties like hardness, abrasion resistance, 300% modulus and tear strength while lower values and decreasing trend than that of aromatic oil as plasticizer in properties like Tensile strength, specific gravity, Elongation at break. Careful formulation is necessary to optimize the filter sediment waste as plasticizer levels to get the desired properties of rubber compound of Aromatic oil as a plasticizer. According to data analysis results and future trends, the sample with 25% of Aromatic oil replacement of filter sediment waste significantly shows positive feedback and composite can be utilized in moulded formulation as per the required properties. Further laboratory trials must be done ensure the sharp optimal amount of filter sediment waste to be added. The replacement of Aromatic oil by Virgin coconut oil filter sediment in rubber compounds initiation would be a better insight in the way of health concern and sustainable utilization of materials.

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