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Unlocking the tribological behaviour of unsaturated banana oil infused with different layer types of graphene nanoparticles

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ABSTRACT

Developing bio-based lubricants from banana peel oil is emerging as a promising alternative to conventional lubricants. Infusing this biolubricant with graphene nanoparticles has the potential to enhance its tribological performance significantly by creating a tribofilm at the contact surface. This study aims to investigate the effectiveness of graphene-infused banana peel oil, with a focus on its tribological behaviour. Oil was extracted using Soxhlet extraction, and nanoparticle infusion was accomplished using ultrasonic homogenization. Tribological tests were conducted using the 4-ball tribometer to record the coefficient of friction (CoF) and wear scar diameter (WSD). The results showed that Sample 8 (0.5 vol%, 20 minutes, industrial graphene) obtained the best tribological performance, with the lowest CoF (0.0825) and WSD (137 μm), while Sample 13 (0.3 vol%, 20 minutes, technical graphene) presented the highest COF (0.0939). Sample 14 (0.3 vol%, 20 minutes, technical graphene) exhibited the most severe wear in WSD value (170 μm). In addition, Sample 8 demonstrated Graphene's crystal structure and its types having optimised composition to help reduce friction and wear by forming a protective layer that minimised direct surface contact. Furthermore, the developed bio-lubricants also demonstrated similar lubricant performance when compared to conventional engine oil.

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1.0 INTRODUCTION

The evolution of lubricants dates back to history, when animal fats such as beef tallow and mutton fat were used to reduce axle friction in chariots (Puhan, 2020). The emergence of petroleum led to the substitution of mineral oil-based lubricants for conventional plant and animal-derived oils, signifying a notable transformation in lubricant technology (Berman, 2024). Throughout the 20th century, lubricants evolved into complex compositions that not only reduce friction but also enhance heat transfer, minimise wear, and prolong machinery longevity (Puhan, 2020). The implementation of synthetic lubricants significantly improved performance by providing greater friction reduction and versatility for industrial applications (Hu and Li, 2022). Contemporary innovations, including the addition of nanoparticles, have enhanced lubricant characteristics, meeting the increasing industrial demands for efficiency and sustainability (Birleanu et al., 2022).

The development of biobased oils in lubricants has experienced significant transformations in recent decades. The use of eco-friendly lubrication was primarily motivated by regulatory initiatives, such as the European Green Deal and the UN Sustainable Development Goals. The use and advancement of bio-based oils in lubricants have increased over the past two decades due to environmental concerns, the depletion of oil supplies, and regulatory requirements, leading to their growing popularity (Hamnas and Unnikrishnan, 2023). Biobased oils in lubricants have gained significance due to sustainability concerns, highlighting the principles of green chemistry and tribology as eco-friendly alternatives to petroleum-based formulations (Pichler et al., 2023). Vegetable oils, including soybean, sunflower, rice bran, and castor oil, are employed to manufacture polymeric additives for environmental applications.

Banana, a widely consumed fruit, belongs to the genus Musa and is categorised within the family Musaceae which consists of several species, including Musa acuminata, Musa balbisiana, and Musa paradisiaca (Korni et al., 2023). The banana peel, abundant in bioactive components such as phenolics, flavonoids, and dietary fibre, constitutes approximately 30-40% of industrial processing waste. The banana is a fruit that is widely cultivated and consumed in both its green and ripe forms (Priyadarshana et al., 2022). Nearly every component of the banana plant is vital and beneficial to humanity in many ways. Additionally, studies have explored the potential of utilising oil derived from the banana peels of the Musa Aluminata balbisiana (MBS) species as a bio-lubricant. The oil possesses advantageous physicochemical properties and a fatty acid profile suitable for lubricant formulation (Hamid et al., 2017).

Graphene is a widely recognised nanomaterial. Graphite, the most stable form of carbon, is utilised as pencil lead and as an industrial lubricant. Graphite is a layered material consisting of carbon atoms organised in hexagonal configurations similar to those found in benzene rings within each layer. Graphene denotes a single layer of graphite (Guo, 2023). This material is extraordinary and possesses various outstanding attributes. It is the thinnest and toughest substance yet studied (Kumbar et al., 2020). Graphene nanoparticles are carbon structures that are one atom thick and exhibit exceptional mechanical, thermal, optical, and chemical properties. Graphene’s applications span several domains, including technology, medicine, defence, desalination, and athletics (Yusaf et al., 2022).

Due to its exceptional tribological properties, graphene nanoparticles have emerged as a transformative component in the lubricant industry. The incorporation of these nanoparticles significantly enhances the performance of lubricants by reducing friction and wear. The effective dispersion of these nanoparticles is crucial, as employing suitable techniques such as ultrasonication, thermal agitation, and mechanical shearing helps prevent clumping and ensures consistent performance (Sidh et al., 2023). Furthermore, the amount of graphene present in lubricants is of significant importance. Studies indicate that the addition of 0.05 wt.% of graphene nanoplatelets to synthetic oil can result in a notable decrease of approximately 34% in both friction and wear. The significant improvement in tribological properties is attributed to the formation of a protective film on the worn surfaces, as confirmed by scanning electron microscopy and energy-dispersive X-ray spectroscopy (How et al., 2022). Furthermore, the ability of graphene to form lasting lubricating layers and its remarkably low friction coefficients make it an advantageous addition for various industrial applications (Gao et al., 2022). The thin laminated structure, high specific surface area, elevated surface energy and self-shear capabilities of graphene-based nanomaterials enable rapid infiltration into the friction interface, effectively preventing contact between surfaces.

Despite notable advancements in nano lubricant technology, a significant research gap remains in understanding the synergistic effects of bio-based oils and advanced nanomaterials under tribological conditions. While numerous studies have explored the efficacy of nanomaterials such as graphene in synthetic and water-based lubricants, their integration into viscous, oil-based bio-lubricants remains limited, particularly due to dispersion challenges and compatibility issues. Although banana peel oil has shown promising physicochemical properties for lubrication, and graphene nanoparticles are recognised for their outstanding tribological performance, studies combining these two components remain limited. Furthermore, the effects of different graphene layer structures and optimised concentrations on bio-lubricant performance have not been sufficiently investigated. Therefore, this study aims to fill that gap by examining the frictional behaviour and lubrication mechanisms of banana peel oil infused with varying graphene nanoparticle layers under controlled tribological testing.

