IPS Journal of Engineering and Technology
IPS J. Engr. & Tech., 1(2): 70-74 (2025)
DOI: https://doi.org/10.54117/ijet.v1i2.15

The Effects of Plants Essential Oils on Biodiesel Fuel Properties during Storage

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Abstract

Dilapidation of biodiesel engineering properties is one of its major challenges during storage. The main goal of this research is to evaluate the feasibility of inhibiting the rapid deterioration of palm oil biodiesel (POME) fuel properties during extended storage by blending (incorporating) it with essential oils. POME, produced in accordance with American Society for Testing and Materials (ASTM) guidelines, was fortified with 1% wheat germ oil (Blend 1), 1% avocado seed oil (Blend 2), and a combination of both wheat germ oil (1%) and avocado seed oil (1%) (Blend 3). The fuel properties of these blended biodiesels—acid value and kinematic viscosity—were determined using ASTM procedures. Results obtained from this study revealed that the acid values of the control unit and Blends 1 to 3 increased by 35.90%, 23.93%, 26.04%, and 23.13%, respectively, over the course of 60 days of storage. Furthermore, the kinematic viscosity of the control group and Blends 1 to 3 increased from 4.45 to 4.71, 4.45 to 4.59, 4.45 to 4.62, and 4.45 to 4.56 cSt, respectively, as storage progressed to the 60th day. Remarkably, it was also noted that the hybridization of wheat germ oil and avocado seed oil exhibited the most effective fuel property stabilization results. Individually, the wheat germ oil-treated biodiesel yielded better results compared to the avocado seed oil blend. These findings provide valuable insights into inhibiting the oxidation of palm oil biodiesel. This knowledge has the potential to foster environmental sustainability by reducing dependence on synthetic additives.

Keywords: *Agricultural residues, antioxidants, biodiesel quality, climate change, fuel oxidation inhibition*

Article History
Received: 07 Apr 2025
Accepted: 14 Apr 2025
Published: 16 Apr 2025

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How to cite this paper: Sinebe, E. J., & Hilary, U. (2025). The Effects of Plants Essential Oils on Biodiesel Fuel Properties during Storage. *IPS Journal of Engineering and Technology*, *1*(2), 70–74. https://doi.org/10.54117/ijet.v1i2.15

1. Introduction

Traditional fuels are primary drivers of many nations' economies, even though emission associated with their combustion is a principal contributor to climate change through greenhouse gasses (GHS) emission. Fossil fuels provide the necessary energies required for domestic and industrial operations; hence, increasing the real time value chain of most materials. Some harmful compounds discharged during fuel combustion process include: particulate matter (PM), carbon (ii) oxides, carbon (iv) oxides, heavy metals, nitrogen oxides (NOx), methane (CH_4), sulfur oxides (SOx), dioxins and Volatile Organic Compounds (VOCs). The concentration of these toxics in the emission is influence by the chemical compositions of the primary fuel. Fuel sourced from coal tends to have more SOx and PM, oil-based fuel tends to exacerbate the NOx, SOx and VOCs levels in the atmosphere, while natural gas emits low volume of COx, SOx, NOx and PM. These compounds are the ability of causing climate change by enhancing the greenhouse effect. Biofuel fuel properties are dependent on their feedstock physiochemical properties. Plants physiochemical and phytochemical properties, which usually impact biofuel qualities, are influenced by field practices and post-harvest operations (Edafeadhe and Uguru, 2020; Edema *et al.*, 2022).

Advancement in the production of green fuels plays very essential parts, in mitigating the environmental impact, linked to the combustion of fossil fuels. Green fuels are obtained from more sustainable materials – usually agricultural products residues, and they have lower carbon footprints compared to traditional fossil fuels. Production of biofuel which is a subset of green fuel has have the ability of reducing Carbon (iv) oxide (CO_2) and other toxic gasses accumulation in the environment. Plant which is the main feedstock for biofuel production is a principal air purifier, as it absorbs harmful pollutants (phytoremediation) and improves the surrounding air quality. Also during photosynthesis process, plant absorbs CO_2 from the atmospheric air and release oxygen (product of photosynthesis) which is a healthier and harmless gas into the air. Additional significant merits of production and utilization of biofuels include: production of lower PM during combustion and ability enhancing effective waste management through conversion of biological waste into potential energy (Mahapatra *et al.,* 2021; Eboibi *et al*., 2022; Rajeev *et al*., 2022).

