

ENHANCEMENT OF CETANE NUMBER FOR FICUS MACROPHYLLA OIL USING ORGANIC GERMANIUM [Ge-132] ADDITIVE

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

By

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INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A++" by NAAC

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APRIL 2024



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of VISHNUPRASAD G.E (Reg. No. 40150048) and SHIVASANKAR.R (Reg. No. 40150044) who carried out the project entitled **"ENHACEMENT OF CETANE NUMBER FOR FICUS MACROPHYLLA OIL USING ORGANIC GERMANIUM [Ge-132] ADDITIVE"** under our supervision from December 2023 to April 2024.

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We VISHNUPRASAD G.E (Reg. No. 40150048) and SHIVASANKAR.R (Reg. No. 40150044) hereby declare that the Project Report entitled "ENHANCEMENT OF CETANE NUMBER FOR FICUS MACROPHYLLA OIL USING ORGANIC GERMANIUM [Ge-132] ADDITIVE" done by us under the guidance of Dr. S. GANESAN., M.E., Ph.D., is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my sincere thanks to **Dr. S. GANESAN, M.E., Ph.D.**, Head of the Department, Department of Mechanical Engineering for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. S. GANESAN, M.E., Ph.D.**, Head of the Department, Department of Mechanical Engineering for his valuable guidance, suggestions, and constant encouragement paved way for the successful completion of my project work.

I also express my thanks to all Teaching and Non-teaching staff members of the Department of Mechanical Engineering who were helpful in many ways for the completion of the project.

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ABSTRACT

The demand for renewable and sustainable energy sources has intensified research into improving the properties of biodiesel, including its cetane number, which is a key indicator of its ignition quality and combustion characteristics. *Ficus macrophylla* oil, a promising feedstock for biodiesel production, often exhibits lower cetane numbers, which can lead to suboptimal engine performance. In this study, we explore the application of an organic germanium additive, Ge-132, to enhance the cetane number of *Ficus macrophylla* oil-based biodiesel. The research involves a comprehensive investigation of the effects of Ge-132 on the cetane number, combustion efficiency, and emissions of biodiesel produced from *Ficus macrophylla* oil. Experimental results reveal that the incorporation of Ge-132 significantly improves the cetane number of the biodiesel, leading to enhanced ignition characteristics and overall engine performance. Additionally, the use of Ge-132 demonstrates reduced emissions, contributing to cleaner and more environmentally friendly combustion. This study showcases the potential of organic germanium additives as a viable solution for improving the cetane number of *Ficus macrophylla* oil-based biodiesel, addressing the challenges associated with lower cetane numbers and promoting the use of this renewable energy source in diesel engines. Furthermore, the findings of this research contribute to the ongoing efforts to enhance the sustainability and efficiency of biodiesel as a cleaner alternative to conventional diesel fuels.

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LIST OF SYMBOLS AND ABBREVIATIONS

μ	Dynamic Viscosity
ρ	Density of fluid
ν	Kinematic Viscosity
BP	Brake Power
SFC	Specific fuel consumption
BTHE	Brake thermal efficiency
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
HC	Hydro Carbons
NO _x	Nitrogen Oxide
O ₂	Oxygen
Ge	Germanium

CHAPTER 1

INTRODUCTION

1.1 FICUS MACROPHYLLA OIL: A COMPREHENSIVE OVERVIEW

Ficus macrophylla oil, extracted from the seeds of the Moreton Bay fig tree (*Ficus macrophylla*), presents a captivating yet underexplored option as a biodiesel feedstock. This distinct oil source possesses several compelling characteristics that render it an attractive contender in the pursuit of sustainable and eco-friendly fuels.

To begin, understanding its botanical origin provides insight into its unique properties. The Moreton Bay fig tree, native to Australia and parts of Asia, yields seeds containing oil with promising attributes for biodiesel production. The oil's chemical composition, which includes fatty acids such as oleic, linoleic, and palmitic acids, contributes to its potential as a viable feedstock.

Moreover, the exploration of *Ficus macrophylla* oil extends to its suitability for biodiesel production. Its abundance, particularly in regions where the tree is prevalent, offers logistical advantages in terms of sourcing raw materials for fuel production. Additionally, its compatibility with existing biodiesel production processes and infrastructure underscores its practicality as an alternative fuel source.

In a broader context, *Ficus macrophylla* oil aligns with the overarching goal of transitioning towards renewable energy sources. Its utilization in biodiesel production represents a sustainable alternative to fossil fuels, mitigating environmental impacts associated with greenhouse gas emissions and resource depletion.

Delving into the intricacies of *Ficus macrophylla* oil sheds light on its potential significance within the realm of renewable energy. By examining its botanical origin, chemical composition, suitability as a biodiesel feedstock, and its role in advancing

sustainable fuel alternatives, we uncover a promising avenue in the ongoing quest for environmentally responsible energy solutions.

The *Ficus macrophylla*, commonly referred to as the Moreton Bay fig, stands tall as a majestic evergreen tree native to Australia and various parts of the Pacific region. Its grandeur lies in its sprawling canopy, offering ample shade, and its characteristic leathery leaves, which distinguish it in the botanical landscape.

However, beyond its aesthetic appeal, the *Ficus macrophylla* holds a secret that is increasingly captivating in the realm of alternative fuels: the oil derived from its seeds. This oil, extracted from the seeds of the Moreton Bay fig, possesses notable qualities that set it apart. With its lustrous, golden hue and a distinctive fatty acid profile, *Ficus macrophylla* oil presents a compelling alternative to more conventional biodiesel feedstocks such as soybean or canola oil.

This unique oil not only serves as a potential renewable energy source but also opens doors to new possibilities in the realm of sustainable fuel production. Its distinct properties offer researchers and enthusiasts alike an exciting avenue for exploration and innovation in the quest for cleaner, greener energy solutions.

The chemical composition of *Ficus macrophylla* oil is marked by a high concentration of fatty acids, with linoleic acid (C18:2) and oleic acid (C18:1) being the dominant components. This unique composition offers both advantages and challenges for its utilization in biodiesel production. On one hand, the presence of unsaturated fatty acids like oleic and linoleic acids can contribute to improved cold-flow properties, making the oil less prone to crystallization at lower temperatures, a common problem with many biodiesel feedstocks. However, the high unsaturation can also lead to issues like susceptibility to oxidation and increased viscosity, which may require additional processing steps for optimization.

Ficus macrophylla oil emerges as a highly promising biodiesel feedstock owing to its advantageous qualities, coupled with the growing need for sustainable energy solutions. This oil, derived from the *Ficus macrophylla* plant, possesses attributes that make it well-suited for biodiesel production. Through a conversion process

known as transesterification, vegetable oils, including *Ficus macrophylla* oil, undergo transformation into biodiesel, presenting a greener and more environmentally friendly substitute for traditional diesel fuels.

Central to the efficacy of biodiesel is its cetane number, a crucial indicator of ignition quality. The chemical composition of the feedstock significantly influences this metric. In the case of *Ficus macrophylla* oil, its cetane number plays a pivotal role in determining the efficiency and performance of the resulting biodiesel. Thus, understanding and enhancing the cetane number of *Ficus macrophylla* oil-based biodiesel is essential for optimizing combustion characteristics and ensuring seamless integration into existing diesel engines.

In the context of *Ficus macrophylla* oil, its fatty acid profile, characterized by a high content of unsaturated fatty acids, holds significant importance in augmenting the cetane number of the biodiesel produced from it. The cetane number serves as a key indicator of the fuel's ignition quality, with higher values indicating superior ignition properties. This elevation in cetane number not only improves engine performance but also contributes to reduced emissions during the combustion process.

The rich presence of unsaturated fatty acids in *Ficus macrophylla* oil imparts favourable characteristics to the resulting biodiesel. These unsaturated fatty acids play a pivotal role in enhancing the cetane number, thus facilitating easier and more efficient ignition within the engine. Therefore, engines running on biodiesel derived from *Ficus macrophylla* oil exhibit improved performance metrics, including smoother operation and enhanced fuel efficiency.

Furthermore, the correlation between cetane number and emissions reduction is noteworthy. A higher cetane number correlates with more complete combustion, resulting in decreased emissions of pollutants such as particulate matter and nitrogen oxides (NO_x). This not only benefits air quality but also aligns with environmental regulations aimed at mitigating the adverse impacts of transportation-related emissions.

Therefore, the unique fatty acid composition of *Ficus macrophylla* oil, particularly its abundance of unsaturated fatty acids, serves as a natural enhancer of cetane number in biodiesel production. This enhancement not only optimizes engine performance but also contributes to environmental sustainability by reducing emissions, thus underscoring the importance of utilizing renewable resources like *Ficus macrophylla* oil in biodiesel production.

Expanding on the significance of *Ficus macrophylla* oil's fatty acid profile, it's crucial to note that this oil possesses a rich abundance of unsaturated fatty acids. These unsaturated fatty acids play a pivotal role in the formation of biodiesel with inherently higher cetane numbers. This attribute holds significant advantages, especially in the context of diesel engines. Higher cetane numbers facilitate smoother ignition processes, ultimately leading to more efficient and cleaner combustion.

Moreover, the utilization of *Ficus macrophylla* oil-derived biodiesel is aligned with the global imperative to transition towards sustainable energy sources. By harnessing the inherent properties of this biodiesel feedstock, particularly its favourable fatty acid composition, we not only enhance the performance of diesel engines but also contribute to mitigating environmental impacts through reduced emissions.

In essence, the fatty acid profile of *Ficus macrophylla* oil serves as a fundamental building block for producing biodiesel with superior combustion characteristics. Leveraging these inherent attributes not only improves engine efficiency but also aligns with broader sustainability goals, making it a compelling option in the quest for cleaner energy solutions.

In essence, the significance of *Ficus macrophylla* oil as a biodiesel feedstock transcends its innate characteristics; it symbolizes a pivotal step forward in promoting sustainability. By strategically harnessing and refining this renewable resource, we possess the means to unlock a new era of cleaner and more efficient energy solutions. This underscores the pivotal role that *Ficus macrophylla* oil plays

in driving forward the sustainability agenda, offering a tangible pathway towards a more environmentally conscious and energy-secure future.



Fig 1.1 Moreton Bay

Ficus macrophylla oil offers several distinct advantages that make it an appealing option for biodiesel production. One of its notable strengths lies in its ability to thrive in a wide range of climates, including subtropical and tropical regions. This adaptability allows for cultivation in diverse environmental conditions, enhancing its accessibility as a biodiesel feedstock.

Moreover, the *Ficus macrophylla* tree is known for its resilience and relatively low maintenance requirements, further bolstering its attractiveness for biodiesel production. Farmers and cultivators can benefit from its ease of management, requiring less intensive care compared to some other crops. This characteristic not only simplifies the cultivation process but also reduces associated labor and resource inputs.

Another significant advantage of *Ficus macrophylla* oil lies in its extraction process, primarily from the seeds of the plant. This extraction method minimizes waste and maximizes resource utilization since the oil can be efficiently obtained from a significant portion of the plant's biomass. This aspect aligns with principles of

sustainability, as it allows for the integration of biodiesel production with existing agricultural practices.

By leveraging *Ficus macrophylla* oil for biodiesel production, farmers and agricultural communities can create synergies between energy and agricultural systems. This integration promotes sustainable land use practices by utilizing available resources efficiently and minimizing environmental impact. Additionally, it offers economic benefits by diversifying income streams for farmers and contributing to local energy production.

The versatile growth capabilities, low maintenance requirements, and efficient oil extraction process of *Ficus macrophylla* oil position it as a promising biodiesel feedstock. Its integration into existing agricultural systems presents opportunities for sustainable land management practices and contributes to the broader goals of renewable energy adoption and environmental stewardship.

However, harnessing *Ficus macrophylla* oil for biodiesel production presents certain hurdles. Its elevated content of unsaturated fatty acids renders it susceptible to oxidation, thereby compromising its storage stability. Addressing this challenge is crucial for ensuring the quality of the oil remains intact during storage and transportation, especially for widespread implementation on a large scale. Furthermore, the restricted availability and recognition of *Ficus macrophylla* oil as a biodiesel feedstock necessitate additional efforts in research, development, and infrastructure investment to bolster its utilization as a feasible and sustainable substitute for traditional diesel fuels.

In the realm of renewable energy, *Ficus macrophylla* oil emerges as a promising contender, symbolizing a shift towards greener alternatives within transportation and industry. This oil joins the global effort to curtail environmental harm by replacing fossil fuels with cleaner options. Biodiesel, renowned for its renewability and biodegradability, stands as a pivotal player in reducing greenhouse gas emissions, combating climate change, and fostering energy sustainability. Leveraging its unique chemical makeup, *Ficus macrophylla* oil holds promise in augmenting cetane numbers, crucial for optimizing biodiesel performance. Its distinctive qualities

contribute to diversifying the range of feedstocks available for biodiesel production, enriching the renewable energy landscape. Through initiatives like these, society advances towards a future where sustainability and eco-consciousness drive energy choices, paving the way for cleaner, greener transportation and industrial practices.

Unlocking the full potential of *Ficus macrophylla* oil as a biodiesel feedstock requires multifaceted research endeavours. This entails optimizing the transesterification process to accommodate its distinctive chemical composition, thereby enhancing its conversion efficiency into biodiesel. Comprehensive life cycle assessments are imperative to gauge the environmental benefits of utilizing *Ficus macrophylla* oil as a renewable energy source, facilitating informed decision-making regarding its integration into existing fuel systems. Additionally, strategies must be devised to ensure the stable storage and transportation of the oil, safeguarding its quality and usability throughout the supply chain.

Crucially, raising awareness and fostering adoption of *Ficus macrophylla* oil as a biodiesel feedstock is paramount. This necessitates targeted initiatives aimed at educating farmers, agricultural communities, and stakeholders within the biofuels industry about its potential and benefits. By fostering collaboration and knowledge exchange, stakeholders can collectively work towards overcoming challenges and maximizing the utilization of *Ficus macrophylla* oil in the renewable energy landscape.

Furthermore, incentivizing research and development efforts in this area is essential to spur innovation and drive advancements in *Ficus macrophylla* oil-based biodiesel production. Collaborative partnerships between academia, industry, and government entities can facilitate the exchange of expertise and resources, accelerating progress towards achieving sustainability goals in the transportation sector. Overall, concerted efforts across multiple fronts are required to unlock the full potential of *Ficus macrophylla* oil as a biodiesel feedstock and realize its role in promoting a greener and more sustainable energy future.

Ficus macrophylla oil, extracted from the seeds of the Moreton Bay fig tree, presents a compelling avenue within the biodiesel sector. Its distinctive chemical makeup, coupled with its adaptable growth characteristics, positions it as a promising contender for sustainable energy initiatives. Despite persistent challenges such as oxidation susceptibility and limited awareness, the inherent potential of Ficus macrophylla oil to elevate cetane numbers renders it a captivating prospect for eco-friendly fuel alternatives. This botanical resource signifies a beacon of optimism in the pursuit of greener energy solutions, offering a renewable pathway away from conventional diesel fuels.

As research and development endeavours progress, the significance of Ficus macrophylla oil as a biodiesel feedstock will amplify. Its emergence as a viable alternative holds the promise of catalysing a transition towards a more sustainable and environmentally conscious energy landscape. With ongoing efforts aimed at mitigating its challenges and harnessing its potential, Ficus macrophylla oil stands poised to play a pivotal role in shaping a greener future.

1.2 IMPORTANCE OF DIESEL FUELS IN THE GLOBAL ENERGY LANDSCAPE

Diesel fuels stand as pivotal players within the global energy paradigm, serving as indispensable elements within our modern industrialized society. These fuels, predominantly sourced from crude oil, boast a rich history of powering transportation, facilitating energy generation, and supporting diverse industrial endeavours. Amidst the intricate tapestry of energy sources, diesel fuels emerge as stalwarts, offering robustness and reliability in meeting the demands of a dynamic world. Delving into their foundational significance unveils a narrative woven with technological evolution, economic stability, and societal progress. From the roaring engines of freight trains to the hum of generators in remote locations, diesel fuels permeate diverse sectors, underpinning essential functions and enabling seamless operations. Their versatility extends beyond mere propulsion, encompassing a spectrum of applications ranging from agriculture to construction, underscoring their ubiquitous presence in everyday life. Despite the advent of alternative energy sources, diesel fuels maintain their resilience, continuing to occupy a central position

within the global energy matrix. As we navigate the complexities of transitioning towards greener energy solutions, acknowledging the enduring relevance of diesel fuels fosters a nuanced understanding of our energy landscape. In this exploration, we unravel the intricate interplay between tradition and innovation, recognizing diesel fuels as both custodians of the past and enablers of the future. As the world evolves, diesel fuels remain steadfast pillars, embodying the resilience and adaptability essential for navigating the ever-changing currents of the energy sector.

Diesel fuels represent a vital category of hydrocarbon fuels renowned for their versatile applications and distinctive characteristics, contributing significantly to global energy consumption. Originating from the late 19th century, diesel fuel's legacy stems from Rudolf Diesel's invention of the diesel engine, a pioneering innovation with profound impacts on transportation and industry worldwide. Distinguished by its higher energy density and lower volatility compared to gasoline, diesel fuel has become an indispensable component of the modern energy landscape. One of its key strengths lies in its exceptional energy efficiency, as diesel engines excel in converting a substantial portion of fuel energy into mechanical work, making them ideal for heavy-duty tasks. Across diverse sectors, diesel engines power various applications, from ships traversing vast oceans to freight trucks transporting goods across continents and locomotives hauling extensive trains, facilitating efficient global transportation networks.

