HVO PRODUCTION: CONCEPTS AND PRODUCTION ROUTES

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Abstract: The Hydrotreated vegetable oil (HVO), a renewable biofuel derived from vegetable oils, has attracted great interest due to its low-carbon characteristics and compatibility with existing fossil fuel infrastructure. In this article, we discuss the fundamental concepts of HVO, its raw materials, the varieties of vegetable oils used in production, its properties and the different production routes. The results of the study showed that the sustainability of HVO production depends on the choice of certified raw materials and sustainable agricultural practices.

Keywords: HVO; Fundamental concepts; HVO properties; Production routes; Types of vegetable oils.

PRODUÇÃO DE HVO: CONCEITOS E ROTAS DE PRODUÇÃO

Resumo: O óleo vegetal hidrotratado (HVO), é um biocombustível renovável derivado de óleos vegetais, tem despertado grande interesse devido às suas características de baixa emissão de carbono e compatibilidade com a infraestrutura existente de combustíveis fósseis. Neste artigo, discutimos os conceitos fundamentais do HVO, as suas matérias primas, as variedades de óleos vegetais utilizados na produção, suas propriedades e as diferentes rotas de produção. Os resultados do estudo mostraram que a sustentabilidade da produção de HVO depende da escolha de matérias-primas certificadas e de práticas agrícolas sustentáveis, além disso a utilização de insumos para a produção de HVO pode ter efeitos nas áreas ambientais e socioeconômicas por isso esse trabalho apresenta uma grande contribuição para o tema discutido.

Palavras-chave: HVO; Conceitos fundamentais; propriedades do HVO; Rotas de produção; Tipos de óleos vegetais.

1. INTRODUCTION

Increasing concern over greenhouse gas emissions and the search for renewable energy sources have driven research and development of advanced biofuels. Hydrotreated vegetable oil (HVO), also known as renewable diesel, is a promising example of a biofuel produced from vegetable oils and has a significantly lower carbon footprint compared to fossil fuels due to the renewable origin of its feedstocks [1].

HVO is derived primarily from vegetable oils or animal fats. Commonly used vegetable oils include palm oil, soybean oil, rapeseed (canola) oil, sunflower oil, and others. In addition to these vegetable oils, other oils, such as coconut oil, palm oil, cottonseed oil, and oils from seeds of various oil plants, can also be used in the production of HVO, depending on regional availability and economic feasibility [2]. Animal fats, on the other hand, can come from sources such as beef tallow or poultry fat [3].

These feedstocks undergo specific production processes, such as hydrotreating or cracking, to obtain HVO as the final product. The goal is to transform these vegetable or animal oils into a low-emission biofuel with properties similar to fossil diesel [4].

The origin of the plants or vegetables used in HVO production can generate environmental and socioeconomic effects. For example, palm oil production is associated with issues such as deforestation and loss of species habitat. For this reason, it is fundamental to seek sources and certified raw materials to minimize these negative impacts. Furthermore, it is important to mention that there are also efforts to develop routes to produce HVO from alternative feedstocks, such as waste and microalgae oils, aiming to reduce dependence on controversial sources and maximize the sustainability potential of the biofuel [5].

Vegetable oils and animal fats are the main raw materials used in the production of HVO. These raw materials can have different geographical origins and are extracted from sources such as: [6].

I. Raw vegetable oils: vegetable oils extracted from plants grown specifically for the production of food and other products, such as palm oil, soybean oil, rapeseed (canola) oil, sunflower oil, among others. These vegetable oils are widely available and used in a variety of vegetable crops.

II. Residual vegetable oils: vegetable oils that are by-products or waste from the food industry, such as frying oil used in restaurants or discarded cooking oil. The use of residual vegetable in the production of HVO can contribute to waste reduction and resource utilization.

III. Animal fats: fats from animals, such as beef tallow or poultry fat, which can be evolved as by-products of the meat or food processing industry. The use of animal supplements in HVO production may offer a sustainable alternative to the use of these wastes

Importantly, the sustainability of HVO production depends on the choice of certified feedstocks and sustainable agricultural practices, as well as the mitigation of negative environmental and social impacts associated with vegetable oil production [7].

HVO is obtained through a process called hydrotreating, which involves hydrogenating of the vegetable oil to remove impurities and improve its combustion characteristics. Vegetable oil hydrotreating involves the reaction of hydrogen in the presence of a catalyst to break unsaturated bonds and saturate the fatty acids, resulting in a more stable fuel with low oxygen content [8].

One of the main advantages of HVO is its compatibility with existing fossil fuel infrastructure [1]. HVO can be used in conventional diesel engines without the need for significant modifications. In addition, HVO has similar physical and chemical properties to petroleum diesel, including density, calorific value, and flash point [4].