2.0 EXPERIMENTAL PROCEDURE

The steps used in this study include the extraction of Banana Peel oil (BPO), the infusion of Graphene Nanoparticles into BPO, four-ball testing, and the verification of wear mechanisms using scanning electron microscopy (SEM).

2.1 Extracting the Banana Peel Oil (BPO)

The procedure for treating banana peel waste is illustrated in Figure 1. Banana peels were collected from a local banana fritter stall, yielding a total of 10 kg for processing. The samples were washed with distilled water to remove any dirt or contaminants, then placed in a basket and were left to dry in direct sunlight for one week, with an average of seven hours of exposure per day. Once the banana peels were completely dried (becoming black and reaching constant mass), the peels were crushed in a coffee grinder for approximately three minutes, until they were finely ground. The crushed banana peel was then placed in an airtight container to prevent oxidation and stored in a dark, dry place.

The SZF-06C Soxhlet Extraction Fat Analyser was used to extract banana peel oil, utilising hexane as the solvent. The machine operated at a constant water flow rate and a temperature of 95°C. Five grams of crushed banana peels were placed in a filter paper canister (Nacella) and were secured under a magnetic ring. Each extraction container held 45 ml of hexane and was positioned in the water bath. The condenser pipe was appropriately connected, ensuring that the sample was fully immersed in the solvent. The extraction process lasted for two hours, after which the sample was removed and allowed to cool for 30 minutes. The solvent was collected for reuse, while the used banana peel sample was discarded. The procedure is shown in Figure 2.

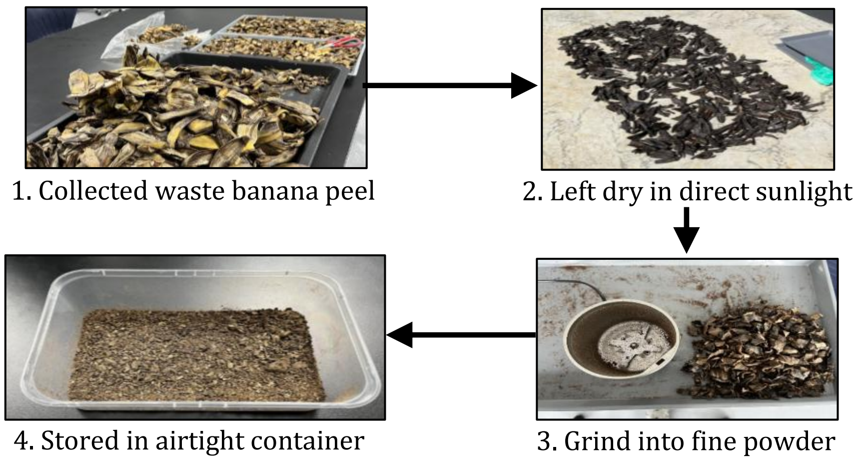

Figure 1: Procedure for processing banana peel waste.

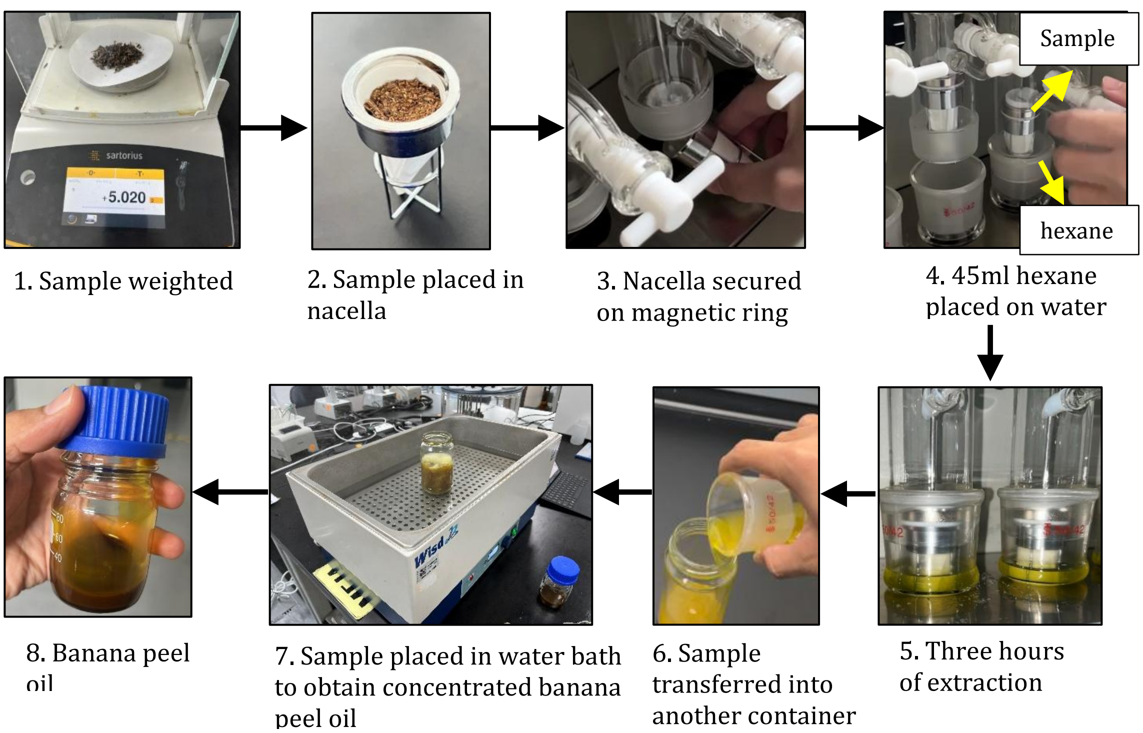

Figure 2: Soxhlet extraction to achieve Banana Peel oil

2.2 Material Properties

Graphene Nanoparticles (GNP) used in this research were sourced from BTCORP Generique Nano PVT LTD, located in Bangalore, India. Three types of graphene nanoparticles were utilised: scientific, technical, and industrial grades, each with distinct densities, as shown in Table 1. Table 2 shows the physicochemical properties of the extracted BPO. The viscosity is 70.8 cSt at 40°C and 8.9 cSt at 100°C. The viscosity index is 98.

Table 1: Graphene grade and density value.

Graphene grade	Layer graphene	Density
Research	1 – 5	0.06 g/ml
Technical	15	0.45 g/ml
Industrial	25	0.60 g/ml

Table 2: Properties of extracted banana peel oil.