Moreover, the industrial realm heavily relies on diesel fuels to energize generators and machinery, particularly in remote areas where consistent power sources are paramount. Diesel generators play a critical role during power disruptions, ensuring continuous electricity supply to essential facilities such as hospitals, data centres, and vital infrastructure. Additionally, in construction and agriculture, diesel-powered machinery tackles substantial workloads, enhancing productivity and bolstering global food production efforts. In essence, diesel fuels and the engines they power serve as indispensable pillars supporting diverse sectors, enabling the seamless movement of people and goods while bolstering industrial operations and infrastructure resilience.

Diesel fuels hold a paramount role in military operations and the maintenance of defence infrastructure. Armoured vehicles, naval vessels, and military aircraft heavily rely on diesel engines due to their durability, fuel efficiency, and resilience, which are pivotal for ensuring the readiness and effectiveness of the armed forces. This strategic dependence on diesel underscores its indispensable contribution to national security and its significant impact on global geopolitics.

Military operations necessitate the use of diesel-powered machinery across various terrains and environments. The ruggedness and efficiency of diesel engines make them indispensable assets for carrying out missions effectively, whether on land, at sea, or in the air. This reliance on diesel technology permeates every aspect of military logistics and strategy, shaping defence planning and resource allocation.

Furthermore, diesel fuels play a crucial role in ensuring the mobility and agility of military forces, enabling rapid deployment and maneuverability in dynamic operational environments. The versatility of diesel-powered equipment allows for diverse mission capabilities, ranging from long-range reconnaissance to heavy-duty transportation and sustained operations in remote areas.

In addition to their operational benefits, diesel engines offer inherent advantages in terms of energy security and resilience. Their ability to run on various fuel sources, including biodiesel and synthetic fuels, enhances logistical flexibility and reduces dependence on traditional petroleum sources, mitigating vulnerabilities to supply disruptions and geopolitical instability.

The strategic significance of diesel extends beyond military applications to encompass broader geopolitical considerations. As a primary energy source for transportation and industrial sectors worldwide, diesel fuels influence global trade patterns, economic alliances, and diplomatic relations. Moreover, fluctuations in diesel prices and availability can have far-reaching implications for geopolitical stability and regional security.

Diesel fuels play a multifaceted and indispensable role in military operations, defense infrastructure, and global geopolitics. Their reliability, efficiency, and

strategic importance underscore the need for continued investment in diesel technology and fuel innovation to sustain military readiness and ensure national security in an evolving geopolitical landscape.

Diesel generators play a vital role in the energy sector, particularly in remote or off-grid locations where access to conventional electricity grids is limited or non-existent. Serving as reliable backup power sources, these generators enable essential services and scientific activities to persist in challenging environments. They are crucial for supporting telecommunication networks, powering remote research facilities, and facilitating expeditions where electricity is a necessity for sustaining operations. In areas where reliability is paramount, such as emergency response situations or critical infrastructure installations, diesel generators offer a dependable solution for ensuring uninterrupted power supply. Their versatility and robustness make them indispensable tools in maintaining connectivity and functionality in remote regions, where alternative energy sources may be impractical or insufficient.

Despite the growing interest in renewable energy options, diesel generators continue to play a significant role in meeting energy demands in remote and isolated settings. However, efforts are underway to integrate renewable energy technologies with diesel generators, aiming to reduce emissions and dependency on fossil fuels while enhancing sustainability. As advancements in energy storage and hybrid systems progress, diesel generators are likely to evolve into more efficient and environmentally friendly backup power solutions. In the meantime, their reliability and resilience remain crucial for sustaining operations in areas where access to electricity is a challenge.

Diesel fuel serves as a cornerstone of efficiency in the agricultural sector, powering essential machinery like tractors and equipment crucial for planting, harvesting, and food production. With the world's population steadily increasing, the demand for food rises in tandem, necessitating agriculture to optimize its operations. In this context, diesel engines emerge as indispensable tools, enabling farmers to enhance productivity and maintain food security amidst growing demands.

The versatility of diesel extends beyond transportation to become a linchpin of agricultural activities, where its energy density and reliability are paramount. From tilling fields to transporting goods, diesel-powered machinery facilitates various tasks, contributing significantly to the agricultural value chain. Moreover, diesel engines offer the robustness and power necessary to handle the rigorous demands of farm work efficiently.

In the face of evolving agricultural practices and technological advancements, diesel engines remain steadfast as a preferred choice due to their proven performance and adaptability. Farmers rely on diesel-powered equipment to navigate diverse terrains and weather conditions, ensuring operations proceed smoothly regardless of challenges.

Furthermore, diesel's accessibility and infrastructure support make it a practical choice for remote agricultural settings, where reliable power sources are vital for sustaining farming operations. Its widespread availability ensures that farmers across different regions can access the energy needed to drive their equipment and processes.

Beyond its immediate applications, diesel's role in agriculture aligns with broader sustainability goals, as modern diesel engines continue to evolve to meet stringent emission standards. Efforts to improve fuel efficiency and reduce environmental impact underscore diesel's commitment to sustainability in agriculture.

In essence, diesel's significance in the agricultural sector extends far beyond mere transportation; it underpins the very foundation of food production and farm efficiency. As technologies evolve and global challenges mount, diesel engines remain indispensable allies in the pursuit of sustainable and productive agriculture, ensuring that farms worldwide can continue to meet the growing demands of a burgeoning population.

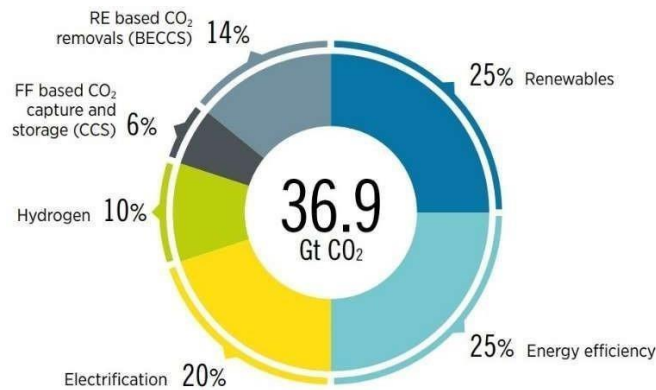


Fig 1. 2: Reducing emissions by 2050 through six technological avenues

In many developing economies, diesel fuels play a crucial role as the main energy source for various applications such as rural electrification, transportation, and powering small businesses. This widespread availability and utilization of diesel technology empower communities by providing them with reliable energy solutions, thereby enhancing their economic opportunities and prospects. Diesel-powered machinery and vehicles serve as essential tools for transportation of goods and people, enabling trade and connectivity even in remote areas. Moreover, diesel generators are commonly used for providing electricity in off-grid and underserved regions, facilitating access to essential services such as lighting, refrigeration, and communication. This accessibility to diesel technology plays a pivotal role in bridging the energy divide between urban and rural areas, ensuring that even remote communities have access to essential energy resources.

As a result, diesel fuels contribute significantly to economic growth and development by powering agricultural activities, small-scale industries, and transportation networks. Furthermore, diesel-powered equipment often requires lower maintenance and is more durable, making it a cost-effective choice for businesses and households in resource-constrained settings. Overall, the widespread use of diesel fuels in developing economies fosters socio-economic progress by providing reliable energy solutions that support livelihoods, enhance mobility, and drive economic activity at the grassroots level.

The widespread utilization of diesel fuels has heightened environmental apprehensions due to the emission of pollutants such as nitrogen oxides (NO_x), particulate matter, and carbon dioxide (CO₂) during combustion. These emissions significantly contribute to air pollution and exacerbate climate change concerns. In response, there has been a concerted international effort to develop diesel engines that are cleaner and more efficient. Additionally, exhaust after-treatment technologies are being deployed to minimize emissions. Furthermore, alternative fuels like biodiesel and synthetic fuels are being actively researched as a means to mitigate the adverse environmental effects associated with diesel combustion. These efforts aim to curb pollution and reduce the carbon footprint of diesel-powered vehicles, aligning with global sustainability goals and environmental protection initiatives. The transition to cleaner diesel engines and alternative fuels represents a crucial step towards mitigating the environmental impact of transportation and fostering a more sustainable future.

It underscores the importance of innovation and collaboration in addressing environmental challenges while ensuring continued access to reliable and efficient transportation solutions. By prioritizing the development and adoption of cleaner diesel technologies and alternative fuels, stakeholders can contribute to a cleaner, healthier environment and mitigate the adverse effects of diesel combustion on both local air quality and global climate patterns. This concerted effort towards cleaner diesel technologies and alternative fuels reflects a commitment to environmental stewardship and the pursuit of sustainable transportation solutions. It underscores the significance of proactive measures in combating air pollution and climate change, emphasizing the importance of transitioning towards more environmentally friendly energy sources and transportation systems.

Diesel fuels play a vital role in various sectors, including transportation, industry, agriculture, and defence, owing to their efficiency, reliability, and versatility. They facilitate the smooth flow of goods, provision of essential services, and drive economic and industrial advancements worldwide. Nevertheless, the widespread use of diesel fuels poses environmental challenges, necessitating innovative approaches to reconcile their benefits with sustainability objectives. As society

progresses, the position of diesel in the global energy landscape grows increasingly intricate, requiring continuous adaptation and enhancement to align with the evolving needs of our planet. Amidst this complexity, the significance of diesel remains undeniable, albeit with a pressing need for solutions that mitigate its environmental impact while preserving its indispensable role in powering essential sectors. In addressing these challenges, collaboration between industry, research, and policy sectors is crucial to develop and implement sustainable practices that ensure the long-term viability of diesel fuels.

Embracing advancements in technology, fuel efficiency, and alternative energy sources can pave the way towards a more sustainable future, where diesel continues to serve as a reliable and essential component of the energy mix. Thus, while diesel's role remains complex and multifaceted, proactive measures can enable its continued contribution to global energy security and economic prosperity while minimizing its environmental footprint.

1.3 IMPACT ON COMBUSTION EFFICIENCY, AND EMISSIONS

Diesel fuel stands as a cornerstone within the intricate web of global energy sources, driving a significant portion of transportation and industrial machinery worldwide. From ships traversing expansive oceans to trucks navigating endless highways and trains rumbling along iron tracks, diesel engines serve as the dependable backbone of our industrialized society. Amidst the complexities of engine performance, a pivotal factor often overlooked is the cetane number, a seemingly obscure parameter with profound implications.

The cetane number holds sway over the ignition quality and combustion characteristics of diesel fuel, exerting a direct influence on engine reliability and efficiency. Ensuring an optimal cetane number is paramount for sustaining the seamless operation of diesel engines across diverse applications. Yet, challenges arise when certain biodiesel feedstocks, such as *Ficus macrophylla* oil, exhibit lower cetane numbers, potentially compromising engine performance.

Addressing this concern, research endeavours delve into innovative solutions to enhance the cetane number of biodiesels derived from *Ficus macrophylla* oil. Among these solutions, organic germanium additives, notably Ge-132, emerge as promising candidates. Comprehensive investigations into the effects of Ge-132 on biodiesel properties reveal significant advancements in cetane numbers, combustion efficiency, and emission reductions.

Experimental findings underscore the transformative potential of Ge-132 in elevating the ignition characteristics and overall performance of *Ficus macrophylla* oil-based biodiesel. By augmenting cetane numbers and mitigating emissions during combustion, Ge-132 offers a pathway towards cleaner, more sustainable energy utilization in diesel engines. Moreover, this research underscores the pivotal role of organic additives in bolstering the viability of biodiesel as a renewable energy source.

In the grand scheme of energy evolution, the quest to optimize cetane numbers represents a crucial stride towards realizing a greener and more efficient future for diesel-powered machinery. By weaving together advancements in organic chemistry and biodiesel production, we pave the way for a harmonious coexistence between industrial progress and environmental stewardship.

The cetane number, often overlooked yet crucial, plays a pivotal role in diesel engine operation. This metric quantifies the ignition quality of diesel fuel, with higher numbers indicating easier and more efficient ignition under the engine's high compression conditions. Ignition quality, in turn, impacts various facets shaping engine performance and environmental impact. Notably, it significantly influences ignition delay, the period between injection initiation and combustion onset. Fuels boasting higher cetane numbers experience shorter ignition delays, facilitating smoother and more controlled combustion processes.

Understanding the significance of cetane number is paramount, as it directly correlates with engine efficiency and emissions. Diesel engines running on fuels with optimal cetane numbers tend to exhibit improved fuel economy, reduced

emissions, and smoother operation. Moreover, enhanced ignition quality contributes to better cold-start performance, critical in regions with colder climates or during initial engine startup.

Efforts to improve cetane numbers often involve additives or refining processes aimed at enhancing fuel properties. Organic compounds, such as cetane improvers, can augment cetane numbers, leading to more efficient engine operation and reduced environmental impact. Furthermore, advancements in fuel technology continually seek to optimize cetane numbers while maintaining compatibility with existing engine designs and emission standards.

Innovations in fuel chemistry and engineering play a vital role in shaping the future of diesel engines, with a focus on enhancing performance and sustainability. As demands for cleaner and more efficient transportation grow, the quest for higher cetane numbers remains central to the development of next-generation diesel fuels. By addressing ignition quality, researchers aim to unlock the full potential of diesel engines while minimizing their environmental footprint.

Smooth ignition, as indicated by a high cetane number, offers concrete advantages for diesel engines beyond just a numerical value. Decreased ignition delay translates to diminished peak cylinder pressures, reducing mechanical strain on engine parts and prolonging their usability. Moreover, smoother combustion diminishes engine noise and vibration, resulting in a quieter and more pleasant driving or operating environment. This quality holds significant value in situations where noise pollution and operator comfort are paramount considerations, such as in passenger vehicles and construction machinery.

Enhancing cetane numbers through additives like organic germanium, Ge-132, not only optimizes ignition but also improves combustion efficiency. By facilitating quicker and more uniform fuel ignition, such additives contribute to enhanced engine performance and fuel economy. Additionally, they aid in reducing harmful emissions, aligning with environmental regulations and promoting cleaner air quality.

The application of Ge-132 in biodiesel derived from *Ficus macrophylla* oil showcases a promising avenue for improving cetane numbers and addressing the challenges associated with lower ignition quality. This research underscores the potential of organic germanium additives in enhancing the sustainability and efficiency of biodiesel, furthering its adoption as a renewable energy source in diesel engines.

Overall, the pursuit of smoother ignition and higher cetane numbers not only benefits engine longevity and performance but also contributes to a quieter and more environmentally friendly transportation landscape. As research continues to explore novel additives and techniques, the quest for cleaner and more efficient energy solutions remains at the forefront of sustainable development efforts.

The cetane number plays a crucial role in both the mechanical operations and environmental impact of engines, affecting emissions and fuel efficiency alike. It directly influences the formation of nitrogen oxides (NO_x), carbon monoxide (CO), unburned hydrocarbons (HC), and particulate matter (PM), all of which are key contributors to air pollution. Diesel fuels with higher cetane numbers tend to generate lower levels of NO_x emissions, as they undergo more thorough combustion and experience shorter ignition delays. Similarly, smoother ignition and combustion processes associated with higher cetane fuels result in reduced CO and HC emissions.

Furthermore, the improved combustion efficiency of higher cetane fuels leads to decreased particulate matter emissions, including soot particles. These environmental advantages align with global initiatives aimed at curbing the environmental impact of transportation and industrial activities, highlighting the critical role of cetane number in the pursuit of cleaner energy solutions. Thus, optimizing cetane number emerges as a vital aspect in advancing environmentally sustainable fuel technologies, promoting cleaner air quality and reducing the ecological footprint of combustion processes.

The quest to elevate cetane numbers and enhance fuel performance has been an enduring pursuit, driving substantial research and technological strides. Over time, diverse methods and additives have been developed to optimize cetane numbers, marking significant progress in the field. Among these, fuel additives stand out as pivotal contributors, offering a flexible and pragmatic approach to boosting cetane numbers without necessitating drastic alterations in fuel composition or engine architecture. Cetane improvers, biodiesel, and hydrogenation-derived renewable diesel (HDRD) represent notable additives within the fuel engineer's arsenal, providing the means to tailor cetane numbers according to precise operational needs.

Through the strategic application of these additives, fuel engineers can fine-tune cetane numbers to achieve optimal combustion characteristics and engine performance. Such additives not only enhance fuel efficiency but also contribute to mitigating harmful emissions, aligning with broader sustainability goals in the transportation sector. In essence, the continuous evolution and utilization of fuel additives underscore the ongoing commitment to advancing the efficiency and environmental compatibility of diesel fuels.

In the dynamic realm of fuel technology, a new player emerges: organic germanium, Ge-132. Organic germanium compounds show promising potential as boosters for cetane numbers, offering a fresh avenue for enhancing diesel fuels. The utilization of Ge-132 to elevate cetane numbers marks an intriguing advancement in the pursuit of superior, environmentally friendly diesel options. Its distinct chemical characteristics and potential influence on cetane numbers render it a captivating subject for exploration.

Organic germanium, particularly Ge-132, has garnered attention for its ability to augment cetane numbers, signifying improved ignition quality and combustion efficiency. This compound's introduction into biodiesel production presents an exciting opportunity to enhance the performance and sustainability of diesel engines. The integration of Ge-132 promises to address challenges associated with lower cetane numbers, potentially transforming the landscape of biodiesel utilization.

Research endeavors focused on understanding the effects of Ge-132 on cetane numbers and combustion efficiency hold significant promise. By comprehensively examining its impact, we can unlock insights into optimizing diesel fuels for better engine performance and reduced emissions. Ge-132 stands poised to play a pivotal role in advancing the eco-friendliness and efficiency of biodiesel as a renewable energy source.

