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Book OF ABSTRACT

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Effect of Copper Oxide Nanoparticles Fuel Additives on the Performance of Diesel Engine

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Abstract

The present work investigates the effect of copper oxide nanoparticles on diesel engine performance and emissions. The CuO nanoparticles were biosynthesized using aqueous extract of orange peels and characterized by UV spectroscopy. Subsequently, the nanoparticles blended diesel samples (D10, D20, and D40) were prepared by mixing a 500 cm^3 of commercial diesel with the CuO nanoparticles in the mass fractions of 10, 20, and 40 mg using homogenizer at 700 rpm for 15 minutes respectively. The performance and emission tests were done in the diesel engine to investigate the effect of nanoparticles using each of the diesel samples as fuel at varying speeds in the range of 1000 - 2200 rpm and constant fuel injection pressure The results obtained were compared with a commercial diesel sample (D). The change in the colour of the aqueous copper nitrate solution from blue to green and the presence of a absorption band at a maximum wavelength of 245 nm in the UV spectrum of the nanoparticles indicate the formation of copper nanoparticles. For the engine performance test, results revealed that all the Cu nanoparticles blended diesel samples show a decrease in brake-specific fuel consumption (10.792, 18.331 and 21.086 %) compared to the commercial diesel sample.

Keywords: Nanoparticles, Fuel Additives, Copper, Diesel Engine, Performance

1.0 Introduction

The sectors of transportation, industry, and electricity generation are crucial to a country's economic growth. Due to their naturally high efficiency, dependability, and outstanding power production, diesel engines have emerged as a source of power for these industries (Strielkowski *et al.*, 2021). Diesel engines are rapidly expanding in popularity and are also turning into a major driver of air pollution. Pollutants produced when fuel generated from petroleum is burned have a negative impact on both the environment and human health (Aminzadegan *et al.*, 2022).

Thus, the world is currently dealing with the depletion of fossil fuels and the destruction of the environment. The amount of underground-based carbon resources has decreased as a result of indiscriminate fossil fuel extraction and excessive use (Kavalli *et al.*, 2022). Therefore, it has become urgent to look for affordable and environmentally beneficial ways to deal with this problem which are compatible with sustainable development, energy conservation, efficiency, and environmental preservation (Kumar *et al.*, 2022). Researchers have been attempting to lessen these issues over the past few decades by finding strategies to enhance the quality of diesel fuel. Combining biofuel with diesel is one of the attempts to change the qualities of diesel fuel to increase combustion efficiency.

However, despite having the potential to be an alternative because of non-toxicity, and biodegradability, biodiesel is constrained by issues including heavy consumption and high raw material costs, which make it expensive and substantially hamper its large-scale production (Neupane, 2023). In this situation, using some compounds as blends or enhancements to petroleum diesel may be a workable solution to the problem. Diesel engines are paying more attention to the use of various fuel additives including alcohols and nanoparticles. Due to their affordability, alcohols, particularly methanol and ethanol, are utilized extensively. However issues including a high auto-ignition temperature, poor lubrication, and a decrease in cetane number limit its use as an additive (Brahma *et al.*, 2022).

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Also, the idea of using nanoparticles as a diesel fuel additive substitute has not been fully explored in the past. On the other hand, Oni *et al* (2022) reported that since they significantly improve engine performance, non-alcoholic materials like nanoparticles are comparatively more advantageous. In addition to these features, they are also readily accessible, have a large surface area, have good heat stability, and have a longer lifespan (Trache *et al*., 2020).

Studies have begun to consider using metal oxide nanoparticles as petroleum fuel additives in recent years, among other nanoparticles (Kavalli *et al*., 2022). Also, several synthetic processes, including co-precipitation, colloidal, sol-gel processing, water-oil microemulsions, hydrothermal, solvothermal, sonochemical, and polyol techniques, among others have been employed to produce metal oxide nanoparticles (Aragaw *et al*., 2021). Nevertheless, most of these methods often involve a lot of time, high temperatures, painstaking steps, or the usage of prolonged steps, leading to longer operations unlike the biosynthetic approach which is simple, rapid, affordable, and versatile (Dikshit *et al*., 2021).