The use of biofuels are extremely likely due to their contribution to the preservation of the environment, contributing to the reduction of environmental pollution, being also a renewable energy option in order to replace or mitigate the market of petroleum products in the future. Among the renewable sources, the most favorable is certainly HVO, as it exhibits immense advantages when compared to biodiesel, such as a greater amount of energy density, lower NOx emission, superior storage properties, production without the presence of glycerol. In addition to being a fuel that can fully replace diesel without any engine modification [9].

There are different production routes for HVO, which vary depending on the raw materials used and the processes employed. One common route is the production of HVO from used vegetable oils. This route involves collecting used cooking oils and then purifying and hydrotreating them to obtain HVO. Another alternative route is the production of HVO from raw vegetable oils. Each route has its specific characteristics and challenges, and the choice of the appropriate route depends on factors such as feedstock availability, economic aspects, and environmental considerations [10]. Thus, the aim of this article was to inform the fundamental concepts of HVO, present its properties and discuss the different production routes available.

2. METHODOLOGY

The present research was conducted through a literature review of the period between the years 2014 and 2023 of national and international publications that had concerns about studies of the HVO production routes.

It was necessary to choose an adequate method to collect the survey of studies. All searches occurred in reference sites with consolidated studies. International journals and repositories dominate the research conducted for HVO production routes, with few studies conducted in Brazil.

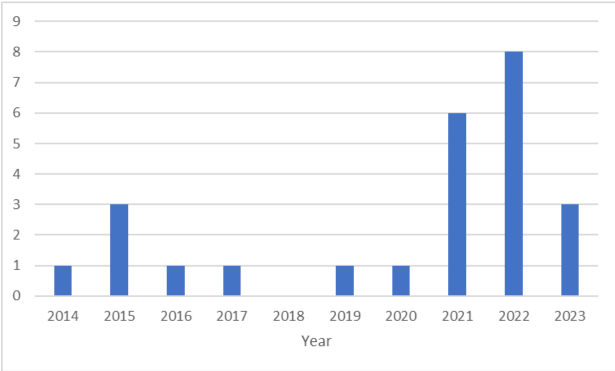
In this systematic review process, the Mendeley platform and Google Scholar were used to collect the articles to be studied, then they were selected by the impact factor of the periodical and organized into groups considering the year of publication in the period 2014 to 2023. After the collection of data and selection of material twenty-five articles were kept and all were searched taking as reference the descriptors "HVO (Hydrotreated Vegetable Oil) production", "HVO PRODUCTION ROUTES (Hydrotreated Vegetable Oil)."

3. RESULTS AND DISCUSSION

The research and studies carried out with the HVO production routes have shown great relevance due to its applications to produce HVO, important in sustainability and in the world environmental area. The selected articles present in their abstracts the discussion about. The evolution of the research in the selected period could be understood from the Figure 1.

Figure 1: Number of publications x year

publication



Source: Authors' elaboration (2023).

3.1 HVO Production Routes

There are different HVO production routes, the most common being the hydrotreating route and the cracking route. The following are the production routes for HVO [8]:

A. **Hydrotreating Route**: In this route, vegetable oil or animal fat is submitted to a process called hydrotreating also known as hydroprocessing, which involves a chemical reaction with hydrogen in the presence of a catalyst, usually a nickel or cobalt catalyst under controlled conditions of temperature and high pressure. Hydrotreating removes impurities and toxic compounds such as oxygen, sulfur, and evolved, resulting in a purer product with characteristics like fossil diesel. This route is known to produce high quality HVO with properties like fossil diesel and with good emissions performance and combustion properties.

B. **Cracking Route**: In the cracking route, vegetable oil or animal fat undergoes a thermal or catalytic cracking process. Thermal cracking involves breaking the oil lines into smaller fragments by applying heat and/or pressure, and occurs in a mixture of light hydrocarbons, like diesel. Catalytic cracking, on the other hand, uses catalysts, such as zeolites, to accelerate the cracking reaction. In this route, hydrocarbon levels are formed, which are then treated and purified to obtain the final HVO. The HVO produced by this route also has quality characteristics like fossil diesel.

In general, HVO production by hydrotreating involves the following steps [11]:

IV. Pre-treatment of raw material: The raw material, which can be vegetable oil or animal fat, is pre-treated to remove impurities and contaminants. This can include processes such as filtration, clarification, and water removal.