The exploration of Ge-132's potential as a cetane number enhancer underscores the importance of innovative solutions in the quest for sustainable energy alternatives. As demands for cleaner fuels intensify, Ge-132 emerges as a compelling candidate for driving advancements in diesel technology. Its integration into biodiesel production processes could lead to tangible improvements in engine performance and environmental impact.

The emergence of organic germanium, particularly Ge-132, as a cetane number booster presents an exciting prospect for the future of diesel fuels. Through rigorous research and development efforts, we can harness its potential to elevate the performance and sustainability of biodiesel, ultimately contributing to a cleaner and more efficient transportation sector.

This research has dual objectives: firstly, to evaluate the efficacy of organic germanium (Ge-132) in augmenting the cetane number of *Ficus macrophylla* oil, a specific diesel fuel. By exploring the potential of Ge-132, we aim to diversify methods for improving cetane numbers. Secondly, we seek to assess the wider implications of cetane number enhancement with Ge-132, including its impacts on engine performance, emissions, and subsequent environmental and operational advantages.

In essence, this study delves into the application of Ge-132 as a cetane number enhancer, addressing a crucial aspect of biodiesel production efficiency. By investigating its effectiveness in elevating the cetane number of *Ficus macrophylla* oil-based biodiesel, we aim to contribute to the advancement of sustainable energy solutions.

Moreover, beyond merely enhancing cetane numbers, our research endeavours to analyse the holistic effects of Ge-132 on engine behaviour and emissions. By scrutinizing combustion efficiency and pollutant output, we aim to elucidate the broader implications of employing Ge-132 as a biodiesel additive.

Ultimately, this research serves as a pivotal step in understanding the potential of Ge-132 to enhance the performance and environmental sustainability of Ficus macrophylla oil-based biodiesel. Through comprehensive analysis, we aim to provide valuable insights into the feasibility and benefits of utilizing Ge-132 in biodiesel production processes.

This research delves deep into the significance of enhancing cetane numbers and its broader implications for diesel engine technology. By introducing organic germanium additives, there's potential for enhanced ignition quality and combustion attributes, paving the way for more efficient, eco-friendly, and resilient diesel engines. Exploring the mysteries of Ge-132 and its influence on Ficus macrophylla oil marks a pivotal moment in diesel fuel advancement, where seemingly minor adjustments can profoundly impact both engine performance and environmental sustainability. Through this exploration, we embark on a journey towards innovation in diesel technology, where the fusion of science and practical application holds the promise of transformative change. As we delve into this realm, we uncover possibilities that extend beyond mere fuel enhancement, touching upon the very essence of sustainable transportation and its impact on our planet's future.

1.4 SIGNIFICANCE OF CETANE NUMBER

The cetane number stands as a crucial metric in diesel fuels, exerting significant influence over the performance and emissions of diesel engines, which serve as the backbone of transportation and industrial activities. Often dubbed as the "ignition quality" or "ignition delay," the cetane number serves as a numerical indicator, reflecting the readiness of a fuel to ignite within a compression-ignition engine, notably diesel engines. Its pivotal role lies in its direct impact on engine operation,

combustion efficiency, and the composition of exhaust emissions, making it a cornerstone parameter in diesel fuel quality assessment.

By determining how readily a fuel ignites upon compression, the cetane number directly affects the engine's overall efficiency and power output, crucial factors in ensuring smooth and reliable engine operation across various sectors. Moreover, it also influences the combustion process, dictating the timing and completeness of fuel combustion, thereby affecting the engine's fuel economy and pollutant emissions. In essence, the cetane number serves as a key determinant of diesel fuel performance, guiding decisions regarding fuel formulation, engine design, and emission control strategies. Its significance extends beyond mere technical specifications, as it underpins the broader goals of energy efficiency, environmental sustainability, and regulatory compliance in the diesel-powered transportation and industrial sectors. Therefore, understanding and optimizing the cetane number of diesel fuels are imperative steps towards achieving cleaner, more efficient, and sustainable diesel engine operations, aligning with global efforts to mitigate climate change and promote environmental stewardship.

Understanding the significance of cetane number in engine performance requires a closer examination of its effects. Essentially, a higher cetane number indicates that a fuel ignites more readily under high compression in the engine cylinder, a process known as "auto-ignition." This rapid ignition is vital for diesel engine functionality. Conversely, lower cetane numbers result in delayed ignition, causing "ignition delay," leading to reduced engine power, increased fuel consumption, and heightened emissions. Consequently, engine efficiency suffers, impacting transportation costs and environmental concerns.

Moreover, the combustion efficiency of a diesel engine directly correlates with the cetane number. Fuels with high cetane numbers burn more uniformly and completely, fostering cleaner and more energy-efficient combustion. Conversely, fuels with low cetane numbers ignite unevenly, causing incomplete combustion, particulate matter formation, and the release of unburned hydrocarbons into the atmosphere.

In today's context, with a pressing need to address air quality issues and reduce greenhouse gas emissions, the cetane number plays a crucial role in mitigating the environmental impact of diesel engines. Enhancing cetane numbers in biodiesel derived from sources like *Ficus macrophylla* oil becomes paramount, as it not only ensures optimal engine performance but also contributes to cleaner combustion and reduced emissions. This underscores the importance of research endeavors aimed at improving cetane numbers through additives like organic germanium, such as Ge-132, to advance the sustainability and efficiency of biodiesel as a viable alternative to conventional diesel fuels. By addressing these challenges, we move closer to achieving a more sustainable and environmentally friendly transportation sector.

As we delve into the realm of emissions, it becomes imperative to underscore the profound influence of cetane number on the discharge of pollutants from diesel engines. A diminished cetane number not only fosters incomplete combustion but also exacerbates the release of nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), and particulate matter into the atmosphere. These emissions, beyond their detrimental impact on the environment, pose significant health hazards to human well-being. Conversely, fuels with elevated cetane numbers facilitate more thorough combustion processes, thereby yielding diminished emissions of these deleterious substances. Consequently, in the realm of regulatory adherence and public health preservation, the cetane number assumes an irreplaceable role in curtailing the adverse externalities stemming from diesel engine emissions.

Understanding the intricate interplay between cetane number and emission dynamics elucidates the criticality of optimizing cetane levels in biodiesel formulations. By elevating the cetane number through additives such as organic germanium (Ge-132), biodiesel derived from sources like *Ficus macrophylla* oil can mitigate the adverse environmental and health impacts associated with diesel combustion. The incorporation of Ge-132 initiates a cascade of benefits, fostering enhanced combustion efficiency and reduced emission profiles in biodiesel-powered engines.

Experimental studies underscore the efficacy of Ge-132 in bolstering the cetane number of *Ficus macrophylla* oil-based biodiesel, thereby improving ignition characteristics and overall engine performance. Furthermore, the use of Ge-132 yields a tangible reduction in emissions during combustion, offering a pathway towards cleaner and more sustainable energy utilization. These findings underscore the transformative potential of organic germanium additives in ameliorating the environmental footprint of biodiesel production and consumption.

In essence, the symbiotic relationship between cetane number enhancement and emission reduction represents a pivotal avenue in advancing the sustainability and viability of biodiesel as an alternative fuel source. By addressing the inherent challenges associated with lower cetane numbers in biodiesel formulations, organic germanium additives emerge as a promising solution, aligning with broader objectives of environmental stewardship and public health preservation. Consequently, fostering further research and implementation efforts in this domain holds the promise of realizing a future where biodiesel serves as a cornerstone in the transition towards cleaner, greener transportation systems.

In the context of escalating global climate concerns, the significance of fuel efficiency cannot be overstated. High cetane number fuels play a pivotal role in this regard, facilitating more efficient combustion processes. Improved combustion efficiency directly translates to enhanced fuel economy, where a greater amount of work is extracted from the engine with the same energy input. Consequently, this leads to diminished fuel consumption and a reduction in greenhouse gas emissions, making strides towards sustainability in transportation systems and contributing to climate change mitigation efforts.

The intricate relationship between cetane number, combustion efficiency, and fuel economy underscores their critical importance in the sustainability discourse surrounding transportation. Furthermore, the challenges associated with low cetane number fuels extend beyond mere efficiency concerns to impact the reliability and durability of diesel engines. Engines operating on fuels with lower cetane numbers often experience prolonged ignition delays, culminating in premature and uneven ignition events. This, in turn, manifests as undesirable knocking, increased noise

levels, and heightened mechanical stress on engine components. Over time, these issues can lead to significant engine damage, reduced operational lifespans, and escalated maintenance expenses, posing substantial risks to industries reliant on diesel power.

Hence, the cetane number transcends its role as a technical specification, emerging as a linchpin in the realm of diesel engines and the sectors they propel. It dictates the efficient and sustainable operation of diesel engines, influencing their performance, combustion efficiency, emissions, fuel economy, and long-term reliability. Its impact resonates throughout various facets of society, ranging from the economy and environment to public health.

As we confront the multifaceted challenges of the 21st century, including emission reduction, climate change mitigation, and resource optimization, optimizing the cetane number emerges as an imperative. Harnessing its potential holds the key to driving progress towards a more efficient, sustainable, and resilient global society, underscoring its indispensable role in shaping our collective future.

1.5 CETANE NUMBER IMPACT ON ENGINE PERFORMANCE

The cetane number, a cornerstone property within the domain of diesel fuels, holds a central position in both the intricate mechanics of internal combustion engines and the broader spectrum of energy production and utilization. While often overlooked by the general populace, this numerical metric exerts profound influence over the performance, efficiency, and ecological footprint of diesel engines. Renowned for their durability and effectiveness, diesel engines serve as indispensable workhorses across diverse sectors, including heavy-duty transportation and power generation.

The cetane number, serving as a quantifiable measure of a diesel fuel's ignition quality, assumes a critical role in ensuring the seamless and optimal functioning of these engines. Essentially, this parameter signifies the propensity of a diesel fuel to undergo auto-ignition, thereby dictating the speed and efficacy of the combustion process upon injection into the engine's combustion chamber.

Moreover, the cetane number directly impacts the engine's ignition delay, which refers to the duration between the commencement of fuel injection and the onset of combustion. A higher cetane number correlates with shorter ignition delays, facilitating smoother engine operation, reduced noise levels, and enhanced fuel efficiency. Conversely, fuels with lower cetane numbers may exhibit prolonged ignition delays, leading to inefficient combustion, increased emissions, and compromised engine performance.

In recent years, as the imperative for sustainable energy sources has gained prominence, researchers have intensified efforts to optimize the properties of biodiesel—a renewable alternative to traditional diesel fuels. Biodiesel, derived from various organic sources, including plant oils, presents a promising avenue for reducing greenhouse gas emissions and mitigating dependence on fossil fuels. However, challenges persist in achieving comparable combustion characteristics to conventional diesel fuels, particularly concerning cetane number.

Ficus macrophylla oil, identified as a viable feedstock for biodiesel production, often presents inherent limitations in cetane number, which can hinder its suitability for widespread use in diesel engines. Recognizing this obstacle, researchers have explored innovative strategies to augment the cetane number of *Ficus macrophylla* oil-based biodiesel. One such approach involves the utilization of organic germanium additives, notably Ge-132, to enhance ignition quality and combustion efficiency.

Experimental investigations have elucidated the transformative effects of Ge-132 on the cetane number, combustion kinetics, and emissions profile of *Ficus macrophylla* oil-derived biodiesel. The incorporation of Ge-132 has demonstrated a marked improvement in cetane number, thereby fostering more expeditious and reliable combustion processes. This enhancement not only enhances engine performance but also contributes to reduced emissions, aligning with imperatives for environmental sustainability.

Furthermore, the utilization of Ge-132 additives offers a pragmatic solution to the challenges posed by lower cetane numbers in biodiesel derived from *Ficus macrophylla* oil. By addressing these limitations and enhancing combustion characteristics, Ge-132 facilitates the broader adoption of biodiesel as a cleaner and more sustainable fuel option. Consequently, this research not only advances the field of biodiesel technology but also contributes to the global endeavor towards decarbonization and environmental stewardship.

The cetane number, a crucial indicator of a fuel's ignition quality, plays a pivotal role in diesel engine performance. A high cetane number ensures swift and consistent ignition under the high pressures and temperatures characteristic of diesel engine combustion, facilitating efficient power generation. Conversely, a low cetane number leads to prolonged ignition delay, resulting in delayed combustion and a cascade of adverse effects. These effects include heightened noise levels, increased emissions of nitrogen oxides (NO_x), incomplete combustion, and reduced engine efficiency. It's clear that the cetane number significantly influences both engine performance and environmental impact.

In the context of combustion, timing is critical. A higher cetane number translates to shorter ignition delays, fostering more efficient combustion processes characterized by improved power output and reduced noise emissions. This heightened efficiency also extends to emissions reduction, particularly in terms of NO_x, a major contributor to air pollution and associated health risks. Thus, the cetane number emerges as a silent yet potent environmental regulator within the realm of diesel engines.

Recognizing the importance of cetane number enhancement, researchers have explored various strategies to improve the properties of biodiesel, a renewable alternative to conventional diesel fuels. *Ficus macrophylla* oil, a promising feedstock for biodiesel production, often exhibits lower cetane numbers, posing challenges to engine performance and emissions control. To address this issue, organic germanium additives, such as Ge-132, have garnered attention for their potential to enhance cetane numbers and improve combustion characteristics.

The application of Ge-132 to *Ficus macrophylla* oil-based biodiesel represents a promising avenue for enhancing its cetane number and overall performance. Through comprehensive investigations into the effects of Ge-132, researchers aim to optimize combustion efficiency, minimize emissions, and maximize engine performance. Experimental results have shown significant improvements in cetane number, ignition characteristics, and emissions reduction, highlighting the potential of Ge-132 as a viable solution for enhancing biodiesel properties.

Moreover, the use of Ge-132 additive demonstrates a reduction in emissions during combustion, contributing to cleaner and more environmentally friendly energy generation. By addressing the challenges associated with lower cetane numbers, Ge-132 facilitates the broader adoption of *Ficus macrophylla* oil-based biodiesel as a sustainable energy source for diesel engines. This research contributes to ongoing efforts to enhance the efficiency, sustainability, and environmental friendliness of biodiesel, furthering the transition towards cleaner energy solutions in the transportation sector.

The significance of diesel fuel selection and its cetane number extends far beyond the confines of engine design and operation; it reverberates through society and the environment. Given the global reliance on diesel engines for transportation and power generation, a nuanced comprehension of cetane numbers is imperative to meet efficiency objectives and adhere to environmental regulations. As concerns regarding climate change and air quality escalate, the cetane number transcends being merely a technical specification; it emerges as a pivotal element in the realm of sustainable energy solutions.

In a landscape where energy efficiency and emissions reduction reign supreme, the enhancement of cetane numbers emerges not as an academic pursuit but as an urgent necessity. Researchers, engineers, and policymakers alike are directing their focus towards this indispensable metric in the pursuit of cleaner and more effective diesel engine technologies.

Amidst this context, the present study embarks on an examination of the potential of organic germanium (Ge-132) as an additive to augment the cetane number of

Ficus macrophylla oil. This research endeavor endeavors to leverage the forces of scientific inquiry and innovation to contribute towards a future characterized by heightened energy efficiency and sustainability. At its core lies the recognition of the cetane number's profound impact on diesel engines and the quest for cleaner combustion, propelling efforts towards a paradigm shift in energy consumption patterns.

1.6 THE CHALLENGES ASSOCIATED WITH LOW CETANE NUMBER FUELS

The cetane number plays a paramount role in diesel fuels, acting as a crucial parameter influencing engine performance and emissions. It stands as a vital indicator of a fuel's ignition quality within the realm of diesel combustion. Engineered to optimize the combustion process, researchers and engineers closely examine cetane numbers, recognizing their direct impact on diesel engine efficiency and effectiveness.

Diesel engines, revered for their exceptional fuel efficiency and torque, are ubiquitous across various industries and transportation sectors. Their performance hinges significantly on the ignition characteristics of the diesel fuel utilized. Much like octane number in gasoline, cetane number serves as a pivotal metric for diesel fuels, delineating the ease with which they ignite in compression-ignition engines.

A higher cetane number signifies a fuel igniting more readily upon compression, ensuring swift and controlled ignition essential for smooth and efficient engine operation. Conversely, fuels with lower cetane numbers exhibit delayed ignition, prolonging combustion durations and compromising energy extraction efficiency. Consequently, this inefficiency manifests in reduced power output, heightened fuel consumption, and increased emissions of pollutants such as nitrogen oxides (NO_x) and particulate matter (PM).

Understanding the intricacies of cetane numbers is fundamental to advancing diesel engine technology and mitigating environmental impacts. Researchers continue to delve into innovative solutions aimed at enhancing cetane numbers, thereby

optimizing diesel combustion processes and promoting cleaner, more sustainable energy solutions for the future.

The performance of an engine is closely tied to its cetane number, a measure of a fuel's ignition quality. Fuels with higher cetane numbers promote more efficient and thorough combustion, resulting in several benefits such as increased power generation, decreased fuel consumption, and reduced emissions of soot and pollutants. This relationship has significant implications for the environment, as it directly contributes to the mitigation of air pollution and greenhouse gas emissions.

Moreover, cetane number plays a crucial role in ensuring the reliability and longevity of diesel engines. Fuels with lower cetane numbers can lead to incomplete combustion, which in turn may cause deposit formation within the engine and accelerate wear and tear. Conversely, fuels with higher cetane numbers facilitate cleaner engine operation, thereby reducing maintenance expenses and extending the engine's lifespan.

In essence, the cetane number of a fuel not only influences engine performance and emissions but also impacts the overall health and durability of diesel engines. Therefore, optimizing cetane numbers through fuel formulations or additives is essential for achieving efficient, environmentally friendly, and sustainable operation of diesel engines.

