EXPLORING RECENT ADVANCES IN BIODIESEL PRODUCTION AND FEEDSTOCK DIVERSITY

Biodiesel has emerged as a compelling focus of research within the realm of renewable and sustainable oils. Through various techniques and complex methods, Biodiesel can be manufactured from raw materials and biostock. In recent years, there has been extensive research on the methods used for biodiesel manufacturing due to an array of benefits, extending from reduced greenhouse gas emissions, improved air quality, and decreased dependence on fossil fuels. By utilizing diverse feedstocks, biodiesel production helps promote resource efficiency, waste reduction, and the development of a more sustainable energy sector. This article provides a review of conventional and newly emerging biostock used in biodiesel synthesis and an in-depth analysis of the methods used for biodiesel production. The article reviews and compares several studies of unique raw materials used in this process, ranging from vegetable oils, animal fats, algae, and waste oils. A comparative analysis of different methods will provide key insights into the financial, economic, and environmental benefits and shortcomings in large-scale applications.

Introduction

Biodiesel has gained significant attention in the field of renewable and sustainable oils, becoming a prominent subject of research in recent decades. In response to the demand for a more environmentally sustainable and renewable alternative to diesel fuel, it is now possible to produce biofuel from a range of raw materials and biostocks. This abundance of feedstocks and raw materials has spurred increased efforts and commitment toward exploring biodiesel production. There are four primary methods of biofuel production: direct use and blending, microemulsions, thermal cracking (pyrolysis), and transesterification (alcoholysis) [1]. Extensive research has been conducted on the transesterification of diverse raw materials for biodiesel production. Raw materials used for the production of biodiesel can be either crude, refined, or waste [2]. Feedstock can also be classified as plant-derived, animal-derived, microbial, or waste materials [3].

Feedstocks used in the transesterification process are vegetable oils, animal fats, and recycled greases [4]. In comparison to this, pyrolysis is able to create high-value bio-oil from biomass [5]. Direct use and blending, alongside micro-emulsification, utilize crude and pure vegetable oil in tandem with specific procedures in order to produce their own versions of 'hybrid fuels' [6].
This review paper comprehensively examines the feedstocks and raw materials used across different biodiesel production technologies, beginning with transesterification, moving on to pyrolysis, and concluding with direct use and blending, as well as microemulsions.

Types of methods to create Biodiesel:

3.1 Transesterification

Transesterification has emerged as the predominant technology for biodiesel production. It is a chemical process whereby the glycerin is separated from either fat or vegetable oil, leaving behind methyl esters and glycerin [7]. Methyl esters, commonly referred to as Biodiesel, are the primary components of this process. The process of transesterification can occur through two main approaches: catalytic and non-catalytic methods. Among the catalytic reactions, the three commonly utilized catalysts in transesterification are acid-catalyzed, alkali-catalyzed, and the use of lipase as a catalyst. The general process remains consistent among different catalysts wherein triglycerides undergo a reaction with an alcohol, typically methanol or ethanol, resulting in the formation of esters and glycerin, facilitated by the addition of a catalyst [8].

Transesterification offers a wide range of raw materials for biodiesel production, including vegetable oils, animal fats, and microalgae. Analyzing geographical layouts reveals the utilization of various biodiesel sources across multiple countries [9].

Table 1: Production of Biodiesel in Different Countries [9]

Country	Source of Biodiesel
USA	Soybean
Brazil	Soybean
Europe	Rapeseed Oil (>80%) and Sunflower Oil
Spain	Linseed and Olive Oil
France	Sunflower Oil
Italy	Sunflower Oil
Ireland	Animal fat, beef tallow
Indonesia	Palm Oil
Malaysia	Palm Oil
Australia	Animal fat, beef tallow, and rapeseed oil
China	Guang Pi
Germany	Rapeseed Oil
Canada	Vegetable oil/animal fats

