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Advancing Sustainable Aviation Fuel Production Through Novel Technologies In Support Of The National Mission

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Sustainable aviation fuel is a viable alternative to conventional jet fuel in the aviation industry. This review provides an introduction to SAF, their properties and various production technologies such as Fischer-Tropsch hydro processed synthesized paraffinic kerosene (FT-SPK); alcohol to jet, hydroprocessing of esters and fatty acid, sugar to jet, and co-processing. In addition to these future aspects, to enhance the enlargement of this aviation fuel in order to meet the criteria of a 10% reduction of greenhouse gas emissions by 2050 was also discussed.

Keywords: Sustainable aviation fuel, biojet fuel, biomass, production technologies.

1.0 Introduction

Air transport plays a very important role in the rapid availability of tourism, trade and other social activities, but it exhibits huge dependency on petroleum fuel, which in turn pollutes the environment at a very fast rate [1]. The most important factor that contributes to climate change is emission of anthropogenic substances, among which "Aviation" comes out as a primary contributor. Therefore, an alternative sustainable fuel for the aviation industry needs to be developed that can overcome the global challenge and reduce the GHGs emissions by 2050 and used for air transport [2,3]. Among these alternatives, sustainable aviation fuel (SAF), which is also known as bio-jet fuel, could play an important role [4, 5]. These fuels are defined as substitute liquid hydrocarbons that have similar properties as those of conventional jet fuel (kerosene) but carbon content is less. These types of fuels are generally mixed with regular jet fuel in order to alter its properties, but their applications do not require any modifications in the airport substructure and in an engine [6-8]. Therefore, such types of fuels are also known as "drop-in-fuel" as these are only made up of hydrocarbons and do not require extra charge for implementation [7]. Not all biofuels are called as sustainable; only those fuels are called SAF which fulfill the criteria for sustainability with the mission to reduce greenhouse gas emissions.

Such type of fuels can be produced from various sustainable feed stock material (biomass, cooking oil, solid waste, forest waste etc.) and comes out as a promising solution to reduce

greenhouse gas emission and enhanced efficiency. Among different feedstock materials, waste oils (either used cooking oil and animal oil) is most common and cost effective. These feedstock materials can absorb CO_2 during the growth and forming a close type loop cycle of carbon upon its combustion which ultimately reduced CO_2 emission but the development of SAFs and its existence in the market is difficult as it has to face huge tolerance and many difficulties for ground level transport in comparison to alternative fuels [4, 9, 10].
In 2016, International Civil Aviation Organization (ICAO) has implemented the new scheme known as carbon offsetting and reduction scheme for international aviation (CORSIA) which focuses to counterbalance the increase in emission above the 2020 threshold by purchasing the carbon credits from different sectors and to set sustainability standards for the raw materials used. If the value is greater than the level value of 2020, then aircraft operator is compulsory to counterbalance CO_2 emission by procuring allowance.

2.0 Production of sustainable aviation fuel

SAF can be produced from different feedstocks materials such as biomass (waste, animal etc.), used cooking oil and various energy crops as shown in Fig. 1. Based on feedstock materials different routes have been designed, and to date total six possible routes have been certified for the production of SAF or biofuel, which are as follows:

1. Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene (FT-SPK)
2. FT synthesized paraffinic kerosene with aromatics (FT-SPK/A)
3. Produced paraffinic kerosene from hydroprocessed fatty acids and esters (HEFA)
4. Iso-paraffin synthesis from hydroprocessing of fermented sugars (HSF-SIP)
5. Alcohol to jet synthesis (ATJ-SPK)
6. Co-processing of synthetic crude oil

Among these processes, the most widely used process is HEFA. Table 1 shows the various certified conversion processes along with different feedstock materials [11-13].

Table 1: Possible conversion process [11. 13-15]

S.No.	ASTM Reference	Conversion Process	Possible Feedstock	Possible Mechanism	Maximum Blend Ratio
1	ASTM D 7566 (Annex A1)	FT-SPK	Coal, Natural gas and biomass	Employed for the manufacture of liquid hydrocarbons such as gasoline, kerosene, diesel etc. using syn-gas (CO and H_2)	50%
2	ASTM D 7566 (Annex A2)	HEFA	Vegetable oil, animal fats, used cooking oil	This process used various residue oil such as vegetable, animal fats, waste cooking, algal oil etc. for the formulation of jet fuel	50%

3	ASTM D 7566 (Annex A3)	SIP	Biomass used for sugar production	It is used for the production of synthetic hydrocarbons through hydroprocessing and farnesene fraction from fermentation of sugar.	10%
4	ASTM D 7566 (Annex A4)	FT-SKA	Coal, natural gas, biomass	Employed for the manufacture of liquid hydrocarbons such as gasoline, kerosene, diesel etc. using syn-gas (CO and H_2)	50%
5	ASTM D 7566 (Annex A5)	ATJ-SPK	Ethanol, isobutanol	This is a biochemical conversion process which involves the conversion of alcohol (methanol, butanol and long chain alcohols) into sustainable aviation fuels.	50%
6	ASTM D 7566 (Annex A6)	Catalytic hydrotherm olysis jet fuel (CHJ)	Vegetable oil, animal fats, used cooking oil	It consists of a series of reactions such as cracking, hydrolysis, decarboxylation, isomerization and cyclization.	50%
7	ASTM D 7566 (Annex A7)	HEFA	Algae	involves biological originated hydrocarbons and comes from oils present in botryococcus braunii algae	10%
8	ASTM D 7566 (Annex A8)	ATJ-SKA	C2=C5 alcohol from biomass	It involves the conversion of alchol into biojet fuel	