Physicochemical properties	Value	
Viscosity	**Temperature @40°C**	**Temperature @100°C**
	70.8 Cs	8.9 Cs
Viscosity Index	98	

2.3 Sample preparation using Design of Experiment (DOE) by RSM, Box-Behnken Design

The homogenisation of graphene nanoparticles involved incorporating nano-sized graphene particles into the bio-lubricant oil formulation. To optimise the mixing process, the RSM with a Box-Behnken Design (BBD) was employed due to its effectiveness in evaluating multiple variables while reducing the number of experimental runs. This method was implemented using Minitab software. Table 3 presents the selected factors and responses, along with their corresponding variation levels, used in this study. Once the inputs were entered into the software, Minitab generated 15 experimental runs with different mixture combinations based on the levels defined in Table 3. The details of all 15 sample runs are shown in Table 4.

Table 3: RSM factors and response.

Independent Variable	Variation Levels		
	-1	**0**	**+1**
Composition of graphene nanoparticle, vol. %	0.1	0.3	0.5
Homogenous time, minutes	10	20	30
Type of Graphene, Grade	Research	Technical	Industrial

The required weight of the Graphene Nanoparticle was calculated using the density equation (shown in Equation 1), given that the density of the Graphene Nanoparticle differs from each other as shown in Table 1.

$$\rho = \frac{m}{v} \quad (1)$$

where, $\rho = Density\ (g/cm^3), m = Mass\ (g)$ and $v = Volume\ (ml)$.

Table 4: Response data generated by Minitab.

Trials	Independent Variable		
	Composition, wt. %	**Homogeneous time, minutes**	**Type, Grade**
1	-1	-1	0
2	1	-1	0
3	-1	1	0
4	1	1	0
5	-1	0	-1
6	1	0	-1
7	-1	0	1
8	1	0	1
9	0	-1	-1
10	0	1	-1
11	0	-1	1
12	0	1	1
13	0	0	0
14	0	0	0
15	0	0	0

2.4 Ultrasonic Hemogenizer

The mixture of nanoparticles and BPO was homogenised for 30 minutes using an ultrasonic homogeniser, as shown in Figure 3 (Abdullah et al., 2014). The frequency and amplitude were set at 60 Hz and 0.5, respectively. An MS 72 micro tip probe size was used to prevent changes in the oil's properties due to the temperature rise. Thermocouples were also used to ensure that the oil temperature remained within the range of 60–70°C during the homogenisation process. The oil mixture was placed inside a water bath containing water and ice to control the temperature, thereby preventing a sudden temperature rise. This ultrasonication process improved the stability and uniformity of the mixture.

2.5 Four-ball Tester

The Koehler 4-ball testing machine (Model K93190-M-CE) was used to determine the coefficient of friction (COF) and wear scar diameter (WSD). The graphene-infused bio-oil samples were tested following ASTM D4172. Table 4 lists the testing parameters used in the 4-ball experiment. Figure 4 shows the setup, where three steel balls (12.7 mm in diameter) were clamped together and coated with the lubricating oil sample. AC motor-driven spindle with a unique collet retained the fourth ball with an identical diameter. The other three balls were fixed in the test oil encounter the spinning top ball. These balls were secure in the pot. The locking nut applied force to the steel balls, which were securely clamped within the ball container. A heating block located at the base of the ball pot regulated the temperature of the lubricating oil sample.

Loading was applied by operating a lever and placing weights on a designated loading pan. A load cell was attached to the loading lever to measure the applied normal load. The ball pot was supported above the loading lever by push bearings and plungers. Frictional torque generated by the three lower balls was measured using frictional force load cells. WSD was determined using the optical microscope as shown in Figure 5.

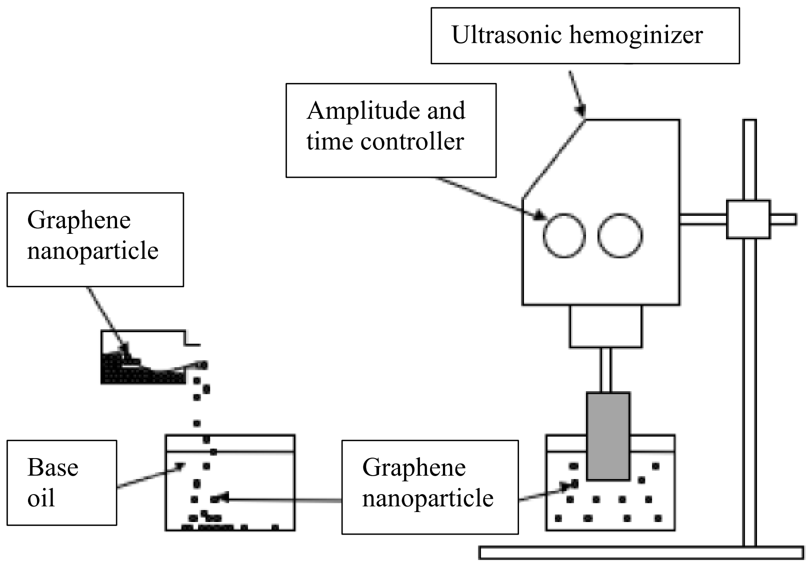

Figure 3: A schematic of the sample preparation using ultrasonic method.

Table 4: Parameter setup for 4-ball testing.

Parameter	**Value**
Speed	1200 rpm
Force	392 N
Time	3600 second (1 Hour)
Temperature	75 ∘ C

2.6 Scanning Electron Microscopy (SEM) Surface Analysis

The Zeiss Evo 18 SEM was employed to assess the scar properties of the balls. Figure 6 illustrates the SEM machine. Three different magnifications were used to perform a thorough investigation of the scar: 110x, 500x and 1000x. This was done to identify the scar pattern and the nanoparticle debris that had adhered to the abraded surface.

