PERSPECTIVES AND CURRENT SCENARIO OF ALTERNATIVE FUELS IN AVIATION VIA THE ALCOHOL TO JET (ATJ) ROUTE

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Abstract: The aviation industry still relies on and burns fossil fuels, resulting in significant environmental damage. Alternative fuels have been widely encouraged globally due to their various benefits compared to conventional ones. These biofuels contribute to environmental sustainability and outperform petroleum derivatives, improving air quality after combustion in the engine chamber. In this context, this article aims to present a comprehensive analysis of the current scenario of aviation biofuel known as Alcohol to Jet, based on technological and academic databases to understand the state of the art in large-scale production and commercial use. As a viable and sustainable alternative to fossil fuels in the aviation industry, it seeks to mitigate the negative environmental impacts associated with the sector.7097b

Keywords: Sustainable Aviation Fuel; Biofuel; Decarbonization of Industry.

PERSPECTIVAS E CENÁRIO ATUAL DOS COMBUSTÍVEIS ALTERNATIVOS NA AVIAÇÃO: A ROTA *ALCOHOL TO JET* (ATJ)

Resumo: A indústria de aviação ainda depende e queima combustíveis fósseis, resultando em danos ambientais significativos, os combustíveis alternativos têm recebido amplo incentivo global devido aos diversos benefícios que oferecem em comparação com os convencionais. Esses biocombustíveis contribuem para a sustentabilidade ambiental e são superiores aos derivados de petróleo, melhorando a qualidade do ar após a combustão na câmara do motor. Nesse contexto, este artigo busca apresentar uma análise abrangente do cenário atual do biocombustível de aviação conhecido como *Alcohol to Jet*, baseada em base de dados tecnológicas e acadêmicas para compreender o estado da arte na produção em larga escala e uso comercial. Uma vez, que se apresenta como uma alternativa viável e sustentável aos combustíveis fósseis na indústria de aviação, visando mitigar os impactos ambientais negativos associados ao setor.

Palavras-chave: Combustível Sustentável de Aviação; Biocombustível; Descarbonização da Indústria.

1. INTRODUCTION

With the growth of the energy and fuel industry in the energy transition, questions about environmental sustainability arise in this field. Effective actions are necessary to deal with the increasing global energy demand. The exponential development of the fossil fuel-consuming industry is one of the main contributors to climate problems, such as global warming [1]. This is largely due to the emission of greenhouse gases (GHGs) during fuel combustion and production.

The aviation industry is a significant example of this commercial and industrial sector, as it consumes and burns large quantities of fossil fuels, primarily Jet-A1 aviation kerosene, conventionally produced through petroleum distillation. This results in the release of a considerable amount of anthropogenic carbon dioxide into the atmosphere [2]. It is estimated that the global aviation industry consumes around 1.5 billion barrels of kerosene per year, emitting approximately 705 million tons of carbon dioxide (CO_2) [3]. In Brazil, the domestic air transport sector has experienced a growth of over 100% in the last ten years, resulting in an increase of about 5% to 10% in carbon dioxide emissions from the industry globally [1].

The growing environmental impact of the aviation industry and its rapid expansion demand alternatives to current fuels and production processes. One of the alternatives is the use of Sustainable Aviation Fuels (SAFs). SAFs are essentially aviation biofuels, aiming to offer a more sustainable option compared to conventional kerosenes. These biofuels have nearly identical physicochemical characteristics to conventional kerosene and aim to reduce the carbon footprint in their production, transportation, and use [4].

Among the main routes for the production of SAFs under testing and research, the following stand out: the Hydroprocessed Esters and Fatty Acids (HEFA) pathway, which uses pre-refined vegetable and/or animal oils as feedstock in industrial hydroprocessing; the Fischer Tropsch (FT) process, which aims to thermochemically convert specific vegetable feedstocks into syngas (synthesis gas) for biofuel production; and the Alcohol to Jet (ATJ) method, which allows the use of a wide range of biomass as feedstock, biochemically converting it through sugar fermentation to produce ethanol to be hydroprocessed [4].

The primary objective of this article is to present a comprehensive overview and perspectives of Sustainable Aviation Fuels (SAFs) production, with a particular emphasis on the Alcohol to Jet (ATJ) processing, which is regarded as one of the most promising pathways in the aviation industry. The article will focus on well-established commercial processes and delve into the current production costs associated with this method.

2. METHODOLOGY

As the first step of the methodology, a relevant research topic was identified, and its scope for the journal's development was established. Subsequently, the Lens.Org search platform, from the Cambia group, was selected for collecting scientific articles and patents relevant to the topic. In the next step, the search began with a bibliometric analysis to collect relevant documents for the research. Figure 1 presents each step and its respective description:

Figure 1. Stages of the research and their descriptions.