However, previous studies have reported that the oxides of aluminum, zinc, titanium, manganese, and iron showed exceptional results in achieving high brake power and high brake thermal efficiency among the investigated nanoparticles (Soudagar *et al*., 2018; Valihesari *et al*., 2019). Thus, this study focuses on the biosynthesis of copper oxide nanoparticles as diesel fuel additives for the determination of the performance of a diesel engine.

2.0 Materials and Methods

2.1 Materials

The chemicals (sodium hydroxide and copper (II) nitrate (VI) pentahydrate) used in this study were of analytical grade. Meanwhile, orange peels were obtained from Fruit Market in Kasuwan Gwari, Minna Niger State while commercial diesel was obtained at the NNPC gas station in Minna, Niger State.

2.2 Methods

Preparation of Orange Peel Extract: Orange peels were washed with tap and deionized water several times. The peels were left for five days in the sun to dry and ground into powder using a blender. The peel extract was prepared by weighing about 4 g of powder into 150 cm^3 of deionized water, followed by 20 minutes of magnetic stirring and boiling. The extract was then filtered and stored at 4 °C for use.

Biosynthesis of Copper Oxide Nanoparticles: To synthesise the copper oxide nanoparticles, a 200 cm^3 solution of $(CuNO_3)_2 \cdot 5H_2O$ was treated with 20 cm^3 of the peel extract and magnetically stirred at room temperature for 30 minutes until the colour change from the light blue of the copper salt to green, which indicates the formation of the nanoparticles. Subsequently, upon twice the addition of 5 cm^3 of 1M sodium hydroxide at intervals of 5 minutes, the green solution changed to a brown precipitate. The precipitate was repeatedly washed with deionized water to remove impurities after which, it was dried at 60 °C and stored for analysis and use.

Preparation of Copper Oxide Nanoparticles-Petroleum Diesel Blends: The preparation of the blends (Diesel+10, Diesel+20, and Diesel+40) was done by varying the amounts of CuO nanoparticles as shown in Table 1. Diesel+10 was prepared by mixing the 0.5 litres of diesel and 10 mg of biosynthesised CuO nanoparticles with the aid of a homogenizer mixer at 700 rpm within 15 minutes and subsequently mixed using an ultrasonicator at an amplitude of 60% within 30 minutes to disperse the nanoparticles in the diesel so as to facilitates possible agglomerate nanoparticles back to nanometer range. The other samples were prepared using the conditions set out in Table 1.

Table 1: Experimental Runs for the Preparation of Diesel-CuO Nanoparticles Blends

Run	Volume of Diesel (litre)	Amount of CuO nanoparticles (mg)	Sample
1	0.5	10.408	D10
2	0.5	20.816	D20
3	0.5	41.632	D40

Characterisation of the Biosynthesised Copper Oxide Nanoparticles: The CuO nanoparticles were characterized by determining their absorption bands by UV-visible spectrophotometry.

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Engine Performance Test: To carry out a performance test of the diesel engine, firstly, a graduated measuring cylinder containing 50 cm^3 of commercial diesel was attached to the fuel tank of the diesel engine to quantify the fuel flow rate. The engine was connected to the battery terminal, and the start button was pressed while the choke was in the return position. The throttle was then placed at a relatively lower engine speed (1000 rpm) and allowed to run idly for 15 minutes to attain uniform temperature and brake torque and brake engine power were determined. The time taken to consume 50 cm^3 of the commercial diesel at various engine speeds (1300, 1600, 1900, and 2200 rpm) was measured using a stopwatch while brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) were determined using the data obtained from the test. The same procedure was repeated using the prepared blends (D10, D20, and D40) as fuels.

3.0 Results and Discussions

Uv spectrum of copper nanoparticles: The copper nanoparticles were efficiently biosynthesized using orange peel extract with visual observation of colour change from blue to green. The UV–vis absorption spectrum of copper oxide nanoparticles is given in Figure 1. It shows a peak at 256 nm which is attributed to the formation of copper oxide nanoparticles which is in close agreement with the earlier report by Kolahalam *et al* (2022). The formation of copper nanoparticles can be attributed to the presence of a high amount of phytochemicals in the orange peel extract (Liew *et al.*, 2018).