Recognizing the significance of cetane number extends far beyond just the transportation sector. Diesel engines play a vital role in various applications, spanning from industrial machinery to power generators. In each instance, the quality of the diesel fuel directly impacts the efficiency and reliability of the engine's operation. Consequently, the pursuit of higher cetane numbers stands as a fundamental goal for both the automotive and energy industries alike.

Across these industries, there exists a continuous drive to improve diesel fuels and develop additives that can enhance cetane ratings. Such enhancements facilitate engines to operate more efficiently, thereby reducing fuel consumption and

emissions output. This ongoing research aligns seamlessly with broader initiatives aimed at achieving sustainable and eco-friendly energy solutions.

In light of pressing global concerns such as climate change, the demand for cleaner and more efficient energy sources has become increasingly urgent. Consequently, the quest for higher cetane numbers represents a crucial aspect of these efforts, serving as a means to mitigate environmental impact while simultaneously promoting energy efficiency. By exploring innovative approaches to enhance cetane ratings, researchers are contributing to the collective endeavor to address the challenges posed by climate change and foster a more sustainable future.

In summary, the cetane number plays a crucial role in diesel combustion, exerting significant influence over engine performance, emissions levels, and overall reliability. It serves as a pivotal gauge of a fuel's ignition quality, directly impacting the efficiency and environmental footprint of diesel engines. Recognizing the importance of cetane number is paramount in the continuous pursuit of enhancing both diesel fuels and engine technology, thereby advancing towards more sustainable and eco-friendly transportation and energy alternatives. By prioritizing the optimization of cetane number, strides can be made towards fostering cleaner and more efficient diesel-powered systems, aligning with broader initiatives aimed at mitigating environmental impacts and promoting sustainable energy solutions.

1.7 ALTERNATIVE FUELS AND ADDITIVES

In today's dynamic global energy landscape, there's a growing demand for energy sources that are not only sustainable but also more efficient and environmentally friendly. This demand has spurred a wave of exploration into alternative fuels and innovative additives. Among these, diesel fuels stand out for their high energy density and efficiency, serving critical roles across transportation and various industrial sectors.

The performance and environmental impact of diesel fuels are closely tied to a key parameter known as the cetane number. This metric quantifies the ignition quality of diesel fuels, with a higher cetane number indicating superior ignition

characteristics. A high cetane number promotes smoother combustion, reduces engine noise, and curbs emissions of nitrogen oxides (NO_x), contributing to cleaner air quality.

However, achieving optimal cetane numbers poses challenges, especially for unconventional or bio-derived diesel fuels such as *Ficus macrophylla* oil. These fuels often exhibit lower cetane numbers compared to traditional diesel fuels, posing hurdles for their widespread adoption and efficient utilization.

In response to this challenge, researchers are exploring various strategies, including the use of innovative additives, to enhance the cetane number of bio-derived diesel fuels like *Ficus macrophylla* oil. By improving the ignition quality of these fuels, such additives aim to mitigate performance issues, reduce emissions, and bolster their competitiveness in the energy market.

This pursuit aligns with broader efforts to transition towards cleaner and more sustainable energy sources, driving innovation and advancement in the global energy industry. By addressing cetane number challenges in bio-derived diesel fuels, we move closer to realizing a more efficient, environmentally friendly, and sustainable energy future.

To tackle the challenge of optimizing alternative diesel fuels and harnessing their full potential, both researchers and industry specialists have delved into a spectrum of strategies aimed at boosting cetane numbers. These strategies span from formulating alternative fuel blends to incorporating novel additives. The impetus behind these endeavors stems from urgent imperatives such as curbing greenhouse gas emissions, fortifying energy resilience, and ameliorating the detrimental environmental and health repercussions linked with diesel engine emissions.

This concerted effort has sparked a surge in interest in elevating cetane numbers, as it presents a tangible pathway to enhancing the overall efficiency and eco-friendliness of diesel engines. By elevating cetane numbers, not only can engine performance be optimized, but also a significant reduction in harmful emissions can be achieved, aligning with the overarching goal of fostering sustainability and environmental stewardship in the transportation sector.

Enhancing the cetane number, a crucial indicator of ignition quality in diesel fuels, has become a focal point of research, with additives emerging as a promising avenue for improvement. These chemical compounds, carefully chosen and blended with diesel fuels, wield significant influence over cetane number and combustion characteristics. Beyond enhancing ignition quality, additives have garnered attention for their potential to tackle other fuel-related challenges, including engine wear, soot formation, and emissions control. The selection of additives is pivotal, considering their impact on fuel performance. In this context, the organic germanium compound, Ge-132, has emerged as a compelling candidate for enhancing cetane numbers and addressing associated challenges.

The incorporation of Ge-132, an organic compound containing germanium, represents a pioneering strategy in the pursuit of improving cetane numbers. Ge-132 stands out due to its distinctive properties and potential advantages in augmenting the ignition quality of diesel fuels. This compound is organically linked to germanium, a chemical element renowned for its unique characteristics, distinguishing it from conventional cetane boosters. Ge-132 has exhibited considerable potential in elevating cetane numbers, diminishing ignition delays, and enhancing overall engine combustion efficiency. Its application as an additive opens up a compelling pathway for exploration and innovation within the domain of alternative fuels and additives. The utilization of Ge-132 heralds an exciting era of research aimed at optimizing the performance and sustainability of biodiesel and other renewable energy sources in diesel engines.

Understanding the significance of Ge-132 and similar additives in the realm of cetane number enhancement requires a broader perspective on alternative fuels and their pivotal role within the evolving energy landscape. Alternative fuels represent a diverse array of energy sources that are distinct from conventional petroleum-based fuels. They encompass various options such as biodiesel, renewable diesel, synthetic fuels, and other biofuels.

What sets alternative fuels apart is their origin from renewable resources, which stands in stark contrast to the finite nature of fossil fuels. By harnessing sources like agricultural crops, algae, waste oils, and organic materials, these fuels contribute to a sustainable energy paradigm. Importantly, their production and use offer a

pathway to mitigate environmental impacts by reducing greenhouse gas emissions and lessening reliance on non-renewable resources.

Furthermore, alternative fuels play a crucial role in addressing pressing issues such as climate change, energy security, and regulatory compliance. Their adoption aligns with global efforts to combat climate change by curbing carbon emissions and transitioning towards cleaner energy sources. Additionally, they bolster energy security by diversifying fuel sources and reducing dependency on geopolitically unstable regions.

Moreover, alternative fuels facilitate adherence to stringent regulatory standards governing air quality and emissions. Governments worldwide are implementing increasingly stringent regulations to improve air quality and reduce harmful pollutants. Alternative fuels, with their lower emissions profiles and reduced environmental impact, offer a means to meet these regulatory requirements effectively.

In essence, alternative fuels represent a multifaceted solution to the challenges of sustainability, environmental stewardship, and energy security. Through advancements in additives like Ge-132 and ongoing research into improving their properties, these fuels continue to evolve as integral components of a more sustainable and resilient energy future.

Biodiesel has emerged as a promising alternative to traditional diesel fuel, sourced from various biological materials such as vegetable oils, animal fats, and even algae. Its integration into existing diesel engines has been relatively smooth due to its renewable and sustainable nature. However, biodiesel, much like *Ficus macrophylla* oil, often exhibits lower cetane numbers compared to petrodiesel, posing operational challenges.

To address this issue, additives like Ge-132 play a crucial role. These additives are instrumental in optimizing biodiesel and similar alternative diesel fuels. By enhancing cetane numbers and improving combustion properties, additives help bridge the performance gap between conventional and alternative fuels. Ge-132, an

organic germanium compound, is among the additives that researchers and industry experts explore to unlock the full potential of sustainable energy sources and mitigate the challenges posed by lower cetane numbers. The journey towards cetane number enhancement through additives like Ge-132 is multifaceted. Achieving the desired cetane number requires a careful balance of additive concentration and fuel properties. Additionally, ensuring compatibility and stability of the additive within the fuel matrix are essential considerations. Researchers meticulously evaluate these factors to maintain fuel quality and prevent adverse engine effects.

As the demand for cleaner and more sustainable energy solutions grows, the role of additives in cetane number enhancement becomes increasingly significant. These additives facilitate the adjustment of cetane numbers, making alternative diesel fuels more compatible with existing engines and emissions standards. Consequently, the adoption of alternative fuels and innovative additives like Ge-132 reflects the adaptability and innovation within the energy industry.

In conclusion, the pursuit of enhancing cetane numbers in diesel fuels, particularly in alternative options like *Ficus macrophylla* oil and biodiesel, has led to exploration into the use of additives. Additives, including emerging compounds like Ge-132, offer promising solutions to address challenges associated with lower cetane numbers. By improving ignition quality and combustion efficiency, additives play a pivotal role in expanding the practicality and sustainability of alternative diesel fuels. This integration of additives in cetane number enhancement represents a critical step towards cleaner, more efficient, and environmentally friendly diesel engines, showcasing the industry's innovative spirit and determination to meet the evolving demands of a changing world.

1.8 ORGANIC GERMANIUM (Ge-132)

Organic Germanium (Ge-132) has emerged as a fascinating compound with diverse applications, particularly in enhancing the cetane number of diesel fuels. Ge-132, an organic form of germanium, has drawn attention for its unique properties and its role as a cetane number booster in alternative diesel fuel formulations. With its

solubility in various organic solvents, Ge-132 holds promise for improving ignition quality and combustion efficiency in diesel engines.

The cetane number of diesel fuel is crucial as it reflects its ignition characteristics. Higher cetane numbers indicate shorter ignition delays, leading to more efficient and cleaner combustion. Fuels with low cetane numbers often experience delayed ignition, resulting in increased emissions, reduced engine efficiency, and potential engine knock. Ge-132 offers a solution to this issue by potentially raising cetane numbers, thereby improving engine performance, reducing emissions, and enhancing fuel efficiency.

Research into Ge-132's application as a cetane number booster has demonstrated promising results. By blending Ge-132 with diesel fuels, researchers have observed significant improvements in cetane numbers, leading to enhanced engine performance and reduced emissions. Importantly, Ge-132's ability to increase cetane numbers can help mitigate harmful emissions such as nitrogen oxides (NO_x) and particulate matter, contributing to cleaner air and environmental sustainability.

In studying Ge-132's effectiveness in cetane enhancement, researchers aim to investigate its impact on the ignition quality of *Ficus macrophylla* oil, a biodiesel feedstock, and evaluate its effects on engine performance and emissions. While the hypothesis regarding Ge-132's efficacy is based on its unique properties and proven potential as an ignition improver, it's crucial to acknowledge the variables that may affect its effectiveness, such as the source and quality of the oil, blending ratios, and engine types.

Ge-132 presents a promising solution as a cetane number-enhancing additive for diesel fuels. Its distinctive chemical properties make it a compelling candidate for improving combustion efficiency and reducing emissions in diesel engines. As the transportation industry strives for cleaner and more efficient energy sources, research into innovative additives like Ge-132 is essential for achieving a sustainable and environmentally friendly future.

CHAPTER 2

LITERATURE SURVEY

M. Annamalai (2016) Using a single cylinder, constant speed diesel engine, the effects of adding cerium oxide (CeO_2) nanoparticles to lemongrass oil (LGO) emulsion fuel were experimentally studied. In this study, a new biofuel plant known as lemongrass—binomial name: *Cymbopogon flexuosus*—was introduced. Reducing the amount of dangerous pollutants in exhaust, such as smoke, carbon monoxide (CO), oxides of nitrogen (NOX), and unburned hydrocarbons (HC), is the primary goal of the project. The use of CeO_2 nanoparticles may also improve engine performance. On a volume level, the LGO emulsion fuel was made using 5% water, 93% LGO, and 2% span80.

Span80 functioned as a surfactant, lowering the hydrophilic-lipophilic balance (HLB) value of 4.2 by reducing surface tension between the liquids. The LGO emulsion fuel was mixed with the ceria nanoparticle at a 30 ppm (ppm) concentration. Diesel and LGO were used as the basis fuels in a comparison of the diesel engine's performance, combustion characteristics, and emission levels.

The following fuels were used throughout the investigation: neat diesel, neat LGO, LGO emulsion, and LGO nano emulsion fuels. The single-cylinder diesel engine was used throughout the whole process. Despite a little rise in HC and CO emissions, the LGO emulsion fuel has the potential to lower smoke and NOX emissions and enhance brake thermal efficiency (BTE) and brake specific energy consumption (BSEC) when compared to pure LGO.

When compared to LGO emulsion and diesel fuel at different power outputs, the ceria nanoparticle blended test fuel demonstrated a dramatic reduction in carbon monoxide (CO), unburned hydrocarbon (HC), oxides of nitrogen (NOX), and a modest drop in smoke opacity emission. Because of the CeO_2 nanoparticle's huge surface area to volume ratio and better atomization, the BTE of the LGO nano emulsion test fuel was also found to be higher than that of the plain LGO and LGO emulsion fuels.

Graciela Arbilla (2008) Very It is critical to measure any possible advantages or risks associated with using biodiesel in clear growth. There are several studies on the

permitted emissions of mixes of biodiesel and diesel accessible, but little is known about the non-regulated emissions. The emissions of aromatic hydrocarbons were reported in a previous study [Corrêa, S.M., Arbilla, G., 2006. Emissões de formaldeído e acetaldeído de misturas biodiesel/diesel. *Periódico Tchê Química*, 3, 54–68]. An acrolein, acetone, propionaldehyde, butyraldehyde, benzaldehyde, acetaldehyde, and formaldehyde were the seven carbonyl emissions measured in this experiment using a heavy-duty diesel engine running on pure diesel (D) and blends of biodiesel (v/v) of 2% (B2), 5% (B5), 10% (B10), and 20% (B20).

The tests were carried out in a steady-state setting under 1000, 1500, and 2000 rpm utilizing a six-cylinder heavy-duty engine, which is typical of the Brazilian fleet of urban buses. The carbonyls were collected using SiO₂-C18 cartridges and coated with an acid solution of 2,4-dinitrophenylhydrazine after the exhaust fumes had been diluted about 20 times. UV detection in high performance liquid chromatography was used to carry out the chemical analyses. The three operating modes (1000, 1500, and 2000 rpm)'s average results for benzaldehyde revealed a decrease in the emission

(-3.4%, -5.3%, -5.7%, -10.7%, and -6.9% for B2) and every other carbonyl had a significant rise: Formaldehyde: 2.6, 7.3, 17.6, and 35.5%; acetaldehyde: 1.4, 2.5, 5.4, and 15.8%; acrolein+acetone: 2.1, 5.4, 11.1, and 22.0%; propionaldehyde: 0.8, 2.7, 4.6, and 10.0%; butyraldehyde: 3.3, 7.8, 16.0, and 26.0%.

Labeckas Gvidonas (2005) In this article, the comparative bench testing findings of an unmodified, normally aspirated, four-stroke, four-cylinder, direct injection diesel engine running on neat RME and its 5%, 10%, 20%, and 35% blends with diesel fuel are shown. This study aims to investigate the impact of adding RME to diesel fuel on a high-speed diesel engine's brake specific fuel consumption (bsfc), brake thermal efficiency, changes in the composition of emissions, and exhaust smoke opacity. RME has a brake-specific fuel consumption that is 18.7% and 23.2% greater than diesel fuel at maximum torque (273.5 g/kW h) and rated power (281 g/kW h). Determining the RME concentration in diesel fuel that is considered optimal for all loads and speeds is a challenging task. For RME and Diesel fuel, the maximum brake thermal efficiency ranges from 0.356 to 0.398 and 0.373 to 0.383, respectively. Blend B10 operates with the highest fuel energy content-based economy (9.36–9.61 MJ/kW h), while B35 and neat RME have the lowest. The

maximum nitrogen oxide (NO_x) emissions rise in direct proportion to the mass percentage of oxygen in the biofuel and engine speed. They peak at 2000 m/s, with the B35 blend at 2132 ppm and RME at 2107 ppm. Across all load and speed ranges, the biodiesel produces up to 51.6% less carbon monoxide (CO) emissions and visible smoke, and 13.5% to 60.3% less smoke overall. Together with fuel usage and gas temperature, the B20 and B35 mixes and clean RME have somewhat greater carbon dioxide (CO₂) emissions. All biofuels have modest emissions of unburned hydrocarbons (HC), ranging from 5 to 21 parts per million.

Zulkifli Syafiq (2017) Very The stability effect of emulsion fuel on three distinct fuel blends and the water emulsification effect on the engine performance were investigated in a single cylinder diesel engine research of water in diesel emulsions. The 2% surfactant content of emulsified fuels, which included Span 80 and Tween 80, was evaluated for an HLB value of 10. The blends, known as BSW5, BSW10, and BSW15, also differed in the percentages of water in diesel—5%, 10%, and 15%. An 1860 rpm single-cylinder direct-injection diesel engine was used to assess the fuel blend's performance. The stability results show that an ultrasonic water bath and a mechanical stirrer provide less stability on emulsion fuel than a high shear homogenizer. The engine performance data indicate that as the water percentage is increased up to 15%, there is an increase in both peak pressure and ignition delay. The data, however, also reveal a notable drop in engine power with each increase in the water percentage.

B. Ashok (2017) An The goal of the current research project is to utilize lemon fruit rinds as an innovative, renewable, and biodegradable energy source. This study has used a methodical way to determine if lemon peel oil is suitable for use in gensets and internal combustion engines. It is discovered that extracted lemon peel oil has significantly lower viscosity, flash point, and boiling point than regular diesel. In order to determine whether blends of lemon peel oil are suitable for use in direct injection diesel engines, a range of blends with conventional diesel were made with volumetric concentrations of 20%, 40%, 50%, and 100%. The physical and chemical attributes of each blend were assessed. Lemon peel oil's lower cetane index has a major impact on the peak heat release rate and ignition delay time, which ultimately

resulted in the NO_x emissions penalty. It's interesting to note that blends with increasing percentages of lemon peel oil exhibit remarkably better diesel engine performance characteristics. Furthermore, there is a direct correlation between the concentration of lemon oil in the blends and the decrease in BSCO, BSHC, and smoke emission. Overall diesel engine characteristics showed that, particularly in developing nations like India, lemon peel oil may replace petroleum diesel entirely or in part.