Source: Own Author

2.1 Bibliometric Analysis

Regarding the bibliometric process, a ten-year publication filtering was used for all the articles searched (published from January 2013 to July 2023), aiming to accurately outline the current state-of-the-art of the developed themes. For technological analysis, in order to avoid discussing unfounded technologies, those with little practical development or discontinued, a filtering process was applied to only consider active patents.

Initially, main categories were defined for bibliometric prospecting, guiding the initial selection of keywords for the research. The categories, in sequence, were set as: Product, Process, Production Route, Raw Material, and Use/Application. After creating the categories, keywords related to each category term were collected to establish correlations between them for the research.

After constructing the final framework of keywords, the research in Lens.org was initiated by combining the terms. All words within each category - separated by the boolean operator "OR" - were associated with all other categories individually, in pairs, and if necessary, in trios, thus linked by the boolean operator "AND". In this way, it was possible to observe the number of records found in each search and, based on that, select the most relevant and concise correlations. Three final correlations were selected for the continuation of the bibliometric analysis, as shown in Table 1: 1) Group 1 and Group 3; 2) Group 2 and Group 3; 3) Group 1 and Group 2 and Group 3.

Table 1. Bibliometric Analysis results.

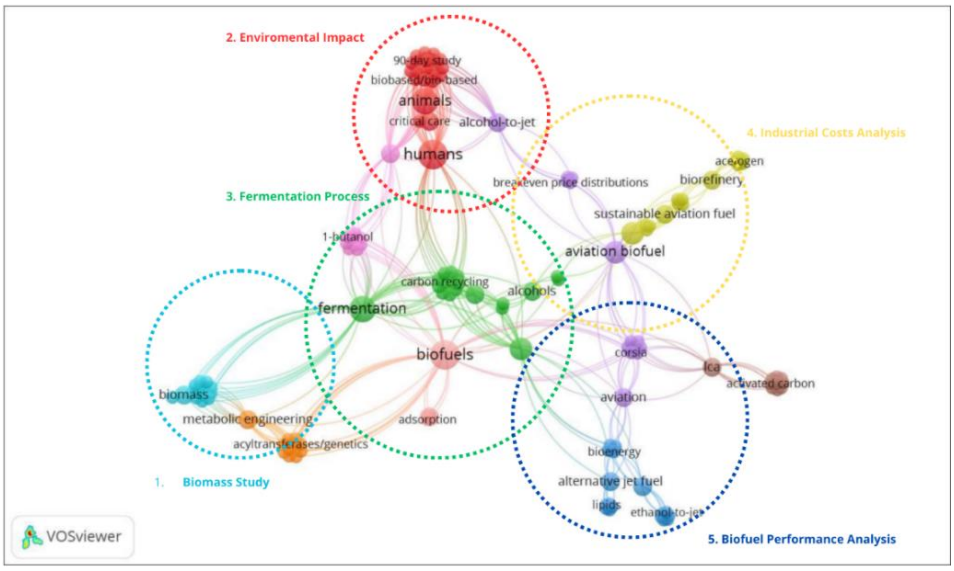
Attempts	Combinations	Search Description	Categories Associations	Article Results	Patents Results
1	#1 AND #3	(“Sustainable Aviation Fuel” OR “SAF”)AND (“Alcohol to Jet” OR “ATJ”)	Product + Production Route	62	16
2	#2 AND #3	(“Fermentation” OR “Biofuel process”) AND (“Alcohol to Jet” OR “ATJ”)	Process + Production Route	37	44
3	#1 AND #2 AND #3	(“Sustainable Aviation Fuel” OR “SAF”) AND (“Alcohol to Jet” OR “ATJ”) AND (“Fermentatio” OR (Biofuel process”)	Product + Process + Production Route	9	8

Source: Own Author

3. RESULTS AND DISCUSSION

For the initial data analysis, the VOSViewer software was used for clustering the identified documents. This method allows the identification of the most recurring terms among the researched articles and patents, enabling an understanding of their correlations and distinctions within the main subject. Five main groups of words could be identified: 1) Biomass analysis; 2) Environmental impact analysis; 3) Fermentation process study; 4) Industrial cost analysis; and 5) Biofuel performance study.