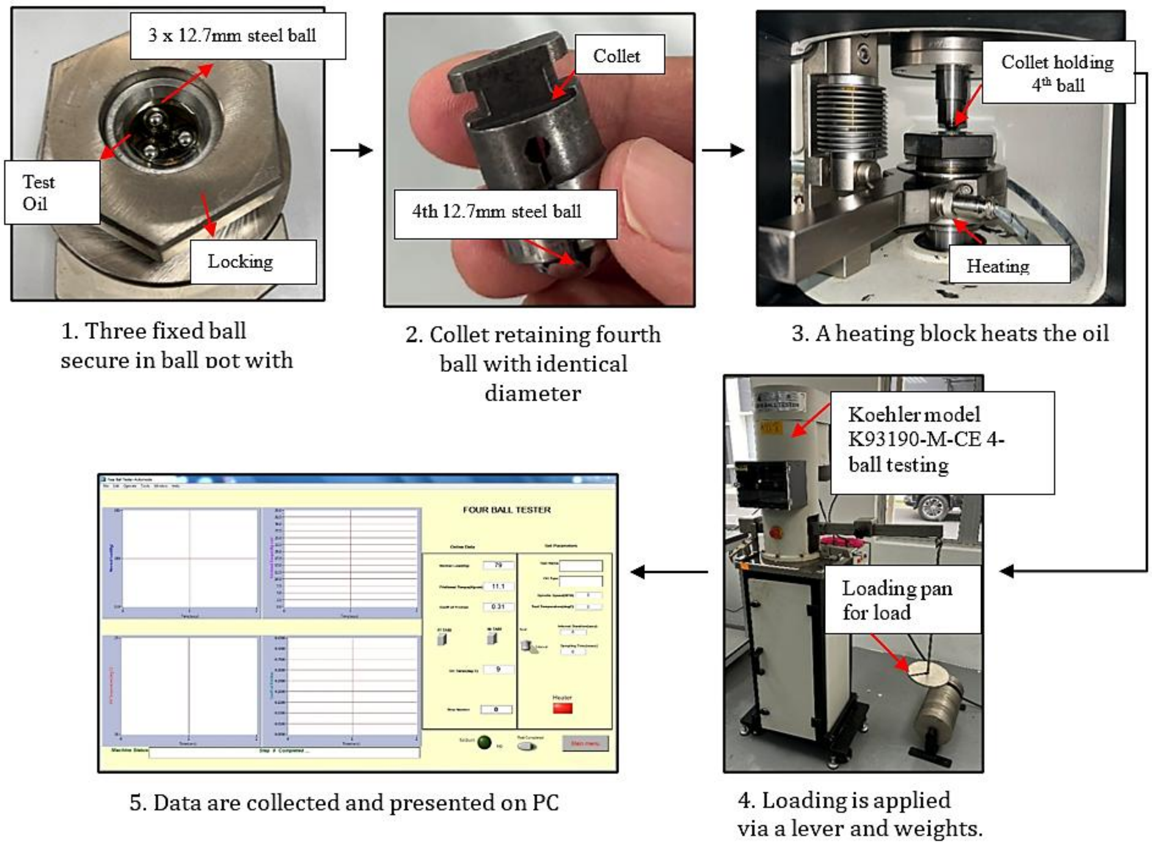

Figure 4: Koehlar model K93190-M-CE 4-ball testing.

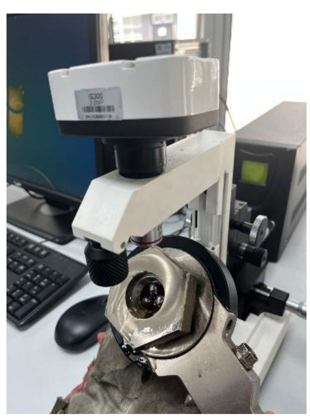

Figure 5: WSD verification using optical microscope.

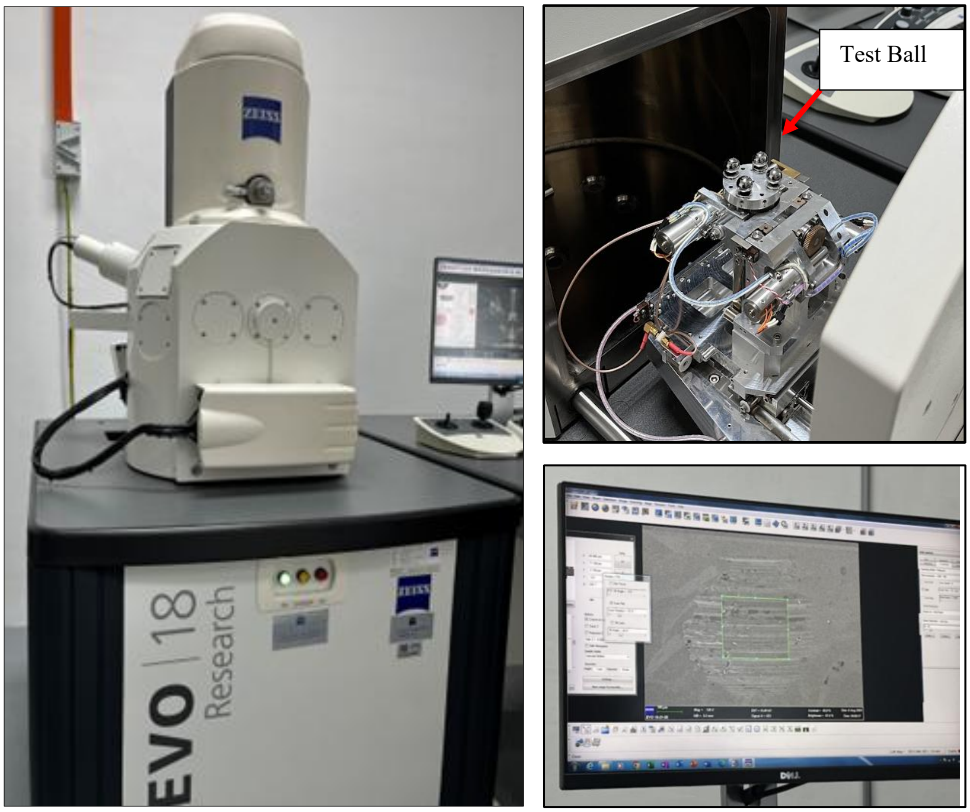

Figure 6: Zeiss Evo 18 SEM machine.

3.0 RESULTS AND DISCUSSION

This section presents the results and analysis of BPO infused with graphene nanoparticles, formulated using the Box-Behnken design of Response Surface Methodology (RSM) in Minitab. The optimisation was based on three independent factors. The aim was to evaluate the lubricant's performance through measurements of the coefficient of friction (COF) and wear scar diameter (WSD) using ASTM D4172 four-ball testing, along with surface analysis via Scanning Electron Microscopy (SEM).

3.1 RSM Box-Bhenken Result Analysis

Table 5 summarises the RSM Box-Behnken study on the effects of graphene composition, homogenisation time, and grade on wear scar diameter (WSD) and coefficient of friction (COF). Sample 8 exhibited the best performance, with the lowest COF (0.0825) and WSD (0.137 mm), using 0.5 vol.% industrial-grade graphene and 20 minutes of homogenisation. In contrast, Sample 13 recorded the highest coefficient of friction (COF) (0.0940), while Sample 9 had the largest wear scar diameter (WSD) (0.167 mm), both indicating inadequate friction and wear reduction.