Oil-based plants are the major feedstock for biofuel production as the yield high quality and quantity oil, which can be converted into biodiesel through transesterification process. Their high oil yield enhances biodiesel production sustainability; hence, minimizing the impact of food security and climate suitability challenges associated with green fuel production. Oil palm, groundnut, sunflower and Jatropha oils are some of the common oils with high quality biodiesel yield potential. Biodiesel produced from groundnut oil generally exhibits fuel properties that are compatible with traditional diesel (Brahma *et al*., 2022). Being organic in nature, biodiesel is usually susceptible to deterioration during handling and storage processes. Principal factors that advance the degradation of biodiesel include: poor production technique, presence of contaminants, and exposure to air, light and heat. Deterioration causes significant increment in the acidity, density and gumminess of the biodiesel, which greatly affects the fuel performance and corrosion and of the engine parts (Christensen and McCormick, 2014; Masudi *et al.,* 2022; Edema, 2023).

Recently, there are improvements in biodiesel stability research through the application of additives that enhance the overall stability of biodiesel. Additives, whether of organic or inorganic origin, are, are specifically designed to hinder oxidation of the fuels. These additives are antioxidants, stabilizers, metal deactivators, corrosion inhibitors, cold flow improvers and biocides. Organic antioxidants, especially Tocopherols (vitamin E), B vitamins, and Ascorbic Acid (vitamin C) have the ability of inhibiting biodiesel oxidation, by acting as free radicals scavengers; thereby, retarding the oxidative processes (Lobo *et al*., 2010; Uguru *et al.*, 2023). Free radicals scavengers play a decisive part in impeding the formation of hydroperoxides within the fuel during prolongs storage. This action helps to enhance the storability of the fuel, by minimizing the degradation rate of fuel properties during storage. Despite numerous studies had focused on the possibility of enhancing stability biodiesel, during processing, handling and storage unit operations (Agarwal and Khurana, 2013; Susanto *et al*., 2018; Peng *et al.*, 2024), there is still a significant information scarcity in understanding the stability of palm oil-based biodiesel. Particularly, information regarding the impact of extended storage period on biofuel quality and engine performance. Therefore, the paramount goal of this research is to, formulate effective stabilization program, for biodiesel by incorporating agricultural residues, such as wheat germ and avocado seeds.

2. Materials and Methods

2.1 Materials

The palm oil, wheat (*Triticum*) and avocado pear (*Persea americana*) used for this study were procured from the local markets in Onithsa, Anambra State, Eastern Nigeria.
The reagents employed in this study were of analytical grade. Measurements were conducted in triplicate, demonstrating a relative standard deviation of less than 5%. The recovery percentages for the Certified Reference Materials (CRMs) ranged from 95% to 110%.

2.2 Methods

Wheat germ oil and avocado oil

The oil from the wheat germ and avocado seed were obtained through the Soxhlet extraction process. N- hexane (a non-polar solvent) was the extraction liquid used in the process. After the extraction process the oil is concentrated by evaporating the solvent, and the oil was further purified rotary evaporation, as described by Eboibi *et al*. (2022).

Palm oil biodiesel production

The transesterification technique was used to manufacture the palm oil biodiesel. During the fuel production procedure, methanol and the palm oil were mixed at a ratio of 6:1, in the presence of 1% sodium hydroxide acting as a catalyst. The mixture was poured into a heat resistance flask, placed on top of a laboratory heater preset at a temperature of 65ºC for 4 hours, and stirred using a velocity of approximately 300 revolutions per minute. Thereafter, product obtained from the fuel production was transferred to a standard separating funnel (produced by Thermo Fisher Scientific Inc. USA), left to stand for another 24 h. This is to separate the palm oil biodiesel (palm oil methyl ester "POME") from the glycerine, which is a byproduct of the transesterification reaction. The palm oil biodiesel is the uppermost stratum, while the glycerine is the bottom liquid layer. Then the raw POME was washed with distilled water, dried at a temperature of 90℃ for 1 h in a water bath, and dried further with a hygroscopic agent- anhydrous sodium tetraoxosulphate (VI) oxide, as explained by Eboibi *et al*. (2022).

Blending of the palm oil biodiesel

The wheat germ oil (WGO) and avocado seed oil (ASO) were integrated with the POME and coded as shown in Table 1. Thereafter, all the experimental units were kept in a cool, dry and dark place, under ambient room temperature (25±4℃) for 2 months.

Table 1: Biodiesel blending plan

Sample code	Constituents (%)
Control	100% POME
Blend 1	99% POME and 1% WGO
Blend 2	99% POME and 1% ASO
Blend 3	98% POME + 1% ASO + 1% WGO

2.3 Laboratory analysis

The fuel properties of the biodiesel specimens produced were tested every 15 days during the experimental period of 60 days

Kinematic viscosity

The kinematic viscosity of the biodiesel was assessed at a temperature of 40°C, following the approved procedures outlined in ASTM D-6751 (2023).