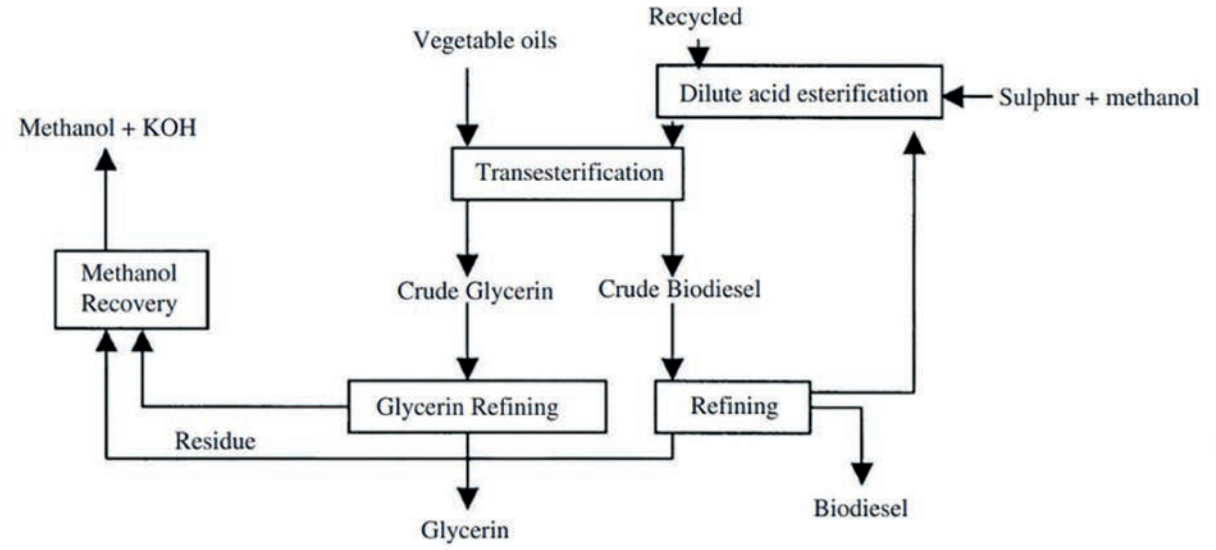

Fig. 1: Basic Scheme for Biodiesel Production [8]