Brake thermal efficiency (BTE): The performance tests were conducted on the diesel engine with commercial diesel and copper oxide nanoparticles blended diesel. Figure 2 shows the variation of brake thermal efficiency with increasing engine speed for different amounts of copper oxide nanoparticles. The average brake thermal efficiencies of the diesel engine upon the addition of copper oxide nanoparticles in diesel increase by 4.280, 9.158, and 10.38% for D10, D20, and D40 respectively. The copper oxide nanoparticles present in diesel fuel encourage longer and more complete combustion as compared to commercial diesel fuel, as copper oxide acts as an oxygen buffer, releasing and storing oxygen depending upon the partial pressure of oxygen (Ampah *et al.*, 2022). The efficiency of copper oxide as a catalyst may be accounted for its high thermal stability and ability to transform from the stoichiometric CuO (+2) state to the Cu2O (+1) valence state by means of a relatively low energy reaction (Zhao *et al.*, 2022; Etim *et al.*, 2021). Meanwhile, the sudden decrease in the brake thermal efficiencies observed for D40 at engine speeds between 1600 to 1900 rpm may be attributed to a decrease in the catalytic action of the nanoparticles in the diesel caused possibly by agglomeration of nanoparticles due to the increased amount of nanoparticles in the diesel fuel (Gad *et al.*, 2023).

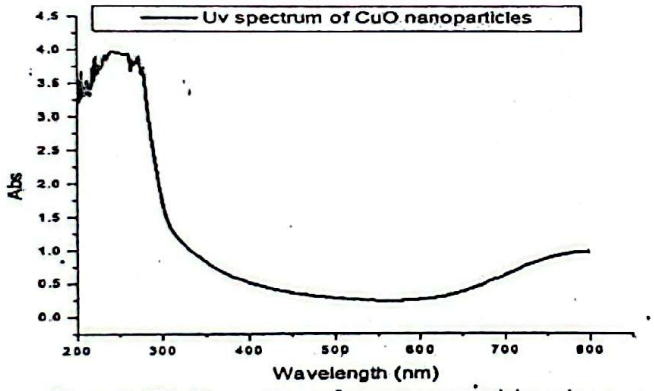

Figure 1: UV–Vis spectrum of copper nanoparticles using orange peels extract

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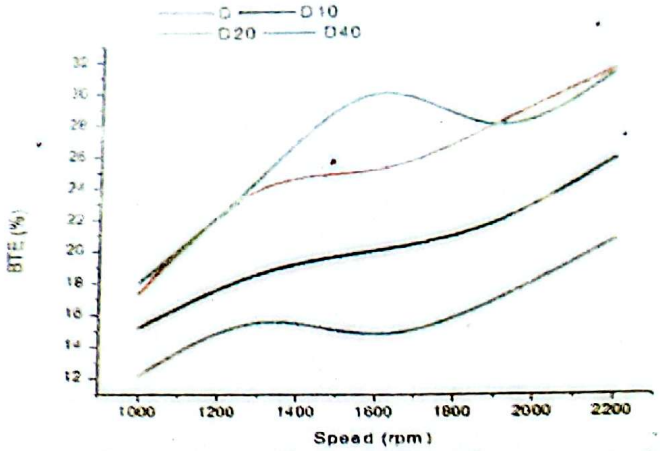

Figure 2: The brake thermal efficiency (BTE) at different engine speeds

Brake specific fuel consumption (BSFC): Figure 3 displays the brake-specific fuel consumption (BSFC) variation with engine speed. Generally, there is a decrease in the BSFC with a rise in engine speed which may be due to adequate combustion of diesel fuel. Also, it can be seen that the BSFC values for D10, D20, and D40 blends were less than those of commercial diesel fuel (D). The BSFC decreased with increasing the amount of CuO nanoparticles in the diesel samples such that the average reduction of BFSC upon the addition of copper oxide nanoparticles was 10.792, 18.331, and 21.08% for D10, D20, and D40 samples respectively. This effect may be due to the increase of the evaporation rates, which leads to a reduction in the ignition delay with an increase of nanoparticles dose by virtue of enhanced surface area to volume ratio which produces more sufficient combustion (Ampah *et al.*, 2022).