V. Hydrotreating reaction: The pre-treatment of the feedstock is followed by the main step, the hydrotreatment. In this step, the vegetable oil or animal fat is subjected to a chemical reaction with hydrogen in a reactor under controlled temperature and pressure conditions. The hydrogen reacts with the compounds, such as oxygen, sulfur, and left, present in the feedstock, converting them into more stable compounds.

VI. Separation and purification: After the hydrotreating reaction, the resulting product is subjected to separation processes to remove impurities and separate the different components. This can involve water removal, separation of light and heavy fractions, and further purification to ensure the quality of the final HVO.

VII. Additive treatment (optional): Depending on the specifications of the desired end product, additives can be added to improve characteristics such as stability, low-temperature fluidity, and combustion properties.

VIII. Storage and distribution: The resulting HVO is then stored and distributed for use in internal combustion engines, where it can be used as a direct substitute or blended with fossil diesel in different proportions, depending on local requirements and regulations.

It is important to mention that the exact conditions of the HVO production process may vary according to specific production technologies and facilities. In addition, it is necessary to adopt practical practices and ensure the responsible sourcing of the raw materials used to produce an HVO with low environmental impact [12].

Both production routes describe above aim to convert vegetable oils or animal vitamins into a renewable, low-emission biofuel. The choice of route may depend on factors such as feedstock availability, available technologies, costs, and quality requirements of the final product [13].

It is important to note that the hydrotreating route is generally considered the most common and preferred route for HVO production, due to the high quality and properties of the resulting fuel. However, the development and optimization of cracking routes are also areas of research in search of more efficient and economically viable processes. HVO is widely used as a substitute or additive for fossil diesel fuel in heavy-duty vehicles such as trucks and buses, as well as in agricultural and marine machinery [14].

Table 1. *Comparison between the production routes of hydrotreated vegetable oil*

Production Process	Important information and article news	Performance	References
Hydrotreating Route	the Hydrotreatment Route that is the best known for producing high quality HVO with properties similar to fossil diesel and with good performance in terms of emissions and combustion properties.	150,000 t/y;25,000 kg/h;26.5 million liters of HVO per year	[15],[19],[20],[17],[10],[4],[8],[11],[23],[25],[26],[27],[28],[29],[30],[31],[32]
Hydrotreating Route and Cracking Route	The most common HEFA biofuel production to date has been a diesel replacement fuel marketed alternately as hydrotreated vegetable oil (HVO) abroad or as renewable diesel in the United States. HEFA fuels are produced by reacting vegetable oil or animal fat with hydrogen in the presence of a catalyst. The equipment and process are very similar to hydrotreaters used to reduce diesel sulfur levels in oil refineries.	39.6 thousand tons/year	[16],[17],[21]
Hydropyrolysis	Conventional pyrolysis is currently the most used due to obtaining the three products Bio-oil, coal and gas. Hydropyrolysis is a process quite similar to pyrolysis, but takes place in an atmosphere of hydrogen, which may be the only gas or may be diluted with an inert such as nitrogen or helium.	Not reported in the articles	[22]
Cracking Route	In this article, hydrocracking is used and has the advantage of reducing the oxidizing character of the mixture.	Not reported in the articles	[24]

High temperature electrolysis process powered by low carbon electricity	This article evaluates the economic feasibility of producing hydrotreated vegetable oil (HVO) using vegetable oil residues as raw material. The supply of hydrogen for oil enrichment is obtained through a high-temperature electrolysis process, powered by low-carbon electricity. The use of waste eliminates competition with food crops (eg soy or rapeseed) and promotes the recycling of substances that must be dealt with for disposal. The results of the study show that the HVO production costs with the considered plant are about 33% higher than fossil diesel. Furthermore, the variable that has the greatest impact on the cost of HVO production is the price of residual vegetable oil, which affects the final results more than the price of electricity and the cost of the electrolyser.	Not reported in the articles	[18]

Importantly, the choice of inputs for HVO production can have environmental and socioeconomic plans. The sustainability of HVO production depends on the selection of inputs from responsible sources and the adoption of practices throughout the production chain.

4. CONCLUSION

This research found some routes of HVO production that are used as the Hydrotreatment Route that is the best known for producing high quality HVO with properties similar to fossil diesel and with good performance in terms of emissions and combustion properties.

It was noted in the study that, after analysing the articles, it was verified that the production route based on Hydrotreatment to obtain the hydrotreated vegetable oil is the most used because the choice of the appropriate route depends on factors such as availability of raw materials, technologies available, costs and quality requirements of the final product.

In the work, it was noted that there is little information regarding the yield of fuel production, but it was detected that the hydrotreatment production route currently has a higher yield and higher production quantity than the cracking route. What makes this work, among others, a differential.

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