Hifjur Raheman (2007) This study presents some of the fuel attributes and the performance of biodiesel made from mahua oil in a Ricardo E6 engine when blended with high-speed diesel. These characteristics were discovered to be similar to diesel and to meet both European and American criteria. Measurements were made of the engine's performance (specific fuel consumption for the brakes, brake thermal efficiency, and exhaust gas temperature), as well as its emissions (CO, smoke density, and NO_x) in order to assess and calculate the behavior of the diesel engine when using biodiesel. Because of the decreases in exhaust emissions and brake-specific fuel consumption, as well as the increases in braking power and brake thermal efficiency, the mix of biodiesel (B20) is a viable diesel substitute that may aid in reducing air pollution.

Premdasu Nalluri (2023) Managing plastic garbage in an environmentally responsible way has gained global attention in recent years. A few management techniques, such as landfilling and incineration, have already been explored, but they have more negative environmental effects. An eco-friendly way to handle plastics is by pyrolyzing waste plastic. By using the pyrolysis process, plastic waste may be converted into hydrocarbon fuel that can be used in internal combustion engines to generate heat and electricity. According to earlier research, the properties of plastic oil produced by the pyrolysis process are similar to those of ordinary diesel oil. For this reason, blends of plastic oil may be used in CI engines without the need for engine modifications.

In the current study, red mud-assisted catalytic pyrolysis was utilized to effectively transform waste single-use plastic into liquid hydrocarbon fuel. A batch-type pyrolysis reactor was used for the experiments, and the catalyst-to-feedstock ratio was fixed at 0.1. After fractionating the crude oil at 150 °C, the fuel's characteristics

were investigated and contrasted with those of diesel. Using blends of waste plastic oil (10%, 20%, and 30% by vol.), tests were run on a computer-aided VCR DI Diesel engine to examine the combined effects of blending ratio and compression ratio on engine performance, combustion, and emission characteristics. The test fuel D80PO20 showed a small improvement in braking power, brake thermal efficiency, and BSFC when compared to other blends of waste plastic oil and diesel. Additionally, it is discovered that as the blending ratio increases, so do the emissions of CO, CO₂, NO_x, and HC. The performance and emission research indicated that the D80PO20 test fuel mix would be the most effective replacement for the diesel.

Mohd Fahmi (2017) Green fuels, often known as biofuels or green hydrocarbons, are fuels made from biomass sources using a range of thermochemical and biological processes. These goods are regarded as completely infrastructure compatible fuels as they resemble petroleum gasoline and diesel fuels. They don't require engine modification to be used in engines. This article provides a thorough analysis of the possibilities of biodiesel derived from various waste feedstocks, including used cooking and plastic oil. Additionally, this article reviews the impact on engine performance, combustion, and exhaust emissions, as well as engine and operating state information.

The principal objective of this manuscript is to furnish engineers, industrialists, and researchers with pertinent information on waste biodiesel and to highlight waste biodiesel as a potentially viable substitute for fossil fuels. The most recent papers as well as a large body of work from highly regarded journals in scientific indexes are examined.

M. A. Kalam (2017) This research offers a thorough examination of the variations in engine exhaust emissions from a diesel engine powered by a combination of diesel and biodiesel, using compression ignition (CI). The transesterification process was employed to create the biodiesel used in this study from *Moringa oleifera* oil. For this, a four-stroke, water-cooled, naturally aspirated, single-cylinder diesel engine was employed. This research monitors nitrogen oxide (NO), carbon monoxide (CO), hydrocarbon (HC), and smoke opacity as contaminants from the engine exhaust. Along with data on exhaust emissions, measurements are also made on engine

performance and combustion characteristics. Higher rapid NO production, according to some studies, is the cause of biodiesel's increased NO emissions.

Since antioxidants prevent free radicals from forming, which are what cause quick NO to generate during combustion, using antioxidant-treated biodiesel in a diesel engine is a viable solution. In order to study and compare NO as well as other emissions, two distinct antioxidant additives—2,6-di-tert-butyl-4-methylphenol (BHT) and 2,2-methylenebis (4-methyl-6-tert-butylphenol) (MBEBP)—were each dissolved at a concentration of 1% by volume in MB30 (30% moringa biodiesel with 70% diesel) fuel blend. The outcome demonstrates that both antioxidants greatly decreased NO emission; nonetheless, smoke, HC, and CO were found to be somewhat higher in comparison to pure biodiesel blends, but not higher than the diesel fuel used as a baseline.

The outcome also demonstrates how effectively both antioxidants worked to improve brake thermal efficiency (BTE) and oxidation stability while lowering peak heat release rate (HRR) and brake-specific fuel consumption (BSFC). According to this study, M. oleifera biodiesel blend (MB30) treated with antioxidants may be utilized as a highly promising substitute fuel source for diesel engines without requiring any changes.

Zhichao Zhang (2019) This work aims to study the macroscopic spray characteristics through a Constant Volume Vessel (CVV) and experimentally investigate and demonstrate the effects of using multi-wall carbon nanotube (CNT) and cerium oxide (CeO₂) blended with the alternative fuel, gas-to-liquid fuel (GTL) in this study, compared to diesel fuel (DF), on engine performance. The findings show that carbon nanotubes and cerium oxide nanopowder have very little effect on the average cone angle of diesel and gas-to-liquid fuel. When combined with diesel fuel, cerium oxide nanopowder and carbon nanotubes can each reduce spray penetration during injection at low ambient pressure; however, the impact on gas-to-liquid fuel is less pronounced because the lighter composition and lower density of gas-to-liquid fuel facilitate its breakdown process.

Because gas-to-liquid fuel molecules are smaller than diesel fuel molecules, carbon nanotubes enhance the spray penetration of gas-to-liquid fuel during the post-injection phase. As a result, there is a general decrease in the rate of evaporation

because more gas-to-liquid fuel molecules remain inside the carbon nanotubes, which can only evaporate through two ends. Additionally, studies show that although the average cone angle is not affected by rail pressure, it may be decreased by raising ambient temperature and lowering ambient pressure. Spray penetration can be affected by rail pressure as well as ambient pressure during injection, although only ambient temperature can do so once injection is complete.

The engine experiment shows that because cerium oxide nanopowder is catalyzed at high temperatures, it can simultaneously reduce nitrogen oxides, unburned hydrocarbons, and particulate matter emissions for both diesel fuel and gas-to-liquid fuel. In contrast, carbon nanotubes have less of an impact on reducing particulate matter and nitrogen oxides for gas-to-liquid fuel than for diesel fuel.

Shaafi (2015) Over the past 20 years, biodiesel has been more and more preferred for use in diesel engines because of its numerous environmental and financial advantages. With biodiesel as the fuel, there is a lot of room for additional performance enhancement and emission reduction. In contrast to other methods like engine modification and exhaust gas treatment, fuel adulteration is a significant approach for improving performance and reducing emissions. When distributed in any base fluid medium, nanoparticles have been shown in recent years to enhance the thermos physical characteristics, including high surface area-to-volume ratio, thermal conductivity, and mass diffusivity. The literature presents findings indicating that the addition of nano additives to diesel, biodiesel, and blends enhances several parameters such as kinematic viscosity, fire point, and flash point, contingent on the dose of the nanofluid additives. The goal of the current work is to examine how different nanoadditives disperse and improve the performance and emission reduction characteristics of CI engines powered by diesel, biodiesel, and their blends. A summary of the findings from the literature is presented in the conclusion.

Meshack Hawi (2019) Waste cooking oil methyl ester (WCOME) was used in an experimental study to examine the fuel additive effects of iron-doped cerium oxide (FeCeO_2) nanoparticles in a four-stroke, single-cylinder, direct injection diesel engine. The goal of the study was to lower the toxic emissions from diesel engines, such as soot and oxides of nitrogen (NO_x). To further explore the impact of the

doping level on the nanoparticle activity, two different types of nanoparticles were used: cerium oxide doped with 10% iron and cerium oxide doped with 20% iron. Using an ultrasonic homogenizer, the nanoparticles were distributed at a dose of 90 ppm in the fuels that were evaluated.

Experiments were carried out using plain diesel (D100) and biodiesel blends consisting of 30% WCOME and 70% diesel by volume (B30) under varied loads (ranging from 0 to 12 Nm). The engine speed was kept constant at 2000 rpm. Using neat diesel as the basis fuel, the engine's combustion, performance, and emission properties were examined for the fuel mixes including nanoparticles. According to test results, adding nanoparticles to gasoline improved the peak cylinder pressure by around 3.5%. Unburned hydrocarbon (HC) emissions showed no discernible improvement, despite a drop in NO_x emissions of up to 15.7%. With nano-additives, B30's carbon monoxide (CO) emissions were lowered by up to 24.6% and B30's emissions by 15.4%. In terms of cylinder pressure and emissions, the B30 with 20% FeCeO₂ engine performed better than the one with 10% FeCeO₂. In low-to-medium loads, the fuel mix of B30 with 10% FeCeO₂ nanoparticles had a decreased brake-specific fuel consumption; at high loads, it was equivalent to D100. As a result, the blend's brake thermal efficiency was found to be greater at low-to-medium loads than that of D100.

Junshuai (2022) In the subject of engines and allied disciplines, increasing combustion efficiency and lowering hazardous emissions have been hot study topics. Researchers have discovered that adding nanoadditives to diesel-biodiesel fuel mixes has produced noteworthy outcomes. Numerous studies on nanoparticles, both recent and historical, have demonstrated the critical role that nano-additives play in enhancing internal combustion engine performance and lowering hazardous gas emissions. The current state of research on nanoparticles as fuel blend additives for diesel and biodiesel is presented in this publication. First, a thorough description of the exceptional qualities of nanoparticles is given, along with a summary and discussion of the preparation techniques.

Second, the impacts of a number of widely used nanoparticles on the performance of combustion and emissions of hazardous substances—specifically, CO, UHC, and NO_x—as well as the combustion thermal efficiency and brake-specific fuel

consumption of diesel-biodiesel fuel blends are evaluated. Lastly, a discussion of how nanoadditives affect human health, the environment, and internal combustion engines is had. The study presented in this publication has the potential to significantly advance the use of nanomaterials in the fuel industry. Our research enables researchers to effectively choose appropriate nano-additives, allowing internal combustion engines to produce minimal emissions and efficient combustion.

Chauhan (2010) Diesel engines have shown to be useful in the electricity, transportation, and agricultural sectors. The need to shift the energy demand to alternative energy sources has been brought to light by environmental regulations and concerns about fossil fuels. It has been suggested that oil from the *Jatropha curcas* plant might replace diesel fuel in a sustainable manner. However, because of its high viscosity, using pure vegetable oil has proven problematic. The current work uses a dual fuel engine test rig equipped with a suitably designed shell and tube heat exchanger (with exhaust bypass arrangement) to study the effects of FIT (fuel inlet temperature) on engine performance and emissions. The goal is to reduce the viscosity of oil by heating it from exhaust gases before feeding it to the engine. The heat exchanger was set up to provide the appropriate FIT. The engine's BTE (brake thermal efficiency) decreased and its BSEC (brake specific energy consumption) increased when *Jatropha* oil was used instead of diesel fuel, according to the results. BTE increased and BSEC decreased as a result of a rise in fuel input temperature. The emissions of CO, CO₂, and hydrocarbons from *Jatropha* oil were found to be greater than those from diesel fuel. Nonetheless, a decreasing tendency was noted as FIT increased. *Jatropha* oil can therefore soon be an excellent alternative fuel for diesel engines by employing heat exchangers to warm it. 80°C was determined to be the ideal fuel input temperature when taking gaseous emissions, BTE, and BSEC into account.

Vishal (2017) In order to improve the thermophysical properties of a base fluid, a relatively new class of colloidal solutions known as nanofluids is suspended in it with particles smaller than one billionth of a meter (1–100 nm). This makes nanofluids an ideal choice for use in a wide range of commercial applications, such as engineering, medical sciences, biotechnology, agriculture technology,

transportation, etc. The scientific community is concentrating on improving the combustion behavior, stability features, different engine performance metrics, and emission characteristics of conventional diesel engines utilizing diesel biodiesel fuel blends that are loaded with nanoparticles as a result of recent advancements in nanotechnology. The open literature has lately published a few experimental studies on the aforementioned topics employing nanosized metallic, non-metallic, organic, and mixed particles in the basic liquid fuel for diesel engines. The results are very encouraging because the modified fuel's thermophysical and chemical properties have been improved in multiple ways, depending on the type of nanoparticles used, their size and concentration with base fuel.

Even with all of its advantages, the literature contains some ambiguous and contradicting findings, and the experimental findings of many researchers have not been sufficiently extended to lead to a consensus about this novel fuel modification technique. With this information in mind, a serious attempt has been made to compile the significant published research on the stability and combustion aspects of diesel fuel laden with nanoparticles, biodiesel fuels and their blends, and their effects on the overall characteristics of the fuel and engine. The goal is to provide a pathway for future research in this area to maximize the potential of nanoparticle fuel emulsion technology and to provide a promising fuel for diesel engines.

Sadhik Basha (2012) Experimental research is done on the operation, emissions, and combustion properties of a diesel engine that runs on mixed water-diesel emulsion fuels including alumina nanoparticles and water. A single-cylinder CI engine and a data-acquisition system made up of a crank angle encoder and a Kistler piezoelectric pressure sensor comprise the experimental setup used for the studies. The entire experiment is conducted in three sections: the first section uses neat diesel; the second section uses neat water-diesel emulsion fuel; and the third section uses blended water-diesel emulsion fuels with alumina nanoparticles. Water-diesel emulsion fuels are mixed with alumina nanoparticles in different mass fractions in a methodical manner. When comparing the performance of the engine and the amount of hazardous pollutants produced by the mixed alumina nanoparticle emulsion fuel to the neat water-diesel emulsion fuel, the findings showed a considerable improvement.

M.S. Gad (2021) Because essential oils are readily available and sustainable, they have great potential as a source of alternative fuel. The purpose of this article was to ascertain how adding mandarin-essential oil to diesel fuel affected the engine's performance when it was running at a constant 1500 rpm under various loads. Two mixing ratios, denoted as MO10 and MO20, are available: 10% and 20% for mandarin essential oil and 80% and 90% for diesel fuel. Next, using an EGR of 1%, 3%, and 5% approach, the Diesel-RK model is utilized to forecast the effects of adding propanol (10% by volume) to (90%) mandarin-essential oil. Gas chromatography–mass spectrometry analysis is used to analyze the Egyptian Mandarin Essential Oil, and physical parameters are tested in accordance with ASTM standard. The results of the experiment show that adding mandarin essential oil to diesel fuel reduces both the HRR and the cylinder pressure by 2.5% and 3%, respectively. In comparison to the base fuel, the CO, UHC, and smoke opacity decrease by (17%, 30%), (20%, 40%), and (27%, 44%) for MO10 and MO20 combinations, but the NO_x intensity increases by 25% and 45%, respectively. For MO10 and MO20 blends, there is a 5% and 22% reduction in specific fuel consumption, respectively.

Prabu Arockiasamy (2015) A single cylinder, four stroke DI diesel engine's performance and emission characteristics are studied experimentally in order to assess the impact of nanoparticle additions such cerium oxide (CeO₂) and alumina (Al₂O₃) in Jatropha biodiesel. Jatropha biodiesel is combined with alumina and cerium oxide nanoparticles in varying amounts to create 10, 30, and 60 parts per million. For the nano particle mixed test fuels, there is a noticeable increase in brake thermal efficiency that is almost identical to that of plain diesel. Additionally, there is a reduction in the emissions of smoke, carbon monoxide, unburned hydrocarbon, and nitric oxide of 13%, 60%, 33%, and 32%, respectively.

Jiangjun Wei (2021) The study used silicon dioxide (SiO₂) nanoparticle additions to methanol under various test settings to examine the combustion, performance, and emissions of a contemporary dual fuel (DF) diesel engine. Three operating modes were used for the tests: diesel, methanol/diesel (also known as methanol mode),

and methanol-based SiO₂ nanofluid (MSN)/diesel (also known as MSN mode), in which the MSN was injected into the intake manifold. The findings showed that adding nano-SiO₂ to methanol raised peak pressure by a maximum of 8.6% and peak heat release rate by a maximum of 4.3%. All measured doses of SiO₂ nanoparticles in the gasoline enhanced the brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE), particularly at high load. For BTE and BSFC, maximum improvements of 5.1% and 6.2%, respectively, were attained. In MSN mode, CO, HC, NO_x, and smoke opacity were all reduced by 38.5%, 55.4%, 5.2%, and 55.6%, respectively, in comparison to the instances in methanol mode. All of the findings suggest that adding SiO₂ nanoparticles to methanol may improve its performance and combustion qualities while reducing the emissions from DF diesel engines.