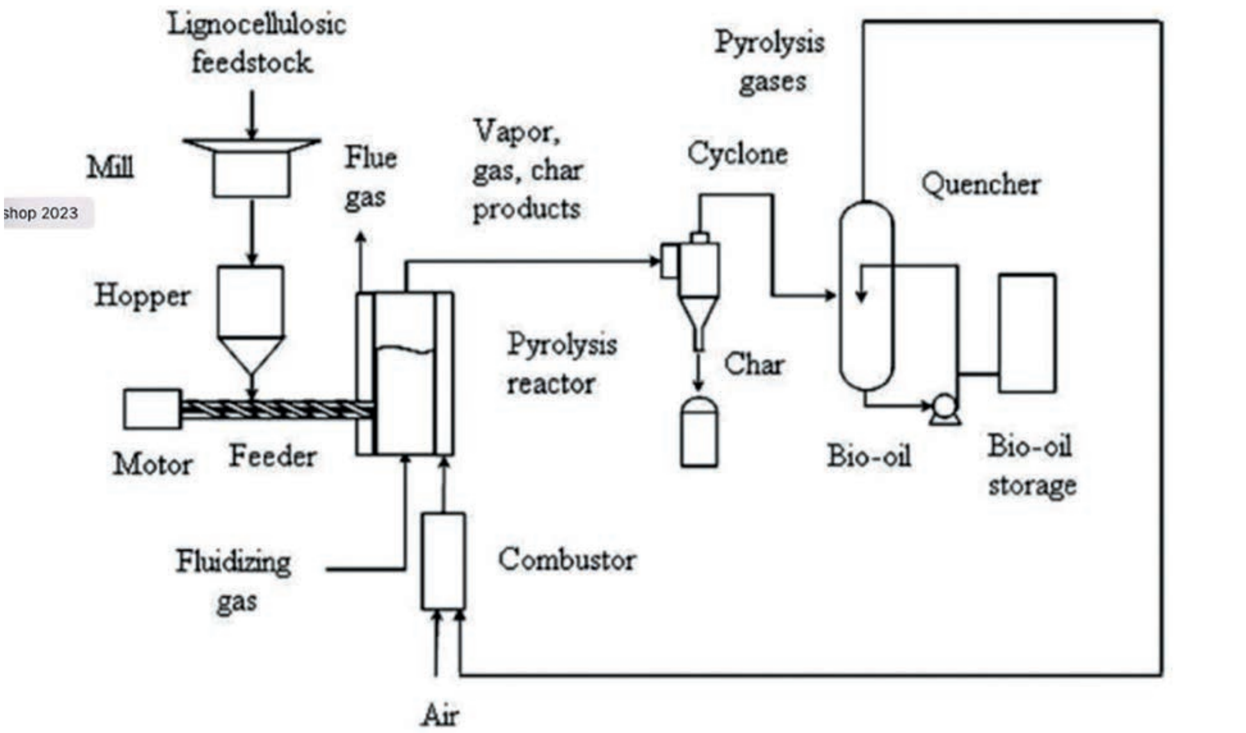

Fig. 2: Fast Pyrolysis Systems [22]

Over 300 oil-bearing plants and trees can be harnessed as potential sources for biodiesel production [10]. Among them, the most popular were found to be canola, coconut, cottonseed, groundnut, jatropha, karanji, olive, palm, peanut, rapeseed, safflower, soybean, and sunflower oils [11]. Waste oils and fats, waste cooking oil, fish oils, and microalgae oil are also recognized as promising alternative feedstocks for biodiesel production [12]. Despite the extensive list of available oil sources, the large-scale implementation of biodiesel is still limited due to the high cost of raw materials. A significant concern arises regarding the utilization of oils and fats derived from plants, as the crops employed for biodiesel production often compete with the demand for food and feed resources [13]. The biodiesel industry must compete with cosmetic, food, chemical, and livestock feed demands for the crops [14]. Further, the expansion of large-scale applications could potentially give rise to environmental concerns. The heightened demand for vegetable oils necessitates increased usage of fertilizers, which in turn contributes to greenhouse gases–a number that could face a 70% increase from biodiesel production alone [15]. However, transesterification has proven to be the simplest and more efficient method for large-scale biodiesel production against less environmentally friendly, costly, and low-yield approaches of pyrolysis and micro-emulsification [12].

3.2 Pyrolysis

Thermochemical techniques offer an alternative approach to converting biomass into valuable energy, with pyrolysis being a prominent example. Pyrolysis involves the thermal degradation of biomass components in an oxygen-free environment, enabling the conversion of biomass into bio-oil, bio-char, and gaseous products [16]. The general process involves the thermal decomposition of organic components in biomass at varying temperatures in the absence of oxygen [17]. These temperatures are determined by the classification of pyrolysis, categorized as either conventional, fast, or flash pyrolysis [5]. Slow Pyrolysis is generally used to enhance char production at low temperatures. However, high residence time causes cracking of the primary production, which makes it unsuitable for good-quality oil production [18]. Conversely, Flash Pyrolysis is characterized by rapid devolatilization, and reaction temperatures between 450°C to 1000°C [19]. Flash pyrolysis can typically achieve up to 75% of bio-oil yield [20]. However, this process also faces several disadvantages, such as poor thermal stability and corrosiveness of the oil, solids in the oil, and an increase in viscosity [21]. In comparison to the aforementioned pyrolysis methods, fast pyrolysis technology is the more popular and preferred method for the production of liquid fuels. Fast pyrolysis involves heating biomass to temperatures between 400°C and 500°C and produces 60%-75% of oily products. Additionally, biochar and gaseous byproducts are generated during this process.

The oily products made from fast pyrolysis, including oil and other liquid substances, can be easily and economically transported and stored [23]. Compared to other processes, fast pyrolysis technology exhibits relatively low investment costs, and high energy efficiencies. There are several advantages to this method, such as renewable fuel for boiler/engine/turbine, power generation, and industrial processes, a low-cost and neutral carbon dioxide balance, and the ability to store and transport liquid fuels [24]. Additionally, fast pyrolysis is capable of utilizing second-generation bio-oil feedstocks and waste materials, such as forest residue, municipal waste, and industrial waste [25].