9	ASTM D 1655 (Annex A1)	Co-hydroprocessing of ester and faity acids in a conventional refinery	Vegetable oil, animal fats, used cooking oil	This process involves co-processing of fats, oils in petroleum refinery for providing refining process.	5%

4.0 Future Aspects of SAF

SAF have the capacity to replace conventional or crude oil aviation fuel and fulfil the current increasing demand as these biofuels have low GHG emission, low carbon intensity etc. But the primary barriers in enlarging the upscale of SAF are their affordability and competiveness with conventional aviation fuel. This problem can be overcome by the development of advanced technology. In addition to this, for the development of SAF a balance between the cost of production and GHG emission is very important [5, 11]. Thus, few recommendations on encouraging the development and uptake of SAF has been designed which are as follows:

1. Utilization of lignocellulosic biomass and waste feedstock.
2. Future research should be concentrated on FT, ATJ and HFS-SIP routes in order to balance the cost effectiveness.
3. Blending is mandatory.
4. Incentives for the adoption of SAF should be introduced along with penalties for GHG emission through a carbon tax system.
5. Multi stakeholder collaboration should be increased.
6. Strong political process are essential for the growth of SAF activities and these must be transparent as well as stable.
7. Government around the world may consider adopting a top-down management strategy by mandating all airlines donate to SAFs consumers and research funds.

5.0 Conclusion

Sustainable aviation fuels are promising alternative to conventional jet fuels in the aviation industry. Its characteristics properties such as compatibility with existing aircraft engine, reduction in GHG emission, social development etc. makes it a valuable fuel. Besides this, some technologies such as FT-SPK, HEFA, ATJ-SKA, FT-SKA etc. are employed using different feedstock materials for the production of SAF. Thus, the future of sustainable aviation mainly depends upon the development of SAF, innovation and strategic policy support with the aim to reduce CO_2 emission at least 10% by 2050. These efforts can empower the aviation industry to move towards a more sustainable pathway.

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Data Availability

Data provided in the manuscript or references was mentioned where applicable.

Conflict of Interest

There is no conflict of interest to show.

References

1. Ershov, M.A., Savelenko, V.D., Burov, N.O., Makhova, U.A., Mukhina, D.Y., Aleksanyan, D.R., Kapustin, V.M., Lobashova, M.M., Sereda, A.V., Abdellatief, T.M. and Baroutaji, A., 2023. An incorporating innovation and new interactive technology into obtaining sustainable aviation fuels. Energy, 280, p.128156.
2. Hirunsit, P., Senocrate, A., Gomez-Camacho, C.E. and Kiefer, F., 2024. From CO2 to sustainable aviation fuel: navigating the technology landscape. ACS Sustainable Chemistry & Engineering, 12(32), pp.12143-12160.
3. Emmanouilidou, E., Mitkidou, S., Agapiou, A. and Kokkinos, N.C., 2023. Solid waste biomass as a potential feedstock for producing sustainable aviation fuel: a systematic review. Renewable Energy, 206, pp.897-907.
4. Heyne, J., Rauch, B., Le Clercq, P. and Colket, M., 2021. Sustainable aviation fuel prescreening tools and procedures. Fuel, 290, p.120004.
5. Qasem, N.A., Mourad, A., Abderrahmane, A., Said, Z., Younis, O., Guedri, K. and Kolsi, L., 2024. A recent review of aviation fuels and sustainable aviation fuels. Journal of Thermal Analysis and Calorimetry, 149(10), pp.4287-4312.
6. https://www.energy.gov/eere/bioenergy/sustainable-aviation-fuels
7. Marszałek, N. and Lis, T., 2022. The future of sustainable aviation fuels. Combustion Engines, 61(4), pp.29-40.
8. Shehab, M., Moshammer, K., Franke, M. and Zondervan, E., 2023. Analysis of the potential of meeting the EU's sustainable aviation fuel targets in 2030 and 2050. Sustainability, 15(12), p.9266.
9. BP. What is sustainable aviation fuel (SAF)? https://www.bp.com/en/global/air-bp/news-and-views/views/what-is-sustainable-aviation-fuel-saf-and-why-is-it-important.html
10. Song, Z., Li, Z. and Liu, Z., 2024. Comparison of emission properties of sustainable aviation fuels and conventional aviation fuels: a review. Applied Sciences, 14(13), p.5484.
11. Ng, K.S., Farooq, D. and Yang, A., 2021. Global biorenewable development strategies for sustainable aviation fuel production. Renewable and Sustainable Energy Reviews, 150, p.111502.

12. Abrantes, I., Ferreira, A.F., Silva, A. and Costa, M., 2021. Sustainable aviation fuels and imminent technologies-CO2 emissions evolution towards 2050. Journal of Cleaner Production, 313, p.127937.
13. Marszałek, N. and Lis, T., 2022. The future of sustainable aviation fuels. Combustion Engines, 61(4), pp.29-40.
14. International Civil Aviation Organization (ICAO). (2023). Sustainable Aviation Fuels Guide. ICAO. https://www.icao.int/environmental-protection/Pages/SAF.aspx
15. Peters, M.A., Alves, C.T. and Onwudili, J.A., 2023. A review of current and emerging production technologies for biomass-derived sustainable aviation fuels. Energies, 16(16), p.6100.