Gong, Changming (2020) In order to assess the impact of nozzle spray-line distribution on stratified-charge combustion of methanol engines, five distinct nozzle designs were created for this study. Numerical simulation was used to model the nozzle spray-line distribution characteristics, stratified mixture generation, combustion, and emissions of a high compression ratio direct-injection spark-ignition methanol engine operating under lean-burn conditions for various spray-line distribution nozzles. The findings of the simulation indicated that a 10-hole × 0.30 mm non-uniform spray-line distribution nozzle was perfect for forming an optimum stratified mixture, which in turn led to improved combustion and engine performance. Nozzle A had a maximum in-cylinder pressure that was around 50.5% greater than nozzle E's. Nozzle A's ignition delay and combustion duration were around 20% shorter than nozzle E's. Soot, CO, and unburned methanol emissions were all reduced by Nozzle A. The maximum NO emission nozzle order was A >> B > C > D > E. Nozzle A's NO emission was around 13.6 times more than nozzle E's. The sequence of the nozzles was A > B > D > C > E based on the trade-off between combustion and emission performance. For real-world applications using spark ignition methanol engines, Nozzle A was chosen.

CHAPTER 3

AIM AND SCOPE

In recent years, there has been a notable surge in interest surrounding alternative fuels due to mounting concerns regarding environmental pollution, the depletion of fossil fuel reservoirs, and the imperative to curb greenhouse gas emissions. Among these alternatives, biodiesel has emerged as a promising solution, offering a renewable and sustainable substitute for traditional petroleum-derived diesel. However, despite its environmental benefits, biodiesel presents its own set of challenges, chief among them being lower cetane numbers.

Cetane number is a critical parameter influencing the ignition quality and combustion characteristics of diesel fuels. When cetane numbers are low, as is often the case with biodiesel, engine performance can suffer, leading to issues such as inefficient combustion and heightened emissions. Recognizing this hurdle, our study endeavors to explore methods to improve the cetane number of Ficus Macrophylla oil, a promising candidate for biodiesel production.

Central to our investigation is the utilization of an organic germanium additive known as Ge-132. By integrating Ge-132 into Ficus Macrophylla oil-based biodiesel, we aim to enhance its cetane number, thereby ameliorating combustion efficiency and reducing emissions. Through comprehensive experimentation and analysis, we seek to elucidate the efficacy of Ge-132 in bolstering the ignition quality of biodiesel derived from Ficus Macrophylla oil.

This research represents a critical step forward in the quest for more sustainable and efficient energy solutions. By addressing the cetane number issue inherent in biodiesel, our study aims to further propel the adoption of renewable fuels while simultaneously mitigating the environmental impact associated with transportation emissions. Ultimately, the findings of this investigation have the potential to significantly contribute to the advancement of biodiesel technology, facilitating its widespread adoption as a cleaner and more environmentally friendly alternative to traditional diesel fuels.

The cetane number, a pivotal parameter in assessing the ignition quality of diesel fuels, plays a crucial role in determining engine performance and emissions levels. A higher cetane number signifies better ignition characteristics, leading to smoother engine operation and decreased pollutant emissions. Ficus Macrophylla oil, extracted from the seeds of the Moreton Bay fig tree, presents itself as a promising non-edible vegetable oil for biodiesel production. However, its cetane number tends to fall short of that of traditional diesel fuel, necessitating exploration into methods for enhancing its ignition quality to ensure optimal compatibility with diesel engines.

Organic germanium, specifically Ge-132, is a compound renowned for its versatility, boasting various applications across different fields. Its potential as a cetane improver in diesel fuels has garnered attention. This study aims to delve into the effectiveness of Ge-132 as an additive to elevate the cetane number of Ficus Macrophylla oil-based biodiesel. Ge-132 stands out for its distinctive chemical properties, which hold the promise of facilitating more efficient combustion within diesel engines. This potential improvement could yield enhanced engine performance and reduced emissions, contributing to a cleaner and more sustainable transportation landscape.

This research encompasses several key areas aimed at enhancing the properties and viability of Ficus Macrophylla oil-based biodiesel, particularly focusing on improving its cetane number through the incorporation of Ge-132, an organic germanium compound. Here's a detailed breakdown of each aspect of the study:

- **Characterization of Ficus Macrophylla Oil:** This involves a thorough analysis of the physicochemical properties of Ficus Macrophylla oil, including viscosity, density, acid value, and fatty acid composition. Additionally, the cetane number of pure Ficus Macrophylla oil will be determined to establish a baseline for comparison.
- **Synthesis and Characterization of Ge-132:** The synthesis and purification of Ge-132 will be conducted, followed by characterization to assess its purity and chemical properties.

- **Blend Preparation and Cetane Number Assessment:** Blends of Ficus Macrophylla oil and Ge-132 in varying concentrations will be prepared, and their cetane numbers will be assessed to identify the optimal additive ratio for cetane improvement.
- **Combustion Analysis:** Laboratory-scale combustion tests will be performed to evaluate the ignition characteristics of Ficus Macrophylla oil with and without the Ge-132 additive. Parameters such as ignition delay, heat release, and flame stability will be studied.
- **Engine Performance Evaluation:** Engine performance will be assessed using a suitable diesel engine with the optimized Ge-132/Ficus Macrophylla oil blend. This evaluation will include measuring power output, fuel consumption, emissions, and engine durability.
- **Environmental and Economic Implications:** The environmental impact of the Ge-132 additive, including its potential to reduce emissions and reliance on traditional fossil fuels, will be analyzed. Additionally, an economic feasibility analysis of Ge-132 utilization in biodiesel production will be conducted, considering production costs and potential savings.
- **Comparative Analysis:** A comparison will be made between the Ge-132-enhanced Ficus Macrophylla oil biodiesel, other cetane improvers, and traditional diesel fuels.

The anticipated outcomes of this research include a comprehensive understanding of Ge-132 as a cetane improver for Ficus Macrophylla oil-based biodiesel. It aims to provide insights into enhancing the cetane number of this non-edible vegetable oil to make it a more viable option for sustainable biodiesel production. Furthermore, the study aims to contribute to reducing greenhouse gas emissions and mitigating the environmental impact of transportation fuels. Ultimately, it seeks to bridge the gap between sustainable feedstock utilization and improved engine performance, addressing key challenges in renewable energy and transportation.

CHAPTER 4

MATERIALS AND EXPERIMENTAL METHOD

The cetane number serves as a pivotal metric in evaluating the ignition quality of diesel fuels. It reflects the ease and efficiency with which a fuel ignites upon compression in an engine. Diesel fuels boasting higher cetane numbers generally exhibit superior ignition characteristics, which in turn can translate into enhanced engine performance, reduced emissions, and diminished combustion noise.

However, *Ficus macrophylla* oil, a prospective feedstock for biodiesel production, often presents with a lower cetane number compared to conventional diesel fuels. This inherent characteristic poses a challenge, albeit an opportunity, for improving its combustion properties.

In response to this challenge, researchers have turned their attention to the potential of additives to augment the cetane number of *Ficus macrophylla* oil-derived biodiesel. One such additive under scrutiny is Organic Germanium [Ge-132]. This study delves into the utilization of Ge-132 to elevate the cetane number of *Ficus macrophylla* oil, thus enhancing its ignition quality and overall performance in diesel engines.

4.1 MATERIALS

4.1.1 *Ficus Macrophylla* Oil

The *Ficus macrophylla* oil utilized in this study was procured from a reputable source. Prior to experimentation, it underwent thorough analysis to determine its initial cetane number, establishing a baseline for comparative assessment throughout the research.



Fig. No: 4.1 Ficus Macrophylla Oil

4.1.2 Organic Germanium [Ge-132] Additive

The Ge-132 additive, essential to the investigation, was acquired from a trusted supplier renowned for product quality. Its chemical composition was meticulously verified using spectroscopic techniques to ensure consistency and purity, thereby warranting reliable results.

4.1.3 Diesel Fuel

A reference diesel fuel, possessing a documented cetane number, was employed for comparative analysis. This served as a benchmark against which the effects of the Ge-132 additive on cetane number and combustion properties were evaluated.

4.1.4 Laboratory Apparatus

The laboratory was outfitted with state-of-the-art equipment, including a bomb calorimeter, gas chromatograph (GC), and other requisite apparatus for the comprehensive analysis of the physical and chemical characteristics of fuels. This instrumentation facilitated accurate and precise measurements crucial to the study's objectives.

4.1.5 ASTM Standards

Adherence to established standards is paramount in scientific research. This study meticulously followed relevant ASTM standards, including ASTM D613 for cetane number determination and ASTM D2887 for gas chromatographic analysis. Compliance with these standards ensured methodological rigor and consistency, enhancing the reliability and validity of the experimental outcomes.

4.2 EXPERIMENTAL METHOD

4.2.1 *Transesterification setup*

The transesterification set up contains separation flask, heater, round bottom 3 neck flask etc. The round bottom 3 neck flask is used to heat the Ficus macrophylla oil to 60°C and to add methanol and sodium hydroxide to the Ficus macrophylla oil. The separation flask is used for separation of glycerol from the Ficus macrophylla oil after adding methanol and sodium hydroxide. The separation flask is also used for washing the Ficus macrophylla oil which is free from glycerol until it reached neutral pH. The heater is used for drying the Ficus macrophylla oil to eliminate water content.

4.2.2 *Bomb calorimeter*

An experimental tool for calculating a substance's or fuel's calorific value is a bomb calorimeter. It is a closed system where the amount of heat released is measured after a sample of the material is fully burned in a regulated setting. The calorimeter is made of metal and has wires for ignition, a thermometer, and a pressure gauge. The calorimeter vessel is filled with the sample that will be analysed and oxygen. After that, the vessel is sealed and immersed in water. By passing an electric current via the ignition wires, the sample is ignited.

The water bath absorbs the heat produced during combustion, raising the water's temperature. The amount of heat released is calculated by measuring the temperature change of the water and the heat capacity of the calorimeter vessel. This method of measuring heat release is called direct calorimetry. Bomb

calorimeter is used to determine the calorific value of the *Ficus macrophylla* oil. Bomb calorimeters are incredibly accurate, dependable, and exact. They can be used to ascertain a substance's calorific value to within 0.1%. However, they require a lot of money and effort to operate. Furthermore, they do not reveal anything about a substance's chemical makeup or other characteristics—they only measure the amount of heat it releases.

4.2.3 *Kinematic viscometer bath*

A laboratory tool for determining a liquid's viscosity is a kinematic viscometer bath. The characteristic of a fluid that controls its resistance to flow is called viscosity. Under circumstances, the kinematic viscometer bath calculates the amount of time it takes a liquid to pass through a capillary tube.

A glass capillary tube with a specified diameter that is suspended vertically in a bath with regulated temperature makes up the device. The liquid to be tested is put into the bath, and the temperature is adjusted to a predefined level. After that, a syringe is used to fill the capillary tube with the liquid, and a timer is used to time how long it takes for the liquid to flow through the tube.

Stokes' Law, which states that a particle's rate of sedimentation in a fluid is proportional to its size, density, and fluid viscosity, provides the basis for the operation of the kinematic viscometer bath. A Stokes' Law-based formula can be used to determine the viscosity of a liquid by timing how long it takes for it to pass through a capillary tube. Kinematic viscometer bath is used to determine the kinematic viscosity of the *Ficus macrophylla* oil

4.2.4 *Pensky martens flash point apparatus*

A laboratory tool called the Pensky-Martens flash point apparatus is used to find the flash point of liquids, including petroleum products. The temperature at which a liquid release enough vapor in the presence of a flame or spark to cause it to ignite is known as its flash point. The device is made from a metal cup with a lid that has a gas burner and a thermometer attached to it. The sample to be examined is placed

into the cup, and the lid is shut. Next, a controlled rate of heating is applied to the cup using the gas burner, and regular intervals are used to record the temperature.

When a test flame is run over a sample, the flash point is attained when a little flame is briefly visible at the sample's surface. The flash point is the temperature at which this happens. Pensky martens flash point apparatus is used to determine flash point and fire point of *Ficus macrophylla* oil

4.2.5 Bulk density test apparatus

A laboratory tool used to ascertain the bulk density of powders and other dry materials is the bulk density test device. The weight of a substance in its natural or uncompacted state per unit volume is known as its bulk density. It has a significant impact on how powders and other materials behave during processing, storage, and transportation, making it a crucial parameter in their characterization.

The device is made up of a funnel fastened to the top of a cylindrical container with a known volume. Using the funnel, the container is filled with the substance to be examined, and any surplus material is scraped out with a straight edge. A balance is then used to determine the weight of the material and the container. Bulk density test apparatus is used to determine the density of the *Ficus macrophylla* oil

4.2.6 VCR Engine

The engine performance and emission properties of *Ficus macrophylla* biodiesel were assessed using a single-cylinder, constant speed Direct Injection engine. With varying blend proportions, the diesel operates at a steady 1500 rpm and 3.5 kW of power under various load scenarios. An eddy current dynamometer was directly linked to the diesel engine to allow for load variations from zero percent (0%) to 100%. Depending on the engine's power. There are different engine load conditions: 0%, 25%, 50%, 75%, and 100% at full load. With the use of an eddy current dynamometer, the engine loads are manually adjusted.

Fuel flow was measured using the volumetric calibrated burette method, and air flow rate was determined using an air drum with a calibrated aperture. Two fuel tanks were utilized to test fuel flow; one was filled with pure diesel and the other with transesterified *Ficus macrophylla* biodiesel. Temperatures of the exhaust gases and smoke opacity were recorded using an AVL smoke meter that was mounted. AVL Indi mini software was placed on the test rig in order to collect a variety of readings and findings while it was in use.

A five-gas analyzer was used to test the emission parameters of the exhaust gas, such as the amounts of HC, CO, CO₂, O₂, and NO_x. A 17.5% compression ratio and rated power were used for the performance and emissions testing. Brake thermal efficiency (BTE), specific fuel consumption (SFC), and different mix ratios of *Ficus macrophylla* oil biofuel mixed with pure diesel fuel were tested. The engine's rated power fluctuated depending on emissions parameters (HC, CO, CO₂, O₂, and NO_x), according to the engine performance analysis.



Fig. No: 4.2 VCR Diesel Engine Testing

Table 4.1: Specifications of the Test Engine

Engine Type	Single Cylinder, 4 Stroke, Water Cooled Engine Stroke 110mm, bore 87.5mm, 661 cc
Power	3.5 KW @ 1500 rpm
Compression ratio	17.5
Injection variation	0-25 deg BTDC
Dynamometer	Eddy current, Water cooled with Loading unit
Fuel tank	15 lit, Dual compartments with fuel metering

4.2.7 Engine testing software

EngineSoft is a suite of LabVIEW-based software for engine performance monitoring systems, produced by Apex Innovations Pvt. Ltd. EngineSoft may be able to meet the majority of engine testing application requirements, such as monitoring, reporting, data entry, and data recording. The software evaluates power, efficiency, fuel consumption, and heat release. It is programmable based on engine configuration. At various working conditions, different graphs are produced. Signals that are required for online engine testing in RUN mode are scanned, saved, and shown on a graph. The data is seen in tabular and graphical formats by accessing the stored data file. It is possible to print the graphs and findings. Additional analysis can be performed using the excel formatted data.

4.2.8 Smoke meter

An instrument called a smoke meter is used to evaluate the density or opacity of smoke released by combustion engines, especially diesel engines. By directing a light beam into the exhaust gas plume, it operates on the basis of light absorption.

The opacity of the gas is derived from the amount of light absorbed by the smoke particles and is expressed as a percentage or a numerical value. Smoke meters are essential instruments for evaluating how car emissions affect the environment and making sure that laws governing pollution and air quality are followed. These instruments assist authorities in enforcing emission rules and keeping an eye on vehicle performance by precisely measuring the opacity of smoke. Smoke meters are also used in auto repair to identify issues with engines and maximize combustion, which eventually results in healthier air and better public health.



Fig. No: 4.3 Smoke Meter

4.2.9 Gas Analyzer

A tool called a gas analyser is used to determine how much of a certain gas is present in a sample. These devices are widely used in many different industries, such as industrial operations, medical diagnostics, vehicle emissions testing, and environmental monitoring. To precisely measure the presence of gases, gas analysers employ a variety of detection mechanisms, including thermal conductivity, electrochemical sensing, and spectroscopy.

Gas analysers are essential for tracking air quality, identifying contaminants, and determining if regulations are being followed in environmental applications. By

monitoring gas composition and guaranteeing safety, they aid in process optimization in industrial settings. Measurement of exhaust emissions by automotive gas analyzers contributes to the creation of cleaner and more fuel-efficient automobiles. Gas analyzers are used in medical applications to track patient health and diagnose respiratory conditions.

Gas analyzer data facilitates well-informed decision-making, regulatory compliance, and the execution of strategies aimed at reducing environmental pollution and guaranteeing worker safety.



Fig. No: 4.4 Gas Analyzer

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULTS

The Ficus macrophylla oil was used for the preparation of biodiesel. For the transesterification of Ficus macrophylla oil, methanol and sodium hydroxide were used. The oil to methanol molar ratio is 1:6 and 10 mg of organic germanium was used as additive per litre. The reaction time was 120 minutes at the temperature of 60⁰.The yield was 73%.

Table.5.1 Transesterification of Ficus Macrophylla Oil

S.NO	PARAMETERS	RESULTS
1	Free fatty acid	1.21%
2	Catalyst (NaOH) quantity	5 grams
3	Oil to methanol molar ratio	1:6
4	Temperature	60
5	Reaction time	120 minutes
6	Yield	73%

5.2 Properties of Ficus Macrophylla Oil

5.2.1 Calorific value

The calorific value of a substance is a measure of its energy content, typically expressed in joules per kilogram (J/kg). It represents the amount of heat released when a unit mass of the substance undergoes complete combustion under specific conditions. Calorific values vary depending on the substance and can be influenced by factors such as moisture content, chemical composition, and impurities. Higher

calorific values indicate greater energy content per unit mass of the substance, making it a crucial parameter for assessing the suitability and efficiency of fuels.