Table 5: Result of RSM Box-Behnken for COF and WSD.

Trails	Independent Factors			Response	
	Composition (vol.%)	Homogeneous Time (minutes)	Type of Graphene (grade)	Coefficient of Friction (COF)	Wear Scar Diameter (WSD)
1	0.1	10	0	0.0868	0.163
2	0.5	10	0	0.0857	0. 153
3	0.1	30	0	0.0841	0.142
4	0.5	30	0	0.0847	0.149
5	0.1	20	-1	0.0878	0.151
6	0.5	20	-1	0.0877	0.148
7	0.1	20	1	0.0876	0.154
8	0.5	20	1	0.0825	0.137
9	0.3	10	-1	0.0835	0.167
10	0.3	30	-1	0.0894	0.149
11	0.3	10	1	0.0871	0.154
12	0.3	30	1	0.0854	0.166
13	0.3	20	0	0.0939	0.148
14	0.3	20	0	0.0855	0.157
15	0.3	20	0	0.0830	0.156

Lowest COF and WSD

Highest WSD

Highest COF

3.2 Effect of Independent Factors on the Coefficient of Friction (COF)

According to Table 5, Sample 8 showed the COF with the lowest average (0.5 vol%, 20 minutes, industrial graphene) with a value of 0.0825. The lowest coefficient of friction (COF) signified the best result, indicating that lower energy was required to overcome frictional forces, thereby enhancing the overall energy efficiency of machinery (Nassef et al., 2023). This could be due to the formation of tribolayer between two contacting surfaces. Graphene nanoparticles affect the coefficient of friction (COF) by filling in the inter-asperity valleys and forming a protective layer between the contacting surfaces, thus providing a lubricating effect that helps reduce surface friction (Jamaluddin et al., 2020). On the contrary, Sample 13 presented the highest value for COF in this experiment (0.3 vol%, 20 minutes, technical graphene), with a COF value of 0.0939. Thus, sample 13 showed a COF slightly higher than the benchmark oil (SAE oil), shown in Figure 8, with a difference of 3.2% and remained within the acceptable COF range for use as a lubricant oil (Hamid et al., 2020). The sample with a moderate coefficient of friction (COF) is sample 14 (0.3 vol%, 20 minutes, technical graphene), with a value of 0.0855. Therefore, it can be concluded that significant COFs were observed for all the BPO addition samples with graphene nanoparticle, with a value range of 0.0825 to 0.0939. Figure 7 shows a consistent performance of oil throughout the testing indicating the steady state was being achieved after 5 minutes of sample running. This signified a good and consistent performance of industrial-grade graphene in protecting the friction surface. The overall sample COF result is shown in Figure 8, with additional

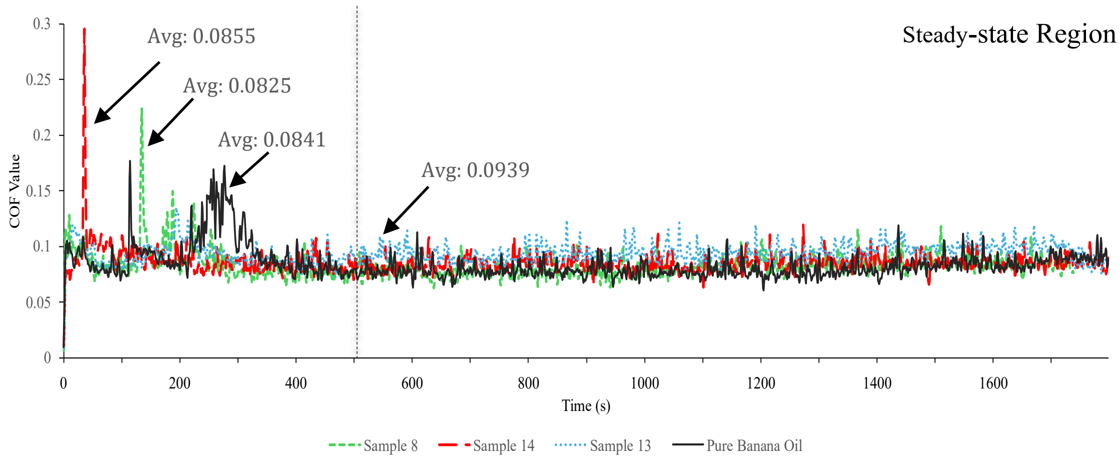

Figure 7: Average COF chart for pure extracted banana oil, Sample 8 (lowest COF), Sample 13 (moderate COF) and Sample 14 (worst COF).

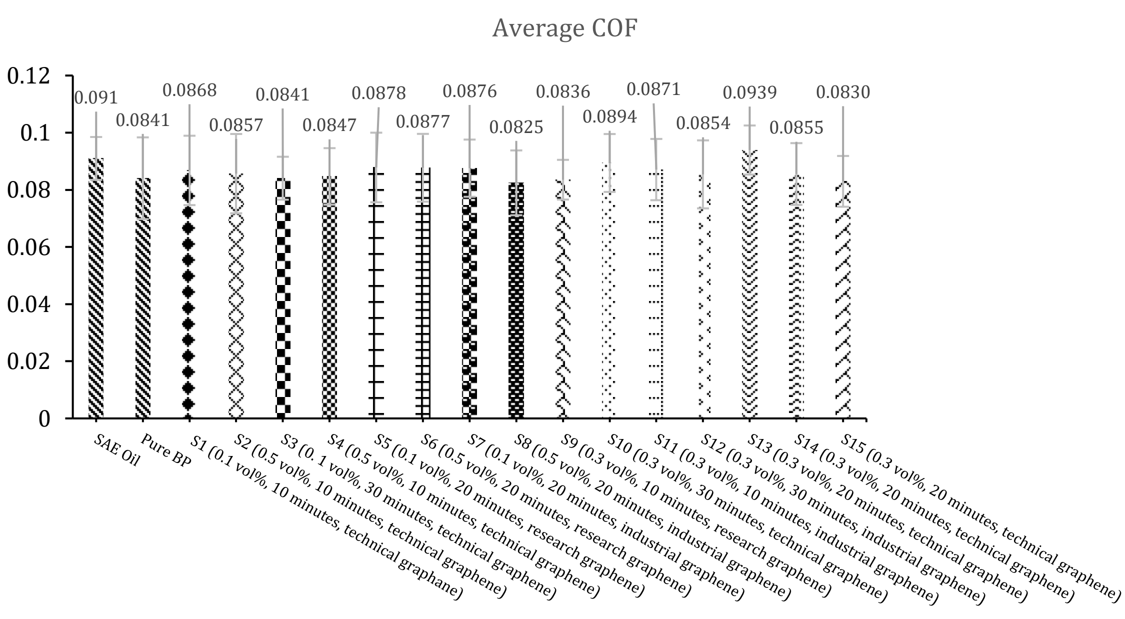

Figure 8: COF bar chart for each sample, SAE oil and pure extracted peel oil.