Acid value (AV)

The biodiesel samples AV was determined using the titration technique in harmony with the ASTM D974 (2022) approved guidelines.

2.4 Statistical analysis

The results obtained from this study were statistically evaluated through line charts and analysis of variance (ANOVA) to access the impact of the additives on the fuel qualities during storage. Each test was conducted in triplicate, and the average value documented.

3. Results and Discussion

3.1 Acid Value

Figure 1 shows the AV results of the different POME blends, and the results shows that the bio-additives have significant influence on the fuel AV level. The control, Blend 1, Blend 2 and Blend 3 AV appreciated from 1.25 to 1.95, 1.24 to 1.63, 1.25 to 1.69 and 1.23 to 1.60 mgKOH/g, respectively over the course of 60 days. It was noted from the outcomes that both the WGO and ASO exerted a notable influence on fuel stabilization when stored under typical ambient environmental conditions. At the end of the investigational storage duration, it was detected through the outcome that, the untreated fuel exhibited the highest AV level. This observation can be attributed to the heightened oxidation of the fuel during storage, particularly in the absence of oxidation inhibition materials. Plants produce a diverse range of antioxidants and related compounds, which play a crucial role in slowing down the degradation of biofuels. This is achieved by reducing the formation of lower acids during storage (Amran *et al.,* 2022). Blending biodiesel with antioxidants concentrate slows down the oxidation reaction within the fuel. Consequently, this helps in maintaining more acceptable fuel properties during storage (Ibrahim *et al.*, 2017).

Devi *et al*. (2017) and Nuhanovic *et al*. (2018) also noted comparable findings in their study on the engineering behavior of biofuel during storage. They reported that the vulnerability of biodiesel to degradation during storage can be mitigated by incorporating an appropriate quantity of plant materials rich in antioxidants and vitamins into the fuel.

3.2 Kinematic viscosity

The results of the kinematic viscosity of the various POME blends are shown in Figure 2. It can be seen in Figure 2 that both the WGO and ASO had considerable influence biodiesel kinematic viscosity mentioned at 40ºC during storage. Figure 2 revealed that the control, Blend 1, Blend 2 and Blend 3 experimental units' kinematic viscosity increased from 4.45 to 4.71, 4.45 to 4.59, 4.45 to 4.62 and 4.45 to 4.56 cst, respectively, after the experimental duration. This reflects that inclusion of organic oils has a positive effect on slowing down the rapid increase in fuel kinematic viscosity during the storage period from Day 0 to Day 60. Similar results were recorded by Agarwal and Khurana (2013) and Susanto *et al*. (2018), as organic compounds had the capability to inhibit the degradation of palm oil biodiesel during storage. However, the results obtained through the combination of the two essential oils (WGO and ASO) surpassed those achieved by Susanto et al. (2018) using pure pyrogallol compound alone. This suggests that the hybridization of essential oils may enhance the effectiveness of inhibiting biodiesel degradation compared to individual compounds.