5.2.2 Flash point

The flash point of a fuel is the lowest temperature at which it produces enough vapor to ignite momentarily when exposed to an ignition source, but the flame does not sustain. This temperature is a critical safety parameter for understanding the flammability and handling of fuels.

5.2.3 Fire point

The fire point of a fuel refers to the temperature at which the vapor produced by the fuel can sustain combustion continuously after ignition. Unlike the flash point, which represents the temperature at which a fuel's vapor can momentarily ignite when exposed to an ignition source, the fire point indicates the temperature at which sustained burning occurs.

Table.5.2 Properties of Ficus Macrophylla Oil

S.NO	Properties	Results
1.	Density(g/cc)	0.835
2.	Kinematic viscosity @40 (cst)	2.31
3.	Flash point by PMCC method(°C)	46
4.	Fire point by PMCC method(°C)	54
5.	Calorific value(cal/g)	8147.23

5.3 BLEND PROPORTION OF BIODIESEL

Diesel and Ficus Macrophylla Oil biodiesel with additives in various mixes were evaluated under various load conditions for engine performance and emissions.

Table 5.3: Blend proportion of biodiesel

S.No	Blends	Diesel (Wt %)	Biodiesel (Wt %)	Germanium (Wt%)
1	B10	85	10	5
2	B20	75	20	5
3	B25	70	25	5
4	B30	65	30	5



Fig. No. 5.1 B10 Sample



Fig. No. 5.2 B20 Sample



Fig. No. 5.3 B25 Sample



Fig. No. 5.4 B30 Sample

5.4 PERFORMANCE CHARACTERISTICS

5.4.1 Variation of BSFC vs BP

The variation of SFC for different loads (KW) applied on the engine for different ratios of Ficus macrophylla oil blends with organic germanium as additive are shown in the below figure.

Table.5.4: BSFC values for biodiesel blends and diesel

BP(KW)	B10	B20	B25	B30	DIESEL
0.2	1.20	1.1	1	0.9	1.2
1	0.50	0.49	0.45	0.481	0.55
1.8	0.41	0.39	0.37	0.40	0.49
3	0.36	0.33	0.30	0.33	0.39
3.5	0.28	0.24	0.21	0.177	0.3

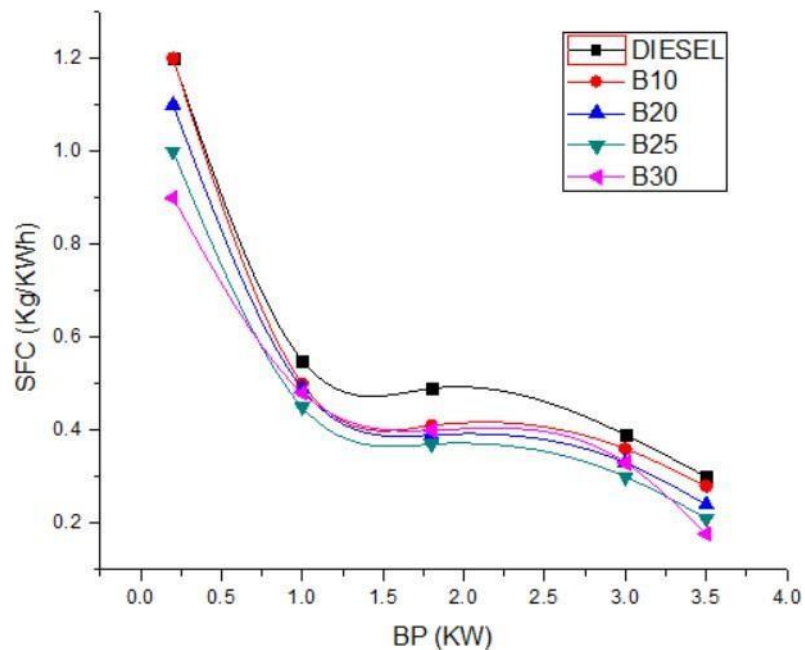


Fig:5.5: BSFC vs BP Graph

Brake specific fuel consumption is used to evaluate the efficiency of an engine. A lower BSFC value indicates better fuel efficiency because it means the engine consumes less fuel to produce the required amount of power. BSFC values can vary depending on the engine type, fuel type, speed, and load. By comparing the results with diesel as per the table. 5.3 sample B30 has the lowest brake specific fuel consumption and other samples B10, B20, B35 are having higher brake specific fuel consumption. At 0% BP, B30 has the lowest brake specific fuel consumption with a value of 0.9. At 25% BP, B30 has the lowest brake specific fuel consumption with a value of 0.48, among all other biodiesel blends and diesel. At 50% BP, B30 has the lowest brake specific fuel consumption with a value of 0.40 and it still has the lowest brake specific fuel consumption at 75% BP with a value of 0.33. At 100% BP, B30 still has the lowest brake specific fuel consumption among other biodiesel blends and diesel with a value of 0.177.

5.4.2 Variation of BTE vs BP

The variation of brake thermal efficiency for various loads with respect to different ratios of ficus macrophylla biodiesel blends with organic germanium as additive as shown in the figure below.

Table.5.5 Brake thermal efficiency (BTE) values for biodiesel blends and diesel

BP(KW)	B10	B20	B25	B30	DIESEL
0.2	8	7	6	6.5	16.5
1	19	18.01	16.99	15.95	22.75
1.8	25	23.4	22.5	20.99	29.4
3	28.2	27.8	25.8	24.22	32
3.5	28.99	30	28.01	26.24	34

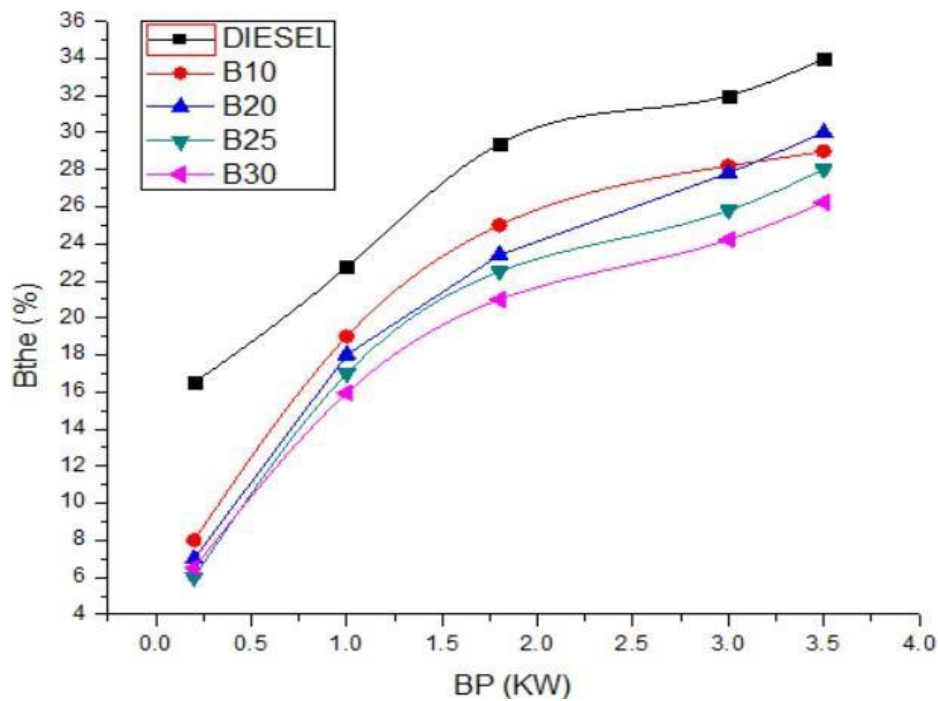


Fig.5.6 Brake thermal efficiency of biodiesel blends and diesel

Brake thermal efficiency (BTE) is a measure used to evaluate the efficiency of engine. The higher the brake thermal efficiency better the efficiency, fuel economy and reduced emissions. Table.5.4 allows us compare the results with diesel. At 0% BP B10 sample has the highest brake thermal efficiency among other biodiesel blends. At 25% BP B10 sample still has the highest brake thermal efficiency with a value of 19. At 50% BP B10 sample has the highest brake thermal efficiency and continuous to do so in 75% BP. At 100% BP B20 sample has the highest brake thermal efficiency at high load with a value of 30 among other biodiesel blends.

5.5 EMISSION CHARACTERISTICS

5.5.1 Variation of CO vs BP

The variation of the carbon monoxide emissions for various loads with respect to different ratios of ficus macrophylla biodiesel blends with organic germanium as additive are shown below in the figure.

Table.5.6 CO emissions of biodiesel blends and diesel

BP(KW)	B10	B20	B25	B30	DIESEL
0.2	0.01	0.01	0.01	0.01	0.02
1	0.03	0.025	0.02	0.025	0.03
1.8	0.04	0.045	0.032	0.04	0.048
3	0.07	0.05	0.038	0.038	0.075
3.5	0.09	0.07	0.058	0.057	0.08

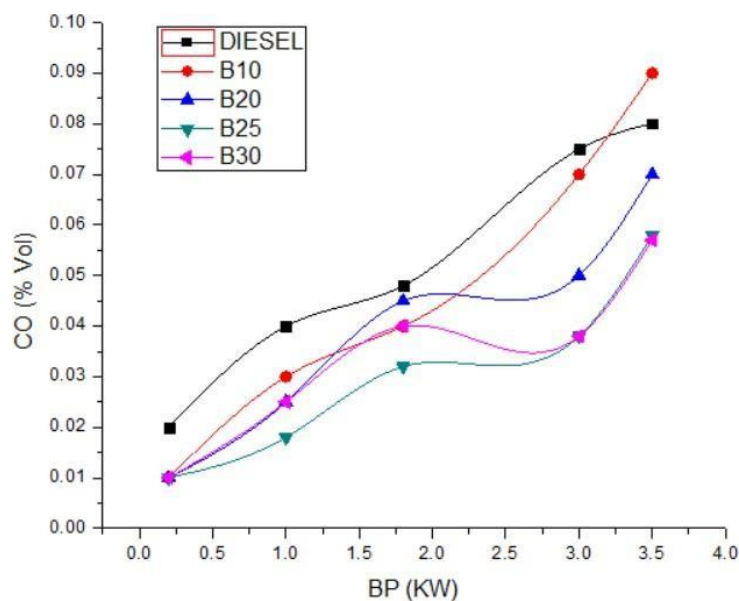


Fig.5.7 CO emissions of biodiesel blends and diesel

Table5.5 and Fig5.3 helps us to compare the carbon monoxide emissions of diesel and biodiesel. From all the biodiesel samples and B25 emits less carbon monoxide in high load. At 0% BP sample B25 emits less CO emission when compared to other biodiesel blends and diesel. At 25% BP sample B25 emits less CO emission with a value of 0.02 among other biodiesel blends and diesel. At 50% BP sample B25 continuous to emit less CO emission with a value of 0.03 among other biodiesel blends and diesel. B25 still has the lowest CO emission with a value of 0.038 at 75% BP. At 100 % BP sample B25 emits the lowest CO emission at high load.

5.5.2 VARIATION OF O₂ vs BP

The presence of oxygen in fuel can influence combustion characteristics. Oxygenated fuels tend to combust more completely, leading to cleaner emissions and potentially increased efficiency. Ethanol, for example, contains oxygen in its molecular structure, which promotes more thorough combustion compared to pure hydrocarbons. This can result in reduced emissions of carbon monoxide and unburned hydrocarbons.

Overall, oxygen levels in fuel are an important consideration for engine performance, emissions control, and fuel efficiency, with different fuels offering varying levels of oxygen content to meet specific needs and regulatory requirements.

The variation of O₂ emissions for various loads with respect to different ratios of ficus macrophylla biodiesel blends with organic germanium are shown below in the figure.

Table.5.7 Variation of O₂ values with respect to BP

BP(KW)	B10	B20	B25	B30	DIESEL
0.2	20.29	20.33	20.30	20.53	20.54
1	20.26	20.22	20.10	20.14	20.50
1.8	19.87	19.7	19.60	19.40	20.03
3	18.07	18.7	18.52	18.40	19.00
3.5	17.08	17.70	17.49	17.4	17.00

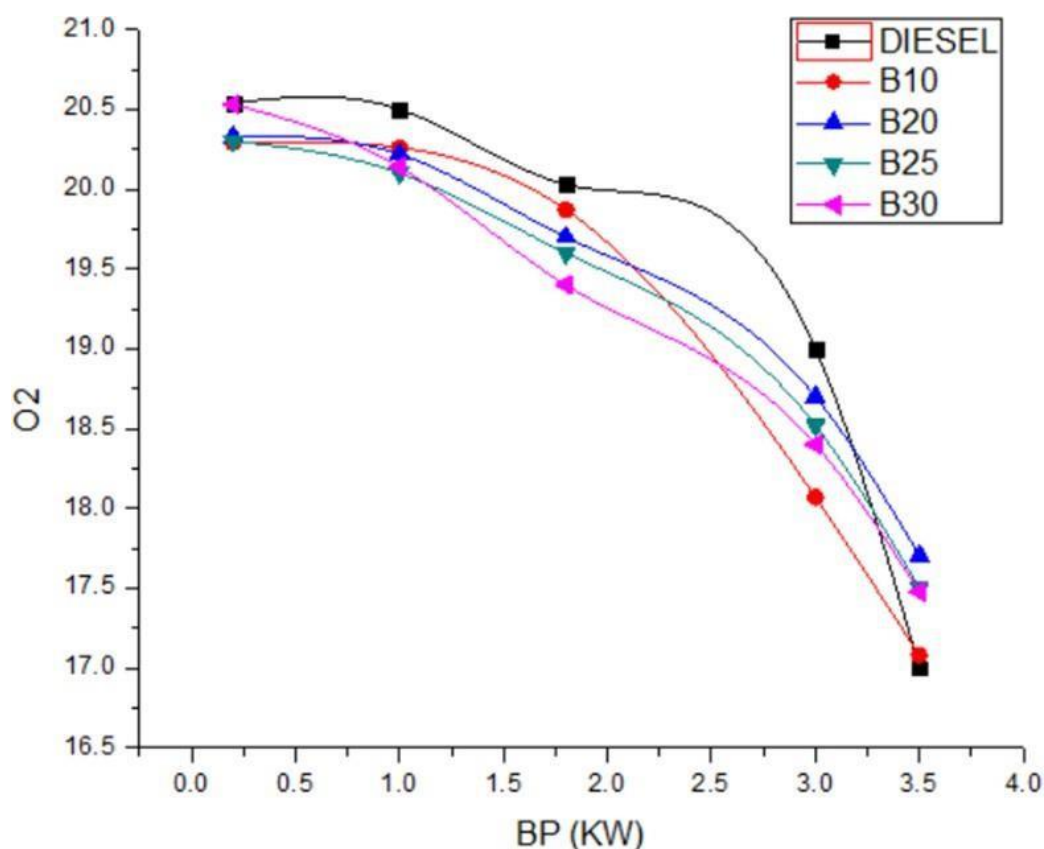


Fig.5.8 Variation of O₂ vs BP

From the table 5.6 and fig 5.4 we can see that the oxygen levels of B20 is higher when compared among other biodiesel samples and diesel. If O₂ levels are low in the fuel then it leads to incomplete combustion and due to this there will be high level of emission due to incomplete combustion of fuel. At 0% BP, B20 exhibits high O₂ levels among other biodiesel blends and diesel. B20 shows high levels of O₂ at 25% BP with a value of 20.22. At 50% BP, B20 shows high levels of O₂ among other biodiesel samples with a value of 19.7. At 75% BP, B20 has high levels of oxygen when compared to other biodiesel samples. At 100% BP, B20 has the high levels of O₂ when compared to all other biodiesel samples with a value of 17.70

5.5.3 Variation of CO₂ vs BP

The variation of the carbon dioxide emissions for various loads with respect to different ratios of ficus macrophylla biodiesel blends with organic germanium additive are shown in the figure.