3.2 Effect of Independent Factors on the Wear Scar Diameter (WSD)

The WSD served as a direct measure of a lubricant's efficacy in minimising friction and wear between mechanical components (Xiao et al., 2021). Based on the WSD in Table 5, the samples showed the value range at 0.14 - 0.17mm. The lowest WSD value recorded was for sample 8 (0.5 vol.%, 20 minutes, industrial graphene), with a value of 0.137. A lower value of WSD is anticipated, as it indicates better oil performance in protecting the friction surface (Knothe, 2008). The sample with a moderate value of WSD was sample 2 (0.5 vol.%, 10 minutes, technical graphene), with WSD value of 0.153. Lastly, the sample with the highest value of WSD was sample 14 (0.3 vol.%, 20 minutes, technical graphene), with a value of 0.17. A higher wear scar diameter in lubricant oil typically indicates greater wear and damage to the surfaces in contact, which is undesirable (Al-Samarai and Al-Douri, 2024). The overall sample WSD result is plotted in Figure 9.

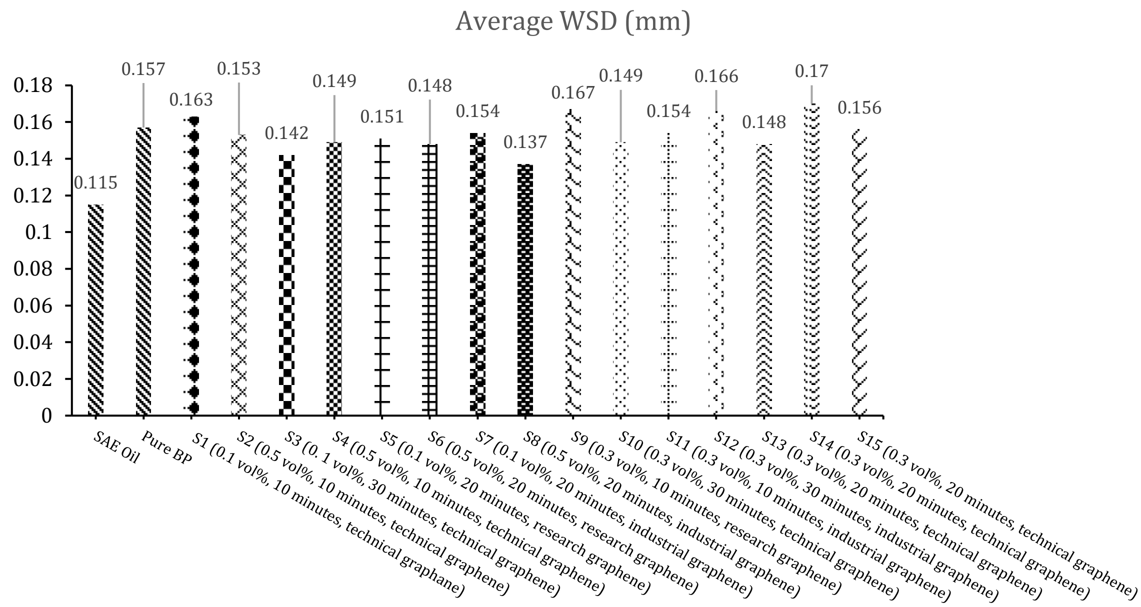

Figure 9: Bar Chart WSD for each sample, Pure BP and SAE.

3.3 Wear Scar Mechanism

SEM was used to analyse the surface morphology. All fifteen ball samples were examined using a Zeiss Evo 18 SEM at 110x, 500x, and 1000x magnifications. Sample 8, shown in Figure 11, which exhibited the best COF and WSD performance, showed scar formation without visible debris, indicating minimal material loss and the formation of a protective tribolayer. This supports the findings by Gao et al. (2022), confirming graphene's ability to form tribofilms and enable self-repairing effects. Additionally, graphene's weak van der Waals forces enhance interlayer sliding, reducing friction and wear. The results highlight the effectiveness of BPO + GNP in protecting the surface and improving tribological performance. Figure 10 illustrates how the BPO + GNP forms a protective layer on the friction surface, thereby protecting it.

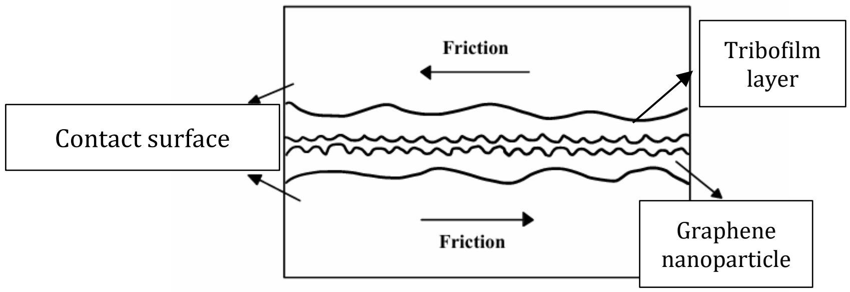

Figure 10: Tribolfilm layer created by graphene nanoparticle.

