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Environmental, economic and social impact of aviation biofuel production in Brazil

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The Brazilian aviation industry is currently developing biofuel technologies that can maintain the operational and energy demands of the sector, while reducing the dependence on fossil fuels (mainly kerosene) and greenhouse gas emissions. The aim of the current research was to identify the major environmental, economic and social impacts arising from the production of aviation biofuels in Brazil. Despite the great potential of these fuels, there is a significant need for improved routes of production and specifically for lower production costs of these materials. In addition, the productive chains of raw materials for obtaining these bioenergetics can be linked to environmental impacts by NO_x emissions, extensive use of agricultural land, loss of wildlife and intensive water use, as well as economic, social and political impacts.

Contents

Introduction

The airline industry has fostered strong economic growth through significant greenhouse gases emissions, which has triggered major political discussions, especially with regard to environmental issues [1]. Many governments have promoted and encouraged the production of biofuels through subsidies and tax exemptions, in addition to goals and standards for fuels [2].

The aviation sector is responsible for approximately 2% of all CO_2 released into the atmosphere, rising to 3.5% when other methods for quantification at altitude are considered [3,4]. Despite the airline industry being 70% more efficient than 40 years ago,

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due to lighter aircraft and modern engines [5], it continues to grow at an accelerated rate, with estimated growth rates of 5% annually until 2030. Fuel efficiency over the same period is only expected to increase by 3% annually, which means that sustained growth will increase fuel consumption and emissions [6]. Several studies have reported new technologies for mitigating the emission of greenhouse gases (GHG) [7,8], but few have been evaluated at a pilot level or with the concept of industrial eco-innovation [1]. Even with the high operational costs caused by the need for high quality fuels, energy efficiency is a major goal of technological development, and this has developed greatly in recent years as a result of intensified activity [9].

Currently, several initiatives and test-flights have been performed with the intention of developing renewable and sustainable biofuels in several countries, including Brazil. Despite many of these initiatives having American Society for Testing and Materials (ASTM) technical certification, none are considered commercially practical. Given this scenario, the goal of the current research is to assess the major environmental, economic and social impacts resulting from the production of aviation biofuels in Brazil.

Biofuels in Brazilian aviation

Several Brazilian researchers have investigated alternative fuels of a quality that can be used in Brazilian aviation. However, fuels obtained by the second-generation route, from cells to hydrogen, via water electrolysis, are still far from viable. Thus, raw materials rich in sugars, starch and lignocellulosic materials are the main sources of renewable aviation fuels [10,11]. Nationally, the availability of the raw materials is not a problem as Brazil has 150 million hectares of new frontiers and rangelands that can be incorporated into agricultural production of vegetable oils [12].

Ethanol is a viable alternative fuel for aviation because of its fixed molecular formula, regardless of the process through which it is obtained or the raw materials used in its synthesis [13] and the already widespread ethanol infrastructure and supply chain in Brazil. In addition to conventional sources, ethanol can also be obtained from the conversion of cellulosic biomass. Various industrial ventures produce alcohol from crop waste and forestry residues, among others, because they are low cost and readily available [14,15]. High-chain alcohols have also been investigated because of their advantages with respect to energy density. One such example is n-butanol which can be produced from the fermentation of lignocellulosic biomass [16,17].

Since the early twentieth century, vegetable oils have been used as a fuel in diesel cycle engines. However, the high viscosity of vegetable oils can cause extensive damage to the injection systems, fuel tanks and engine. Fatty acid esters (FAES) are produced by transesterification of triglycerides and esterification of fatty acids, whether of plant or animal origin [18]. Production of natural and renewable fuels with characteristics similar to diesel fuel can be achieved with short-chain monohydric alcohols in the presence of homogeneous, heterogeneous or enzymatic catalysts[19,20]. Factors such as climate and the region of the country determine which fatty material has the greatest potential for ester production [21].

Biodiesel has many challenges to overcome, such as its low inferior calorific power (ICP) and high freezing point, before it can become a potential aviation fuel. Furthermore, the characteristics and properties of the esters vary considerably depending on the raw material used, while some contaminants may be detrimental in burning engines [22]. In order to meet the specifications required, many test-flights have been conducted with blends of biodiesel and fossil fuels to improve the ICP properties and freezing point [18].

Paraffinic kerosene obtained via Fischer-Tropsh synthesis (FT-SPK) is a material made from raw materials via gasification [23]. The technique uses the same raw materials as biodiesel (i.e. oils and fats) to obtain a fuel similar to kerosene oil. Recently, we have started to use other forms of biomass in the 'BTL' (biomass-to-liquid) process, such as woody biomass, algae, fungi and municipal and industrial waste [16,24,25].

Several other processes for the production of biokerosene, such as hydrothermal liquefaction (HTL) [26], direct liquefaction or liquefaction term [29] and plasma gasification of biomass [27,28], have also been studied. Despite being promising sources of clean energy, there is much discussion about the real sustainability of these raw materials and fuels in relation to agricultural systems and production routes [10,30,31].

If no mitigation measures are taken, the aviation sector may contribute more than 5% of total CO_2 emissions by 2050 [32]. In recent years, this concern for the environment has resulted innumerous studies in Brazil and around the world into different aviation biofuel technologies.

In Brazil and internationally, second generation biofuels are the most cited as attempting to mitigate CO_2 emissions, but this will only be possible in the long-term (2030–2050). Already, third generation biofuels are starting to show great progress in the international scientific community [33]. Several companies are already producing second generation biofuels for use in aviation (Table 1).

The hydrothermal liquefaction (HTL) process has been considered for the production of aviation biofuels, since the airline industry already uses approximately 8% of the world's oil, which will continue to increase if tough initiatives are not taken [34]. In Brazil, the use of algal biomass in the HTL process is taking a different path to the global reality, since the species is primarily cultivated in industrial waste treatment systems, ensuring greater energy balance and carbon cycling [35,36].

TABLE 1

Companies producing second generation biofuels in Brazil

Company	Deployment	Ton/year
Amyris Biomin	2010	–
Amyris Paraiso	2012	–
Amyris Pilot & Demonstration Plant	2009	–
Amyris São Martinho	2013	–
Gran Bio	2014	[b]64,780
Odebrecht Agro	[a]2016	[b]63,200
Petrobras	2007	270
Raízen	[a]2024	[b]31,600

[a] Project.
[b] Capacity.