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Chemical and Thermal Characterization of JET A-1 and HEFA-SAF for Aeronautical Application

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PURPOSE OF THE ABSTRACT

Aviation industry contributes to global carbon emissions, with fossil jet fuels (FJF) producing 2-3% of carbon dioxide (Capaz et al., 2021). Bio-sourced jet fuels (BJF), produced from renewable resources such as plant oils, biomass, wood waste, and algae, are being promoted to reduce air transport's carbon footprint. The most cost-effective BJF is hydroprocessed esters and fatty acids (HEFA) fuel, which reduces greenhouse gas emissions by up to 80% over its lifespan. HEFA also has lower nitrogen and sulphur content, contributing to environmental and health impact (Raji et al., 2024; Zhao et al., 2021). Understanding the thermal and oxidative stability is important, to optimise its use in jet engines, regarding the demanding thermal conditions in which jet propulsion operates. This study aims to compare the characteristics and thermal behaviour of FJF and BJF using thermal analysis (TGA/DTA) under various operating conditions to provide insights for optimizing storage conditions and fuel stability, as well as quality control measures for renewable fuels.

The two jet fuels showed typical densities for aviation fuels, with a slightly lower value for BJF, minimally impacting volumetric energy. BJF's higher energy density improves fuel efficiency without sacrificing range. Its narrower kinematic viscosity enhances atomisation and combustion, vital at high altitudes. BJF heating value closely matches its fossil pair, maintaining comparable performance. Its paraffinic structure supports efficient combustion, slightly boosting energy output while its low acid value prevents fuel system corrosion, enhancing stability. Its higher freezing point compared to FJF meets aviation standards. Its higher flash point enhances safety, and a greater smoke point ensures cleaner combustion, reducing soot. BJF ultra-low sulphur content, achieved via hydroprocessing and hydrocracking, minimizes SO_x emissions and decreases engine corrosion, extending lifespan. FJF decomposes starting at 85°C (fig 1), with the higher mass loss by 200°C. A single-phase decomposition indicates a homogeneous mix of hydrocarbons such as alkanes, cycloalkanes, and aromatics (de Klerk et al., 2023) that was confirmed using GCMS. The peak decomposition temperature (T_p) lies between 154-179°C, shifting slightly at higher heating rates due to thermal lag, demonstrating stability over varying conditions. The thermal

characteristics suggest controlled combustion with consistent decomposition, favouring performance. BJJ begins decomposing at 100°C (fig. 2), achieving complete mass loss by 220°C, indicating thermal stability. Both fuels have comparable initial decomposition temperatures, suggesting BJJ suitability as FJJ replacement. BJJ single-step decomposition is due to its uniform composition of alkanes and alkenes, derived from hydroprocessed esters and fatty acids (Vozka et al., 2019). Its T_p is slightly lower than its fossil pair, ranging from 158°C to 182°C depending on the heating rate, with a slower decomposition under rapid heating. Despite this, it fully decomposes within BJJ's range, revealing that both fuels will perform similarly under varying thrust or altitude conditions.

Thermal study of BSJ confirmed its viability as a sustainable alternative to FJJ, supporting cleaner aviation fuel adoption. Comparable T_{onset} and T_p ensure similar combustion efficiency and stability. The single-step decomposition and minimal residue make it compatible with existing infrastructure, requiring no modifications. The biofuel offers potential operational benefits at high temperatures, aiding performance while reducing aviation greenhouse gas emissions. However real-world conditions such as humidity, pressure, and combustion dynamics may affect fuel performance differently. Future research should involve combustion and field tests, examining biofuels' operational impact and long-term engine effects. Investigating biofuels blending with FJJ could optimise emissions and efficiency.

FIGURES

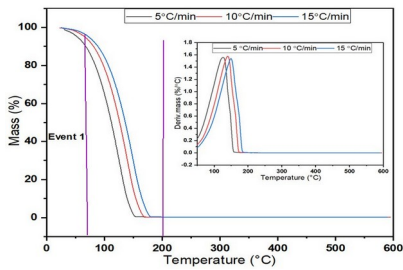


FIGURE 1

Figure 1. TG and DTG curves of fossil jet fuel (FJJ).

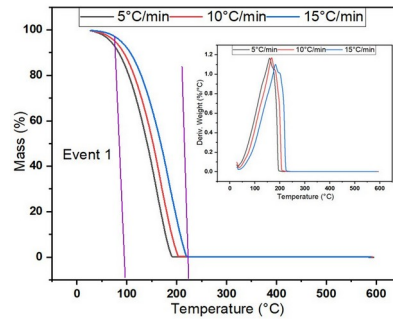


FIGURE 2

Figure 2. TG and DTG curves of biosourced jet fuel (BJJ).

KEYWORDS

JET A1 | SAF | TGA/DTA | GC-MS

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