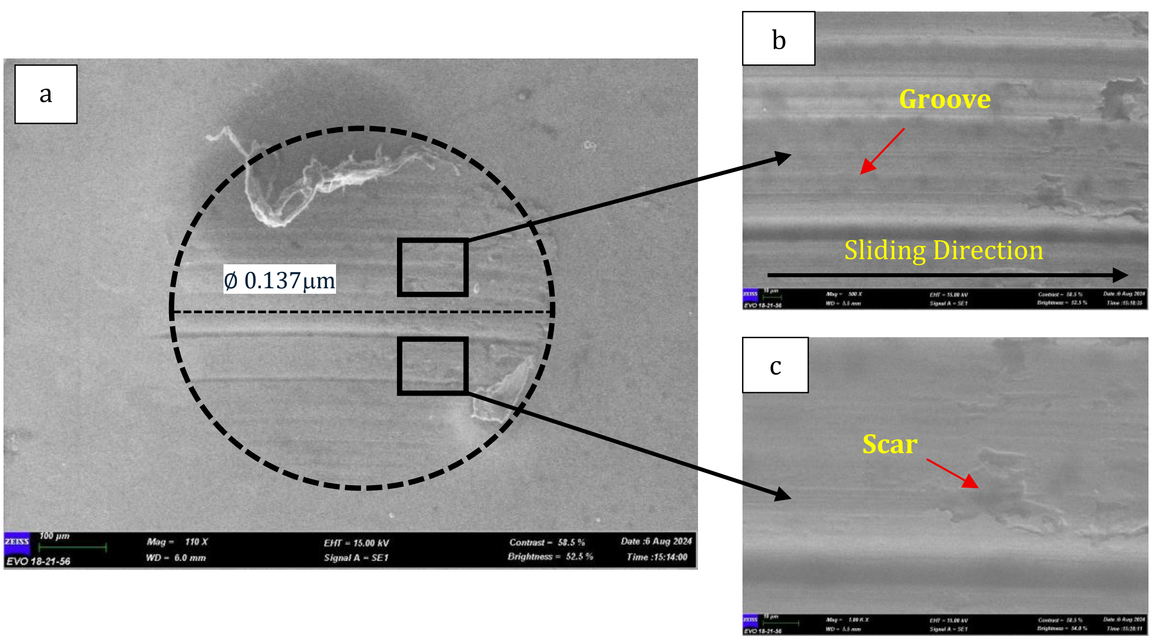

Figure 11: SEM of ball sample 8.

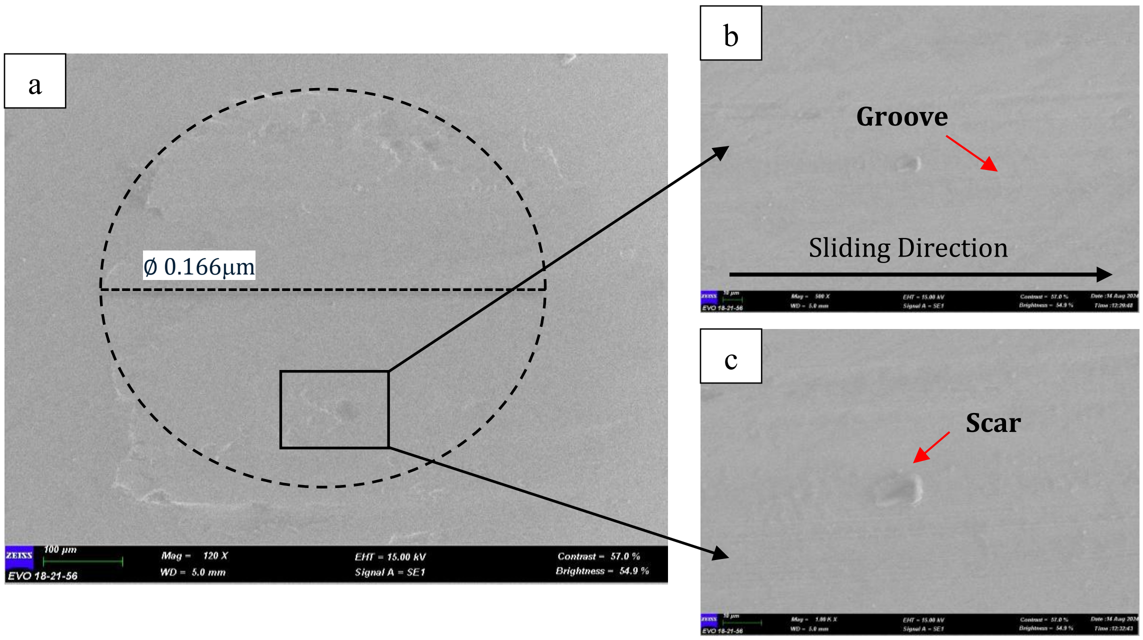

Figure 12: SEM of ball sample 12.

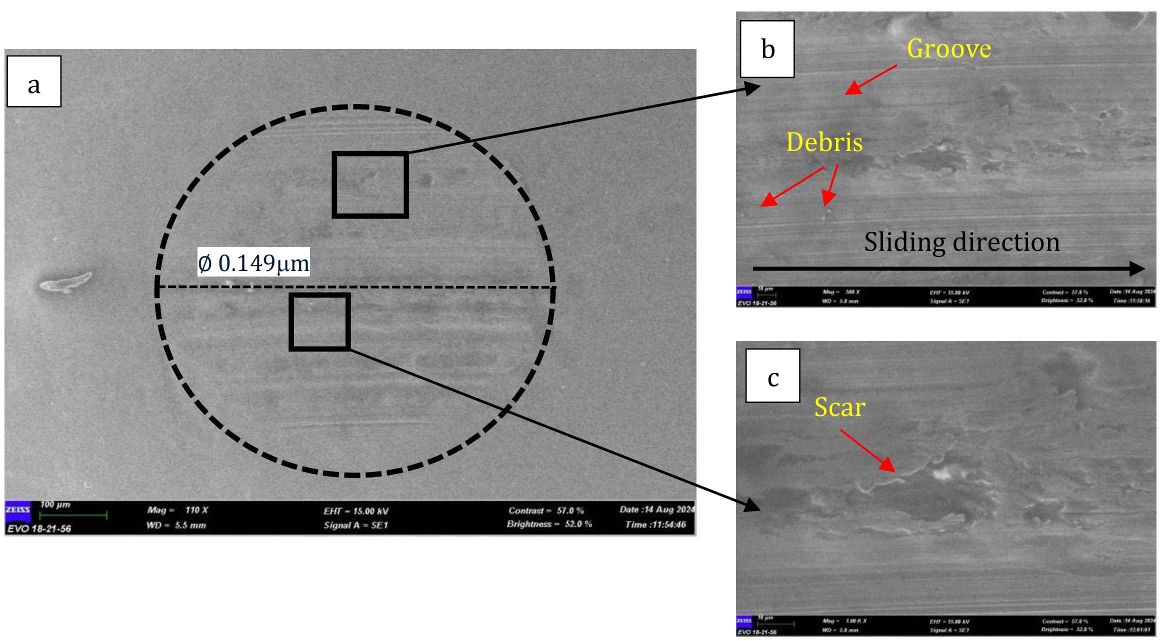

Figure 13: SEM of ball sample 10.