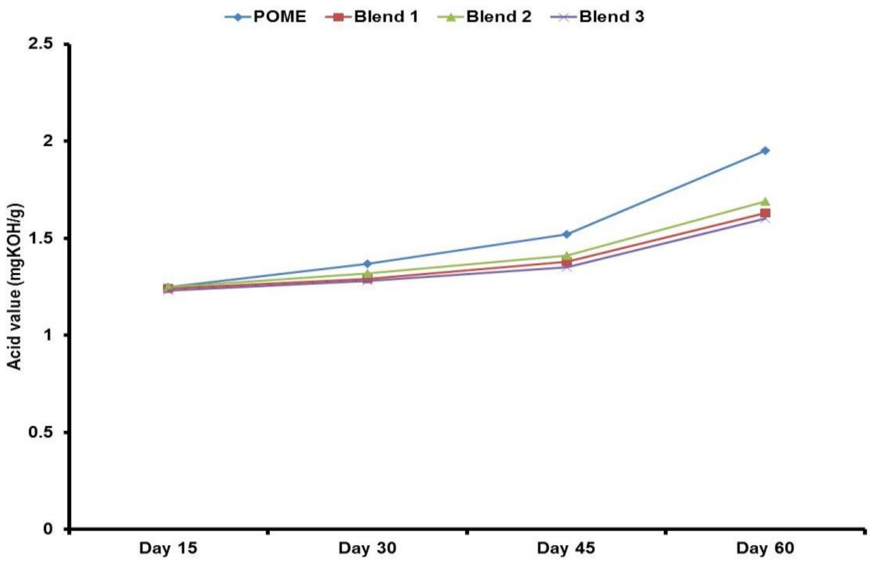

Figure 1: Biodiesel acid value

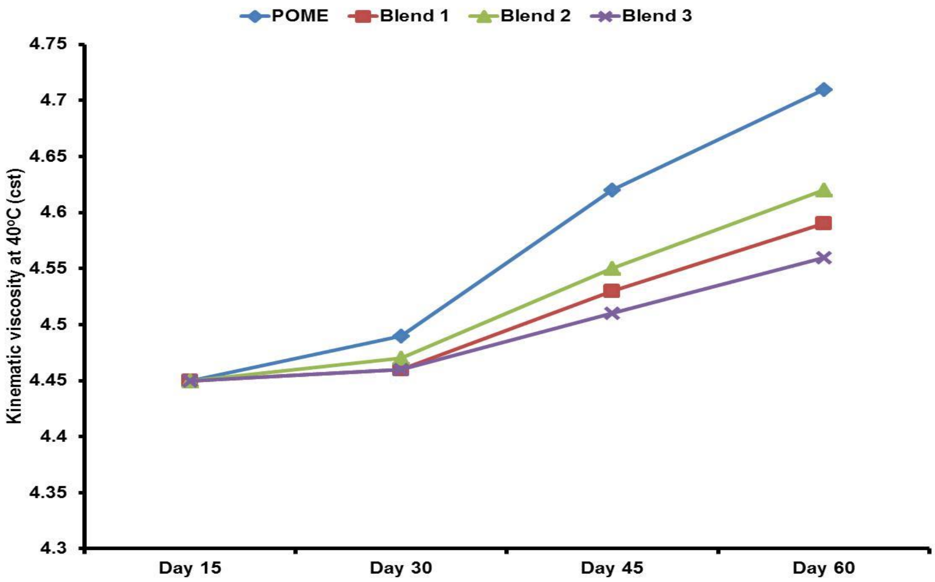

Figure 2: Biodiesel kinematic viscosity

Generally, the combined treatment option (Blend 3) exhibited the most effective stabilization results. Remarkably, it was observed that specimens, treated with 1% WGO, established results with superior values, when compared to POME blended with 1% ASO. This behavioral pattern of the Blend 1 biodiesel, can be associated with the higher vitamin E and antioxidants concentrations present in WGO, in comparison to ASO bioactive compounds components of AGO (Sousa *et al*., 2014). The large proportion of essential vitamins and strong antioxidant attributes of WGO, make it (WGO) an excellent oxidation inhibition material. This tends to effectively retard the rapid deterioration of biofuels engineering properties (Arslan *et al*., 2020). This study's outcomes provide prized insights, into the inhibition of palm oil biodiesel oxidation during storage. Interestingly, the information provided by this research will facilitate promoting the environmental sustainability of biodiesel, by minimizing the dependence on synthetic additives, most of which are not environmental friendly (Liang *et al.*, 2006; Davi *et al.*, 2017). Ultimately, this will aid the reduction of carbon footprint, associated with biodiesel production and utilization; hence, mitigating the greenhouse gases effects and challenges.

4.0 Conclusion

This study evaluated the possibility of impeding the rapid depreciation of fuel properties of palm oil biodiesel (POME), during storage through the utilization of essential plants oils. The POME was treated with wheat germ oil, avocado seed oil, and hybridization of both wheat germ oil and avocado seed oil. The obtained results indicated that after 60 days storage period, the acid values of the control unit, Blends 1 – 3 biodiesel specimens increased by 56.00, 31.45, 35.20 and 30.08%, respectively. Additionally, it was noted that the kinematic viscosity of the control, Blend 1, Blend 2, and Blend 3 experimental unit's increase of 5.84%, 3.15%, 3.82%, and 2.47%, respectively, as the storage period advanced to the 60th day. Remarkably, the Blend 3 biodiesel sample exhibited the most effective stabilization results. Furthermore, the findings highlighted that the Blend 1 biodiesel demonstrated retained better fuel qualities during storage, compared to Blend 2 biodiesel. These findings offer valuable insights into strategies for inhibiting the oxidation of palm oil biodiesel, through the use of plant-based additives. This will contribute significantly to environmental sustainability.

Funding: The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Author contributions: All the authors contributed to the development of the work. All authors read and approved the final manuscript.

Competing interests: The authors declare no competing interests.

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