Figure 2. Main Clusters found from the research

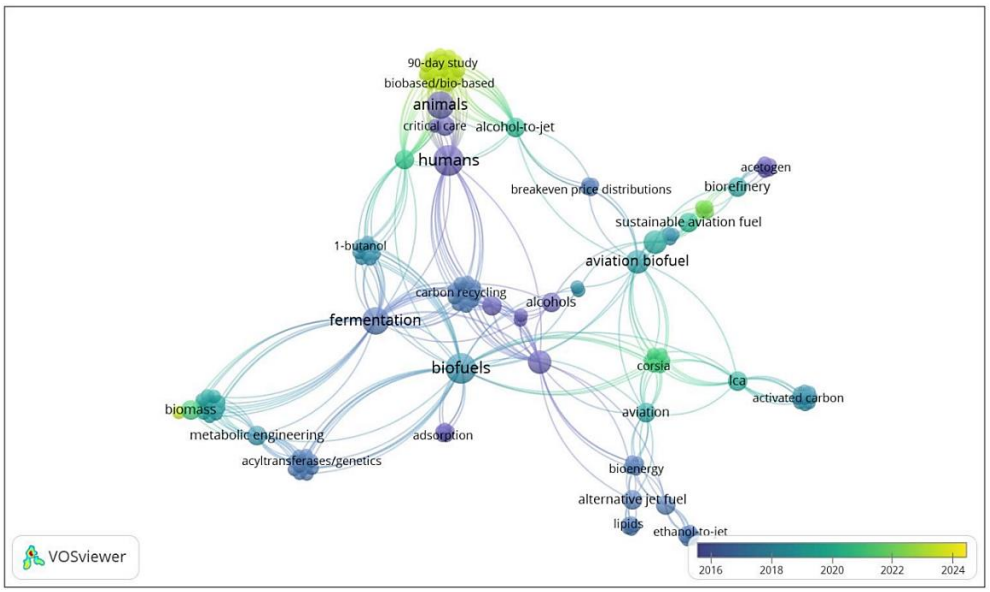


Source: Own Author

The identification of clusters is also important to understand the main themes that are most developed within the main topic. In this view, the density of correlations in Clusters 2 and 4 is noteworthy, guiding the fact that studies on industrial cost feasibility and concerns about the environmental impacts caused by the fuel are central themes for the development of SAF technology.

As for the most recent works related to the Alcohol to Jet topic, Figure 3 is able to represent the current scenario. It's noticeable that the term "bio" correlates with various recent publication terms, suggesting that the environmental aspect is one of the main pillars of the subject. Themes related to Cluster 2 (environmental impacts) are highly contemporary demands, just as biomass study is frequent in new publications and is commonly correlated with the deepening of the fermentation process for biofuels. Another important point is the prominence of the term 'Sustainable Aviation Fuel', compared to terms related to carbon recycling and biofuels, indicating how new and still developing the topic is internationally.

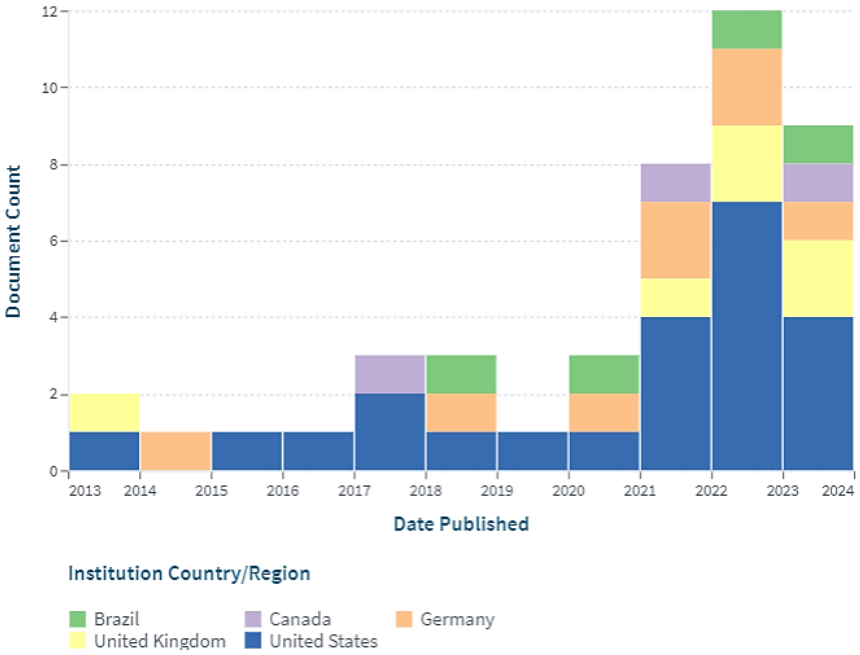
Figure 3. Clusters with most recent academical publications.



Source: Own Author

Regarding the current research context concerning the ATJ technology, since 2013, the United States has predominated in the academic publication scene. However, the average number of publications worldwide varied from 2 to 6 per year until 2021. With the growing demand for decarbonization in the aviation sector, the research landscape in recent years has become much more diverse, with countries such as Germany, Canada, the United Kingdom, and Brazil consistently publishing. Additionally, there has been an increase in the average number of submissions to 9 to 12 academic publications per year. Thus, it is possible to infer the increasing relevance of the topic, which, due to the development of various research institutions around the globe, can also become a target for investments among organizations from different regions. Figure 4 presents this analysis in numbers, showing the proportions year by year since 2013, of the countries that have developed the most academic publications related to the Alcohol to Jet biofuel.