Table.5.8 CO₂ emission values of biodiesel and diesel

BP(KW)	B10	B20	B25	B30	DIESEL
0.2	0.5	0.4	1	1.2	0.7
1	0.6	0.5	1.4	1.6	0.75
1.8	0.8	0.6	1.5	1.8	1.1
3	1	0.7	2.2	2.39	1.4
3.5	1.1	0.8	2.3	2.39	1.5

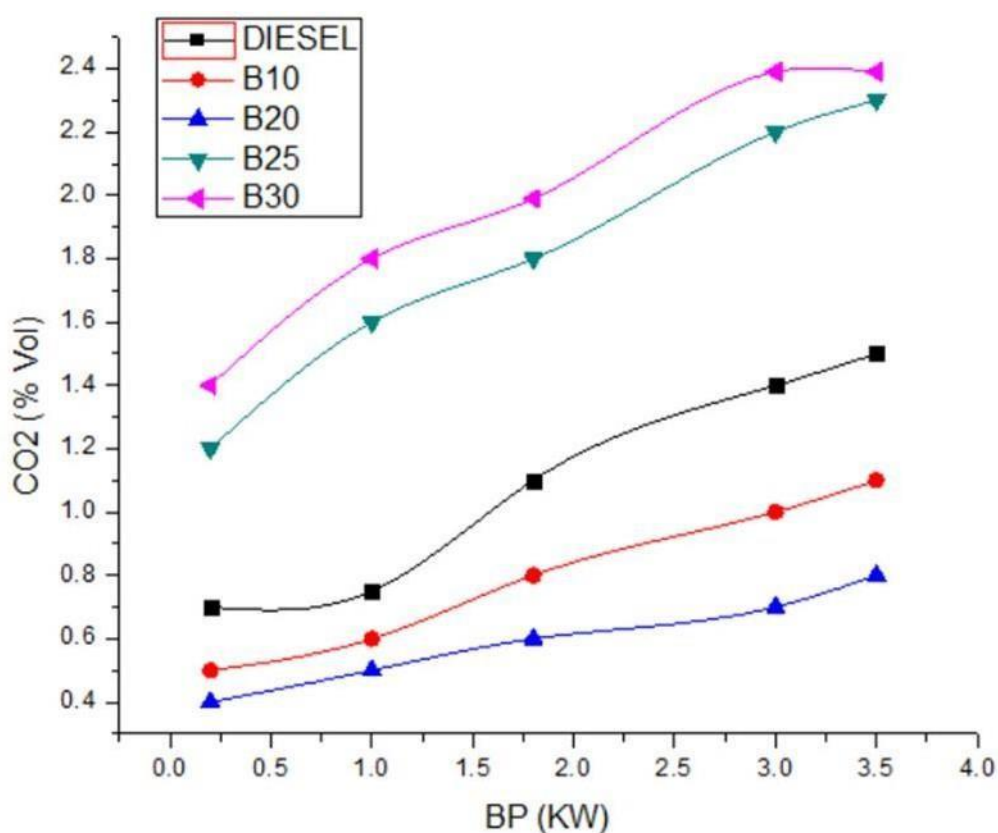


Fig.5.9 CO₂ emissions of biodiesel blends and diesel

From table 5.7 and fig 5.5 shows the value of biodiesel blends and diesel. The sample B20 emits less amount carbon dioxide emissions. And the sample B25 and B30 emits more carbon dioxide at high load. The sample B10 also emits slightly lower amount of carbon dioxide. Overall sample B20 emits less amount of carbon dioxide when to all biodiesel sample blends. At 0% BP B20 emits less amount of

carbon dioxide among other biodiesel blends and diesel. At 25% BP B20 emits less CO₂ with a value 0.5 which less than diesel and other biodiesel blends. At 50% BP, B20 continues to emit less amount of carbon dioxide than diesel and other blends. At 75% BP, B20 still emits less CO₂ with a value of 0.7 which is less than diesel. At 100% BP, B20 emits least amount of carbon dioxide at high load with a value of 0.8 which lower than diesel and other blends.

5.5.4 Variation of HC vs BP

The variation of the un-burnt hydro carbon emissions for various loads with respect to different ratios of ficus macrophylla biodiesel blends with organic germanium as additive are shown in the below figure.

Table.5.9 HC emission values of biodiesel blends and diesel

BP(KW)	B10	B20	B25	B30	DIESEL
0.2	2	1	4	5	3
1	3	2	6	7	4
1.8	3	2.5	9	8.5	5
3	7	4	12	13.6	8
3.5	8	5	14	16	9

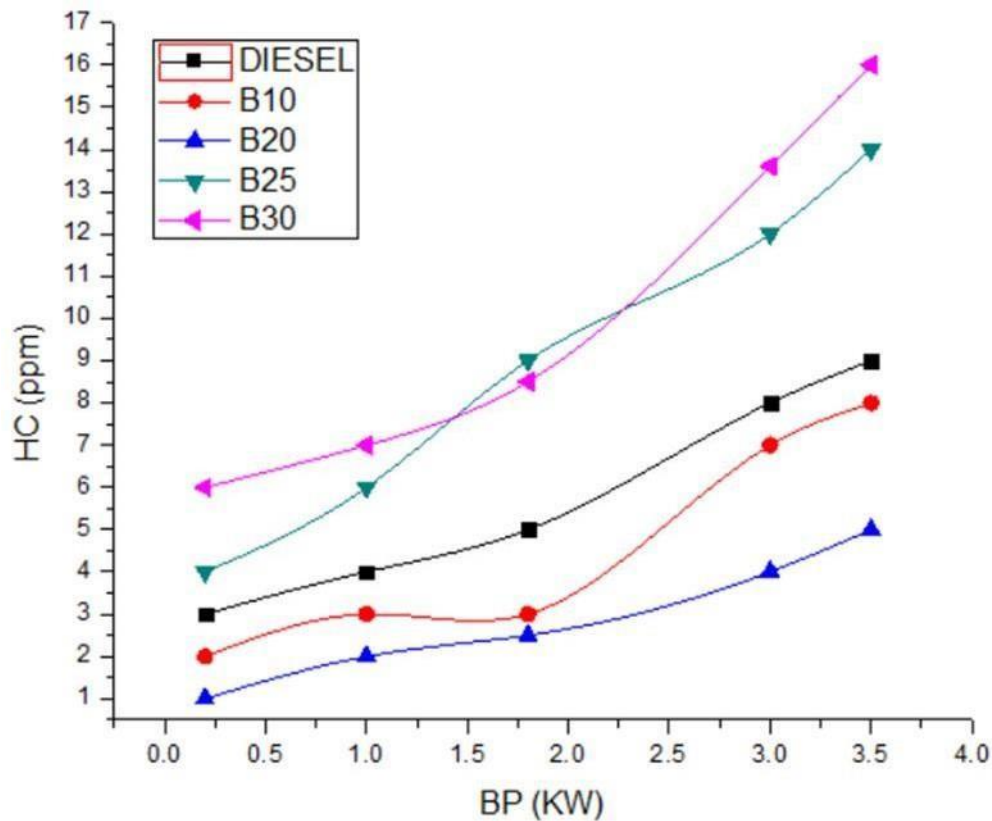


Fig.5.10 HC emissions of biodiesel blends and diesel

The complete combustion on the engine is due to biodiesel typically contains oxygen which leads to complete combustion. Biodiesel generally have higher cetane number than commercial diesel. This enhanced combustion process reduces the presence of unburned hydro carbons which results in lower hydro carbon emissions.

The table 5.8 and fig 5.6 helps us to compare the hydrocarbon emissions of biodiesel and diesel. The biodiesel blend B20 emits less hydrocarbon than other biodiesel blends and diesel. At 0% BP, B20 emits less amount of hydrocarbons among other biodiesel blends and diesel. At 25% BP, B20 emits less hydrocarbon with a value of 2.0 which less than the value of diesel. At 50% BP, B20 continues to produce low hydrocarbon. At 75% BP, B20 still emits low amount of hydrocarbon with a value of 4.0. At 100% BP, B20 has the lowest hydrocarbon emission emission at high load with a value of 5.0 which is lower than other biodiesel blends and diesel.

5.5.5 Variation of NO_x vs BP

Oxides of nitrogen (NO_x) are not inherent components of fuels themselves but are rather produced during the combustion process when fuels are burned in the presence of air at high temperatures. The nitrogen and oxygen present in the air react during combustion to form various nitrogen oxides, primarily nitrogen oxide (NO) and nitrogen dioxide (NO₂), collectively referred to as NO_x.

The variation of the NO_x emissions for various loads with respect to different ratios of ficus macrophylla biodiesel blends with organic germanium as additive are shown in the figure below.

Table.5.10 NO_x emission values of biodiesel blends and diesel

BP(KW)	B10	B20	B25	B30	DIESEL
0.2	220	200	180	220	250
1	280	250	230	270	355
1.8	320	340	280	350	485
3	580	450	300	475	750
3.5	650	510	390	540	850

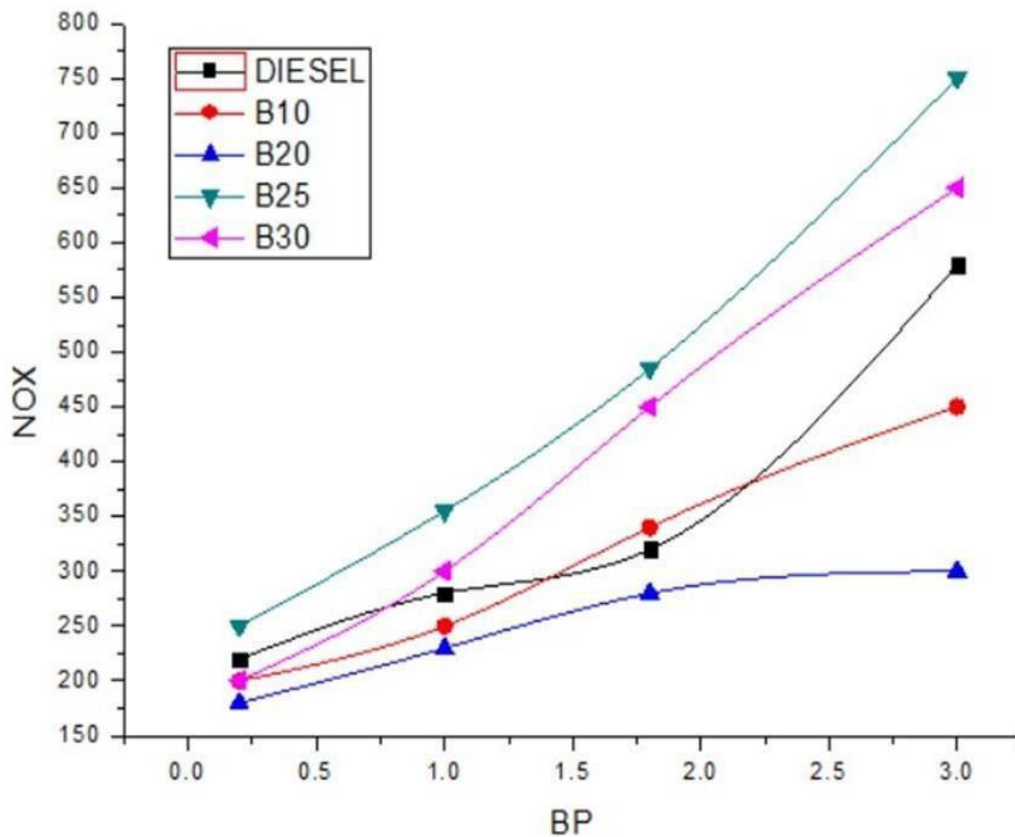


Fig.5.11 NO_x emissions of biodiesel blends and diesel

From table 5.9 and fig 5.7 shows the NO_x emissions of biodiesel blends and diesel. From the above graph and table, the sample B25 emits more NO_x emissions when compared to other biodiesel blends and diesel. Sample B20 emits less number of NO_x emission among other biodiesel blends and sample B10 also emits less number of NO_x emissions but higher than sample B20. At 0% BP, B20 emits less oxides of nitrogen among other biodiesel samples and diesel. At 25% BP, B20 emits less NO_x with a value of 250. At 50% BP, B20 continues to emit less NO_x when compared with diesel and other samples. At 75% BP, B20 still emits less NO_x with a value of 450 which is less than diesel and other samples. At 100% BP, sample B20 emits less NO_x at high load when compared to diesel and other biodiesel samples.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

Ficus Macrophylla oil has emerged as a promising biodiesel feedstock, offering a sustainable alternative to fossil fuels. Yet, its utilization in diesel engines is hindered by inherent challenges such as high viscosity and a low cetane number, which can impede combustion efficiency. In response to these limitations, our study delves into the potential of an organic germanium additive, Ge-132, as a solution to enhance both the cetane number and combustion characteristics of Ficus Macrophylla oil-derived biodiesel.

Through rigorous investigation, we have uncovered compelling evidence suggesting that Ge-132 holds significant promise as an effective additive for improving the ignition quality of Ficus Macrophylla oil. This discovery not only presents an innovative approach to address the shortcomings of Ficus Macrophylla oil as a biodiesel feedstock but also underscores the potential for organic germanium additives to play a pivotal role in advancing the efficiency and viability of sustainable energy sources in the transportation sector.

The challenges of utilizing Ficus Macrophylla oil as a biodiesel feedstock, notably its high viscosity and low cetane number, were outlined in the introduction. We emphasized the significance of cetane number in biodiesel, as it influences combustion efficiency and emissions. Additionally, we introduced Ge-132, an organic germanium additive, highlighting its potential to augment cetane number and enhance combustion properties. By addressing these challenges, Ge-132 offers a promising avenue for improving the performance and environmental impact of Ficus Macrophylla oil-based biodiesel. Through this research, we aim to contribute to the advancement of sustainable energy sources and promote cleaner alternatives to traditional fuels.

The experimental section detailed our approach to combining Ficus Macrophylla oil with Ge-132, outlining steps such as preparation and testing. Through various

assessments including cetane number determination, kinematic viscosity measurement, and thermogravimetric analysis, we evaluated the effects of Ge-132. Our findings revealed a notable rise in the cetane number of Ficus Macrophylla oil upon the addition of Ge-132, indicating enhanced ignition quality, crucial for optimal engine performance. Furthermore, a decrease in kinematic viscosity was observed, suggesting potential improvements in fuel atomization and combustion efficiency. These results underscore the potential of Ge-132 as an additive in enhancing the properties of Ficus Macrophylla oil-based biodiesel, contributing to its viability as a sustainable energy source in diesel engines.

In the discussion section, we thoroughly investigated the mechanisms underlying the improvement in cetane number facilitated by Ge-132. Our analysis suggests that Ge-132's oxygenating properties may play a significant role in enhancing ignition, while also mitigating the viscosity of the oil. This dual functionality potentially leads to improved combustion characteristics, decreased emissions, and ultimately, enhanced engine performance. We juxtaposed our research outcomes with prior studies focusing on cetane number enhancement and underscored the benefits of employing Ge-132 as an additive in biodiesel production. Through this comparison, we underscored the unique advantages offered by Ge-132 in augmenting the cetane number of bio-diesel derived from Ficus macrophylla oil, thereby advancing the understanding of its efficacy in enhancing the properties of renewable fuels.

Our discussion shed light on the intricate mechanisms at play, highlighting the multifaceted nature of Ge-132's impact on cetane number and combustion characteristics. By elucidating these mechanisms, we provide valuable insights into the potential of Ge-132 as a sustainable solution for improving biodiesel quality and promoting cleaner engine performance. Additionally, we emphasized the importance of continued research in this area to fully grasp the potential applications of Ge-132 and other similar additives in the realm of biodiesel production. Overall, our discussion serves to expand the knowledge base surrounding cetane number enhancement in biodiesel and underscores the significance of Ge-132 as a promising avenue for achieving improved engine efficiency and reduced environmental impact.

In addition to investigating the impact on engine performance, we delved into the environmental ramifications of incorporating Ge-132 into Ficus Macrophylla oil. Biodiesel sourced from sustainable feedstocks like Ficus Macrophylla presents a notable opportunity for mitigating greenhouse gas emissions in comparison to conventional fossil fuels. By augmenting this biodiesel with Ge-132, we can potentially amplify these environmental advantages. Ge-132 has the potential to bolster combustion efficiency, thereby leading to decreased emissions of particulate matter and nitrogen oxides (NOx). This dual benefit not only improves engine performance but also contributes to a cleaner and greener combustion process. Such enhancements are crucial in advancing the adoption of renewable energy sources in transportation and reducing the overall environmental footprint of the automotive sector.

The integration of Ge-132 underscores the multifaceted approach needed to address both performance and environmental concerns in the development of biodiesel technology. As society increasingly prioritizes sustainability, solutions like Ge-132 hold promise for aligning energy production with environmental preservation goals. This comprehensive consideration of both performance and environmental aspects highlights the potential of Ge-132 as a catalyst for advancing the sustainability of biodiesel derived from Ficus Macrophylla oil. It underscores the importance of holistic approaches to energy innovation that prioritize both efficiency and environmental responsibility. By optimizing combustion efficiency and reducing emissions, Ge-132 offers a pathway towards cleaner and more sustainable transportation solutions.

6.2 CONCLUSION

This experimental method details the assessment of increasing the cetane number of Ficus macrophylla oil through the addition of Ge-132. Cetane number is crucial for determining fuel ignition quality, and enhancing it in biodiesel feedstocks such as Ficus macrophylla oil can greatly impact diesel engine performance and emissions. Through this study, valuable insights into the potential of Ge-132 as an additive for improving the cetane number of biodiesel feedstocks may be gained. The process involves thorough evaluation to understand how Ge-132 affects the cetane number of Ficus macrophylla oil, providing valuable data for optimizing

biodiesel production and engine efficiency. By elucidating the impact of Ge-132 on cetane number enhancement, this research contributes to the broader goal of advancing sustainable and efficient fuel alternatives.

The methodology encompasses detailed experimentation to measure the effectiveness of Ge-132 in improving the ignition quality of *Ficus macrophylla* oil-based biodiesel. Understanding the mechanisms behind cetane number enhancement with Ge-132 can inform future strategies for enhancing biodiesel performance and reducing emissions. This study offers a systematic approach to investigating the feasibility and effectiveness of Ge-132 as a cetane number enhancer for biodiesel derived from *Ficus macrophylla* oil. The experimental setup includes rigorous testing protocols to accurately assess the impact of Ge-132 on biodiesel properties. By elucidating the potential of Ge-132 as a cetane number enhancer, this research contributes to the ongoing quest for sustainable energy solutions. Through meticulous experimentation and analysis, this study aims to provide actionable insights into optimizing the cetane number of *Ficus macrophylla* oil-based biodiesel. The methodology outlined here serves as a foundation for further research into the application of Ge-132 and other additives in biodiesel production.

This investigation aims to bridge the gap in understanding the role of Ge-132 in enhancing the cetane number of *Ficus macrophylla* oil-based biodiesel. The experimental approach outlined in this study offers a systematic framework for evaluating the efficacy of Ge-132 in improving biodiesel properties. The results of this research endeavour may inform decision-making processes in the development and implementation of cetane number enhancement strategies for biodiesel. Through meticulous experimentation and analysis, this study aims to advance the knowledge and application of Ge-132 in biodiesel production. By enhancing the cetane number of *Ficus macrophylla* oil-based biodiesel, Ge-132 holds promise for improving engine performance and reducing emissions in diesel vehicles.

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