The utilization of specific biomass feedstock in the pyrolysis method holds significant value. Biomass energy, being one of the earliest and most substantial global energy sources, accounts for nearly half of the energy consumption in numerous developing countries with extensive agricultural regions [26]. Biomass species are regarded as renewable energy sources that do not contribute to carbon dioxide emissions. Moreover, the distinguishing characteristic of biomass is its versatility in being converted into solid, liquid, and gaseous fuels, making it the sole renewable energy source with such convenience [27]. The pyrolysis technique incorporates various biomass species, such as beech wood [28], bagasse [29], woody biomass [30, 31], straws [32], seedcakes [33], and municipal solid waste (MSW) [34, 35]. Some recent studies have focused on different feedstock constituents in pyrolysis applications and have found that the ratios of volatile matter, fixed carbon, ash content, and moisture serve as indicators for predicting many high-value yields of pyrolysis products (bio-oil, bio-char, etc.) [36]. Further, in comparison to emissions released by other fossil-based fuels and biodiesel production technologies, the consumption of pyrolysis materials is more beneficial in terms of lower carbon dioxide emissions. Unfortunately, in the case of biomass pyrolysis, the issue arises when taking into account production cost and simple competitiveness in the current fuel market landscape [37]. Pyrolysis holds considerable potential approaches among biomass conversion technologies.

3.3 Direct Use and Blending

The direct use of vegetable oils in fuel engines pose immediate challenges and drawbacks. Due to high viscosity, and low volatility, long-term use in fuel engines poses consequential issues in vehicles [38]. The issue of high fuel viscosity can be effectively addressed through the utilization of alternative methods of biodiesel production, including micro-emulsification, pyrolysis, and transesterification [39]. Blending is another viable approach to enhance fuel quality by reducing viscosity, accomplished through the mixture of ethanol with vegetable oil [40]. The baseline benefits of this approach would be the abundant availability and renewability of the oils. However, it is clear that with decades of research, further improvements in this process may be limited.

3.4 Microemulsions

Microemulsions are clear, stable isotropic fluids with three components an oil phase, an aqueous phase, and a surfactant. Microemulsification presents a promising solution to address the challenge of high viscosity in vegetable oils [6]. This technique involves the formation of microemulsions, where water droplets are effectively suspended in the oil layer with the aid of a suitable surfactant, subsequently undergoing rapid water evaporation [41]. The use of microemulsion offers some advantages over emulsion systems since they are thermodynamically stable and allow the use of reference solutions prepared in an aqueous medium for calibration instead of expensive and unstable organometallic standards [4]. However, it is worth noting that the utilization of dilution, emulsion, and microemulsion methods may encounter certain challenges. While these techniques effectively reduce viscosity, laboratory screening indicates they can lead to incomplete combustion and the formation of heavy carbon deposits [6]. These issues highlight the need for further research within the scope of this method. Nonetheless, microemulsion holds great promise as a valuable tool in advancing the development of biodiesel production methods.

Conclusion

In conclusion, biodiesel production methods offer promising pathways toward achieving a more sustainable and renewable energy sector. Transesterification remains the predominant technology for biodiesel production, utilizing a range of raw materials such as vegetable oils, animal fats, and microalgae. Pyrolysis, on the other hand, provides an alternative thermochemical approach to convert biomass into valuable bio-oil, bio-char, and gaseous products. Direct use and blending, along with microemulsification explore 'hybrid fuels' of vegetable oils. However, it is important to consider certain limitations and challenges associated with these biodiesel production methods. The high cost of raw materials, competition with other industries, and potential environmental concerns highlight the need for further research and development to optimize these processes. Moreover, exploring alternative feedstocks and optimizing the utilization of waste oils and fats can enhance outcomes in biodiesel production. As the world continues to strive for a more sustainable and environmentally friendly energy sector, biodiesel production methods hold immense promise. Embracing diverse biodiesel manufacturing methods not only contributes to reducing greenhouse gas emissions and aiding our industries but also decreases our reliance on fossil fuels. By embracing diverse biodiesel manufacturing methods, we can pave the way toward a cleaner and greener future.

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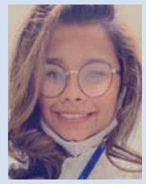

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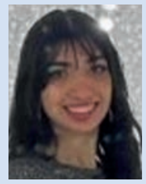

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