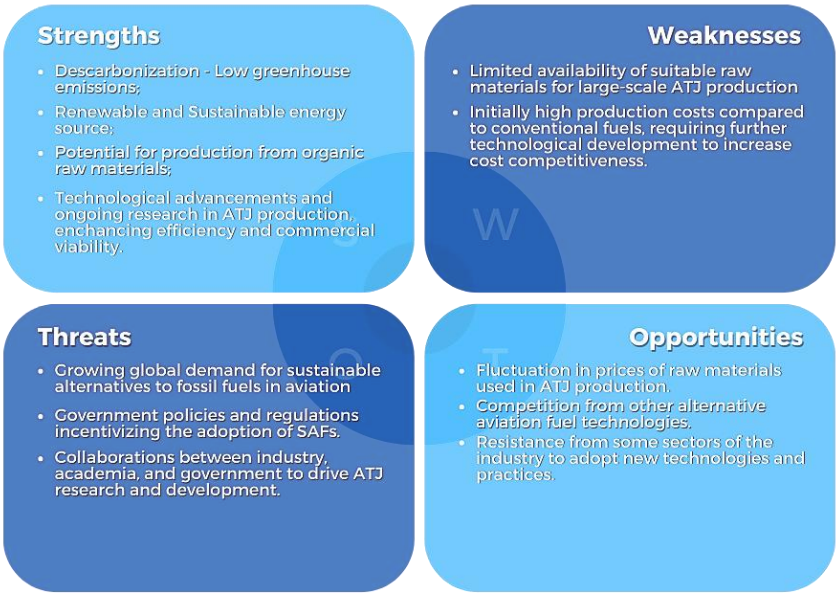
Figure 4. Increase in publications about the ATJ route worldwide, per year.



Source: Own Author

From the analysis of the state of the art developed with the data shown above, it was also possible to establish a matrix of Strengths, Weaknesses, Opportunities, and Threats related to the Alcohol to Jet route of aviation biofuel.Matriz SWOT - Combustíveis Sustentáveis para Aviação (SAFs) via Alcohol to Jet (ATJ).

Figure 5. SWOT Scheme – Sustainable Aviation Fuel from Alcohol to Jet route.



Source: Own Author

It is important to emphasize that the SWOT scheme is a dynamic tool and should be regularly updated as new information and changes occur in the sustainable aviation landscape and the development of alternative fuels.

Concerning the present landscape of large-scale ATJ biofuel production, significant players in the industry with considerable investments in SAFs have already emerged. One of the prominent names in the aviation sector is Gevo Incorporated, a pioneer in the industrial process of aviation biofuel through alcoholic fermentation [6]. In their case, the company uses wood waste as biomass, manipulating the process to produce isobutanol, which is further converted into SAF ATJ-SPK [6]. In terms of figures, Gevo currently has projects to increase their SAF production to 55 million gallons per year by 2025 [7]. Another major player in the aviation biofuel industry is LanzaTech Incorporated. With a slightly different fermentation process, LanzaJet (a subsidiary of LanzaTech Inc) uses carbon-rich gases from industrial waste as a substrate in the fermentative process of ethanol production [8]. As a result, the company completed the construction of its commercial production biorefinery in April 2023, with the aim of producing 10 million gallons of bio-kerosene per year [9]. In addition to these projects, organizations such as Byogy, Cobalt, Honeywell UOP, and Swedish Biofuels are other names currently proposing or implementing large-scale Alcohol to Jet projects [4].

The scenario of Alcohol to Jet biofuel commercialization has changed significantly since 2016 when the American Society of Testing Materials (ASTM) approved the first SAF ATJ-SPK for use in commercial flights [4]. Since then, major airlines have been investing in the promising Alcohol to Jet biofuel. For instance, Delta Airlines has a solidified agreement with Gevo Inc. for the utilization of 2 billion liters of ATJ-SPK in a plan starting in 2026 [10]; another leading player in the market, British Airlines, has also established a project to use Alcohol to Jet in flights between the USA and the UK from 2023 onwards [11]. Additionally, other companies like Virgin Atlantic [4], Alaska Airlines, and United Airlines also have current proposals to implement the biofuel in their commercial flights.

4. CONCLUSION

As presented, a growing international technological development movement is evident in the Alcohol to Jet biofuel production route. In terms of academic advancement, the numbers already indicate a much greater variety of countries studying the biofuel compared to five years ago. Concerning the landscape of production and commercial utilization, it is now possible to identify large-scale production projects with significant investments, such as those by Gevo and LanzaJet. Moreover, major international airlines have already entered agreements for substantial quantities of ATJ to be purchased and used in the coming years. Hence, it can be concluded that SAF ATJ is already a highly promising and relevant reality within the international aviation biofuel scene.

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