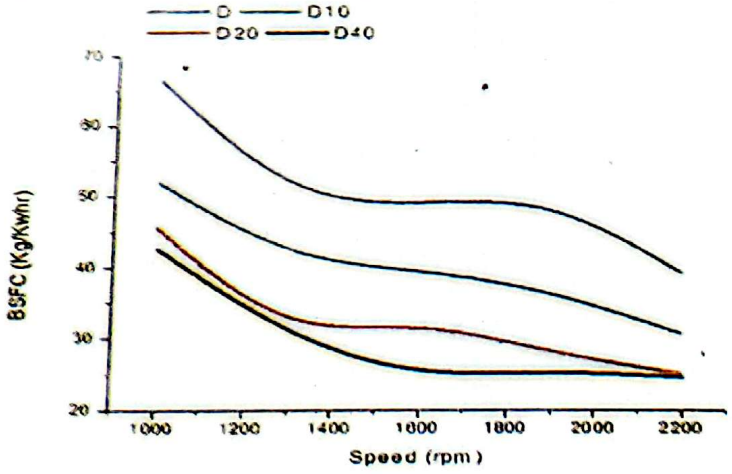

Figure 3: The brake specific fuel consumption (BSFC) at different engine speeds

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Conclusion

The present work aims at the biosynthesis of copper oxide nanoparticles and the investigation of the effect of nanoparticles on engine performance. Uv technique was employed to confirm the formation of copper oxide nanoparticles. Performance test has been done in the diesel engine to investigate the effect of catalytic nanoparticles on the efficiency of the engine. Based on the experiments, it can be concluded that the brake thermal efficiency (BTE) of the diesel engine increases with the increase in the amount of copper oxide nanoparticles in diesel while the brake-specific fuel consumption (BSFC) reduces as the amount of nanoparticles in the diesel increases.

References

Aminzadegan, S., Shahriari, M., Mehranfar, F., & Abramović, B. (2022). Factors affecting the emission of pollutants in different types of transportation: A literature review. *Energy Reports*, *8*, 2508-2529. https://doi.org/10.1016/j.egyr.2022.01.161.

Ampah, J. D., Yusuf, A. A., Agyekum, E. B., Afrane, S., Jin, C., Liu, H., Fattah, I. M. R., Show, P. L., Shouran, M., Habil, M., & Kamel, S. (2022). Progress and Recent Trends in the Application of Nanoparticles as Low Carbon Fuel Additives-A State of the Art Review. *Nanomaterials (Basel, Switzerland)*, *12*(9), 1515. https://doi.org/10.3390/nano12091515.

Aragaw, T. A., Bogale, F. M., & Aragaw, B. A. (2021). Iron-based nanoparticles in wastewater treatment: A review on synthesis methods, applications, and removal mechanisms. *Journal of Saudi Chemical Society*, *25*(8), 101280. https://doi.org/10.1016/j.jscs.2021.101280.

Brahma, S., Nath, B., Basumatary, B., Das, B., Saikia, P., Patir, K., & Basumatary, S. (2022). Biodiesel production from mixed oils: A sustainable approach towards industrial biofuel production. *Chemical Engineering Journal Advances*, *10*, 100284. https://doi.org/10.1016/j.ceja.2022.100284.

Dikshit, P. K., Kumar, J., Das, A. K., Sadhu, S., Sharma, S., Singh, S., Gupta, P. K., & Kim, B. S. (2021). Green Synthesis of Metallic Nanoparticles: Applications and Limitations. *Catalysts*, *11*(8), 902. https://doi.org/10.3390/catal11080902.