To further analyse the severity of the worn surface of the ball, two samples with the worst coefficient of friction (COF) and wear scar depth (WSD) were selected for analysis. Samples 12 (highest COF) and 10 (highest WSD) were chosen. Figure 12 shows the SEM of ball Sample 12 with 110x, 500x and 1000x magnification. Compared with the wear surface of Sample 8, Sample 12 displayed debris and scars on the surface of the ball. This indicated that the test oil mixture provided was insufficient to protect the nanoparticle, resulting in inadequate smooth lubrication and protection against surface friction. The self-repairing effect mentioned by Gao et al. (2022) showed no impact on the surface ball, indicating the lack of a synergy effect between BPO and industrial-grade GNP. Therefore, this justified the high value of COF for Sample ball 12.

Figure 13 shows Sample ball 10 with 110x, 500x and 1000x magnification. This ball sample yielded the worst WSD value compared to all the other 15 samples. As shown in Figure 13(a) and (b), there was an increased number of debris and scars compared to Sample 12. The scar was also indicated by the large diameter. Similar to Ball Sample 12, this sample showed minimal surface coverage by the test oil. It also indicated a reduced synergistic effect between BPO and GNP, which typically aided in forming a protective layer on the contact surface. Therefore, it can be concluded that Sample 10 exhibited more significant wear and a larger scar compared to Sample 12.

4.0 CONCLUSION

Sample 8 demonstrated the optimal graphene configuration, achieving the highest lubrication efficiency. In addition to the RSM optimisation results, the study confirmed the enhanced tribological behaviour and lubrication mechanisms of graphene-infused banana peel oil. Based on four-ball testing, Sample 8 exhibited the best performance, with the lowest coefficient of friction (COF) at 0.0825 and the smallest wear scar diameter (WSD) at 137 µm. In contrast, Sample 13 recorded the highest coefficient of friction (COF) (0.0939), while Sample 14 exhibited the most severe wear, with a wear severity distance (WSD) of 170 µm. The reduced COF and WSD of Sample 8 indicated improved lubrication and wear resistance. Further analysis using Scanning Electron Microscopy (SEM) revealed the detailed wear track patterns and evidence of a graphene-based tribo-film formation. In summary, these findings demonstrate the potential of graphene-infused bio-lubricants to achieve superior lubrication by confirming that they not only enhance lubrication performance and reduce surface degradation but also exhibit tribological characteristics comparable to those of conventional engine oils.

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REFERENCES

Abdullah, M. I. H. C., Abdollah, M. F., Amiruddin, H., Tamaldin, N., & Nuri, N. R. M. (2014). Effect of hBN/Al_2O_3 nanoparticle additives on the tribological performance of engine oil. Jurnal Teknologi, 66, 2180–3722.

Al-Samarai, R. A., & Al-Douri, Y. (2024). Wear mechanisms/models. In Wear Mechanisms/Models (pp. 33–60). Springer Nature.
Berman, D. (2024). Plant-based oils for sustainable lubrication solutions—Review. Lubricants, 12(9), 300.
Birleanu, C., Pustan, M., Cioaza, M., Molea, A., Popa, F., & Contiu, G. (2022). Effect of TiO_2 nanoparticles on the tribological properties of lubricating oil: An experimental investigation. Scientific Reports, 12(1), 1–12.
Gao, Q., Liu, S., Hou, K., Li, Z., & Wang, J. (2022). Graphene-based nanomaterials as lubricant additives: A review. Lubricants, 10(10), 273.
Guo, R. (2023). Graphene growth. Zenodo.
Hamid, H. A., Masripan, N. A. B., & Hasan, R. (2017). Physiochemical properties and fatty acid profiles of oil from Musa aluminata balbisiana. Key Engineering Materials, 740, 183–189.
Hamnas, A., & Unnikrishnan, G. (2023). Bio-lubricants from vegetable oils: Characterisation, modifications, applications and challenges—Review. Renewable and Sustainable Energy Reviews, 182, 113413.
How, H. G., Jason, Y. J. J., Teoh, Y. H., & Chuah, H. G. (2022). Investigation of tribological properties of graphene nanoplatelets in synthetic oil. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 96(1), 115–126.
Hu, W., & Li, J. (2022). Effect of molecular weight on tribological properties of polyether amine derivatives under different contact modes. Lubricants, 10(6), 105.
Korni, R. D., Boddepalli, T., Elusuri, J., & Panda, J. (2023). Banana peel: A potential waste product with numerous pharmacological activities. GSC Biological and Pharmaceutical Sciences, 23(2), 160–174.
Kumbar, S. S., Patil, S., & Jarali, C. S. (2020). Graphene in different extraction techniques. In Advances in Chemistry Research (Vol. 91, pp. 49–72). Elsevier.
Pichler, J., Eder, R. M., Besser, C., Pisarova, L., Dörr, N., Marchetti-Deschmann, M., & Frauscher, M. (2023). A comprehensive review of sustainable approaches for synthetic lubricant components. Green Chemistry Letters and Reviews, 16(1), 1–20.
Pichler, J., Eder, R. M., Besser, C., Pisarova, L., Dörr, N., Marchetti-Deschmann, M., & Frauscher, M. (2023). A comprehensive review of sustainable approaches for synthetic lubricant components. Green Chemistry Letters and Reviews, 16(1), 1–20.
Priyadarshana, R. W. I. B., Kaliyadasa, P. E., Ranawana, S. R. W. M. C. J. K., & Senarathna, K. G. C. (2022). Biowaste management: Banana fibre utilisation for product development. Journal of Natural Fibres, 19(4), 1461–1471.
Puhan, D. (2020). Lubricant and lubricant additives. In A. Patnaik, T. Singh, & V. Kukshal (Eds.), Tribology in materials and manufacturing (Chapter 9). IntechOpen.
Sidh, K. N., Jangra, D., & Hirani, H. (2023). An experimental investigation of the tribological performance and dispersibility of 2D nanoparticles as oil additives. Lubricants, 11(4), 179.
Yusaf, T., Mahamude, A. S. F., Farhana, K., Harun, W. S. W., Kadirgama, K., Ramasamy, D., Kamarulzaman, M. K., Subramonian, S., Hall, S., & Dhahad, H. A. (2022). A comprehensive review on graphene nanoparticles: Preparation, properties, and applications. Sustainability, 14(19), 12336.