Etim, U. J., Zhang, C., & Zhong, Z. (2021). Impacts of the Catalyst Structures on CO_2 Activation on Catalyst Surfaces. *Nanomaterials (Basel, Switzerland)*, *11*(12), 3265. https://doi.org/10.3390/nano11123265.

Gad, M.S., Ağbulut, U., Afzal, A., Panchal, H., Jayaraj, S., Qasem, N.A.A., & El-Shafay, A. S. (2023). A comprehensive review on the usage of the nano-sized particles along with diesel/biofuel blends and their impacts on engine behaviours, *Fuel*, 339, doi.org/10.1016/j.fuel.2022.127364.

Kavalli, K., Hebbar, G. S., Shubha, J. P., Adil, S. F., Khan, M., Hatshan, M. R., Almutairi, A. M., & Shai B. (2022). Green Synthesized ZnO Nanoparticles as Biodiesel Blends and Their Effect on the Performance and Emission of Greenhouse Gases. *Molecules*, *27*(9). https://doi.org/10.3390/molecules27092845.

Kolahalam, L. A., Prasad, K.R.S., Krishna, P. M., Supraja, N., Shanmugan, S. (2022). The exploration of bio-inspired copper oxide nanoparticles: synthesis, characterization and in-vitro biological investigations, *Heliyon*, 8, 6, doi.org/10.1016/j.heliyon.2022.e09726.

Kumar, A., Singh, P., Raizada, P., & Hussain, C. M. (2022). Impact of COVID-19 on greenhouse gases emissions: A critical review. *The Science of the Total Environment*, *806*, 150349. https://doi.org/10.1016/j.scitotenv.2021.150349.

Liew, S. S., Ho, W. Y., Yeap, S. K., & Sharifudin, S. A. B. (2018). Phytochemical composition and in vitro . antioxidant activities of *Citrus sinensis* peel extracts. *PeerJ*, *6*, e5331. https://doi.org/10.7717/peerj.5331.

Neupane, D. (2023). Biofuels from Renewable Sources, a Potential Option for Biodiesel Production. *Bioengineering*, *10*(1). https://doi.org/10.3390/bioengineering10010029.

Oni, B. A., Sanni, S. E., Orodu, D. O., & Ogunkunle, T. F. (2022). Comparing the effects of Juliflora biodiesel doped with nano-additives on the performance of a compression ignition (CI) engine: Part A. *Energy*, *244*, 122635. https://doi.org/10.1016/j.energy.2021.122635.

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Soudagar MEM, Nik-Ghazali N-N, Abul Kalam M, Badruddin IA, Banapurmath NR, Akram N. The effect of nano-additives in diesel-biodiesel fuel blends: A comprehensive review on stability, engine performance and emission characteristics. Energy Convers Manage 2018;178:146–77.

Strielkowski, W., Civín, L., Tarkhanova, E., Tvaronavičienė, M., & Petrenko, Y. (2021). Renewable Energy in the Sustainable Development of Electrical Power Sector: A Review. *Energies*, *14*(24), 8240. https://doi.org/10.3390/en14248240.

Trache, D., Tarchoun, A. F., Derradji, M., Hamidon, T. S., Masruchin, N., Brosse, N., & Hussin, M. H (2020). Nanocellulose: From Fundamentals to Advanced Applications. *Frontiers in Chemistry*, *8*. https://doi.org/10.3389/fchem.2020.00392.

Valihesari M, Pirouzfar V, Ommi F, Zamankhan F. Investigating the effect of Fe2O3 and TiO2 nanoparticle and engine variables on the gasoline engine performance through statistical analysis. Fuel 2019;254:115618.

Zhao, F., Shi, Y., Xu, L., Chen, M., Xue, Y., Wu, C. E., Qiu, J., Cheng, G., Xu, J., & Hu, X. (2022). Designing Highly Efficient Cu_2O-CuO Heterojunction CO Oxidation Catalysts: The Roles of the Support Type and Cu_2O-CuO Interface Effect. *Nanomaterials (Basel, Switzerland)*, *12*(17), 3020. https://doi.org/10.3390/nano12173020.

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