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Research paper

# Biodiesel production feedstocks: current state in Algeria

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**ABSTRACT**

Research and development of affordable, sustainable, and low-carbon energy sources capable of reducing dependence on fossil fuels, contributing to social and economic development, and improving environmental and health skills have become a global priority. In recent decades, biodiesel produced from oilseeds has received significant attention as an alternative biofuel. However, the use of first-generation oilseed crops has sparked controversy, and the use of local non-edible feedstocks is considered a promising alternative. The motivation behind this review is to provide an alternative and enlightening perspective on the use of non-edible vegetable oils for biodiesel production, with a particular focus on the current state of biodiesel production in Algeria. The objective is to assess the conditions under which this production could be sustainable and environmentally friendly while maintaining a balance between energy needs, economic stability, and environmental impact.

## 1. INTRODUCTION

The global energy crisis, encompassing challenges such as fossil fuel dependency, climate change, disparities in energy access, and the imperative for transitioning to sustainable energy sources, highlights the urgency of researching and developing cost-effective and sustainable energy solutions (Zhao et al., 2022; Ozili & Ozen, 2023; Zhou et al., 2023). These innovations should work toward reducing reliance on fossil fuels, promoting social and economic development, and mitigating environmental and health impacts. This imperative is directly aligned with the Sustainable Development Goals (SDGs) of the 2030 agenda, particularly SDG 7, which aims to ensure universal access for all to reliable, sustainable, and modern energy services, at an affordable cost, and increase the share of renewable energies in the

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global energy mix by 2030 (Van Vuuren et al., 2022). In this context, the production of biofuels from biomass shows that biodiesel can help reduce dependence on fossil fuels and ensure global energy security (Dornburg et al., 2008). Biodiesel, with its low carbon footprint, has the advantage of being renewable, biodegradable, and non-toxic (Garcia et al., 2020; Singh et al. 2021). Additionally, Biodiesel has a higher oxygen content and lower levels of sulfur and aromatic compounds, which can improve the performance of combustion engines Manigandan et al., 2020).

Biodiesel can be produced from a wide variety of feedstocks, including edible and inedible vegetable oils (Gale et al., 2019; Adeleke & Babalola, 2020; Blume et al. 2020; Osorio-González et al. 2020; Agarwal et al. 2021; Dey et al. 2021; Ewunie et al., 2021; Russo et al. 2021; Durango-Giraldo et al. 2022; Ahmia et al., 2014; Alloune et al., 2012), animal fats, waste vegetable oils, and microalgae. However, biodiesel production raises significant sustainability and ethical concerns directly related to the sourcing of raw materials, food security, deforestation, and biodiversity loss. The use of edible raw materials leads to increased food prices, land-use change (Di Fulvio et al., 2019), and loss of soil fertility through intensive cultural practices (Amouri et al., 2023). Therefore, it is crucial to develop alternative sources of sustainable raw materials to establish a biodiesel production chain that aligns with sustainable development.

In Algeria, biodiesel production has attracted attention in recent years but is still in its early stages. The limited literature available on this subject consists mainly of experimental studies focusing on biodiesel production from various feedstocks, including waste vegetable oils, animal fats, and edible and inedible oil crops (Ahmia et al., 2014; Alloune et al., 2012; Amouri et al. 2023; Danane et al., 2022; Chader et al. 2011).

This article aims to examine the various raw materials used for biodiesel production by exploring their availability, potential, and the opportunities they offer while considering their limitations and associated challenges. Additionally, the current state of biodiesel production in Algeria will be analyzed.

## 2. RAW MATERIALS FOR BIODIESEL PRODUCTION

### 2.1 Edible oil plants

#### *2.1.1 Oil palm (Elaeis guineensis Jacq)*

Oil palm is a monocotyledonous plant belonging to the Arecaceae family and is native to the tropical zones of the African continent. It was introduced to Asia, particularly Indonesia and Malaysia, at the beginning of the 20th century (Rulli et al. 2019). Currently, these countries are the largest producers of palm oil, accounting for nearly 85% of global production (Durango-Giraldo et al. 2022). Other significant producers include Colombia, Nigeria, and Thailand, while India and China are the largest consumers (Durango-Giraldo et al. 2022). Europe consumes approximately 15% of the world's palm oil, making it the third-largest importer after India (22%) and China (19%) (Noleppa et al., 2016).

Oil palm dominates the industrial oilseed plants sector, contributing around 39 - 41% (figure 1a) of global vegetable oil production (Meijaard et al., 2020; Zakaria et al., 2022). This is due to its remarkable average yield of 5000 Kg per hectare, making it one of the highest-yielding crops (Dey et al., 2020, Durango-Giraldo et al. 2022). Moreover, oil palm occupies only a small area, approximately 9% (Figure 1b), of the total oilseed agricultural land, compared to soybeans, rapeseed, and sunflower, which account for 38%, 11%, and 9% respectively (Ritchie & Roser, 2021).

However, the increasing global demand for palm oil has led to the rapid expansion of oil palm plantations, resulting in significant environmental and climatic consequences (Meijaard et al., 2020). These agricultural practices have contributed to deforestation, loss of plant and animal biodiversity, land erosion, and water and air pollution (Meijaard et al., 2020). Nevertheless, several studies have highlighted the potential of oil palm cultivation to stimulate rural economic growth and development. It has been shown that the establishment of oil palm plantations can generate employment opportunities, leading to job creation and income generation (Bou Dib et al., 2018); Chrisendo et al., 2022).

To address the significant challenges associated with palm oil, the industry must focus on socially acceptable and environmentally friendly production practices (Ayompe et al., 2021). Responsible management of oil palm plantations is essential for the sustainable production of biodiesel and the improvement of the socio-economic conditions in disadvantaged regions. Additionally, research and development efforts are necessary to explore the bioenergy potential of by-products resulting from palm oil processing. These efforts can contribute to maximizing the value and sustainability of the entire palm oil production chain.

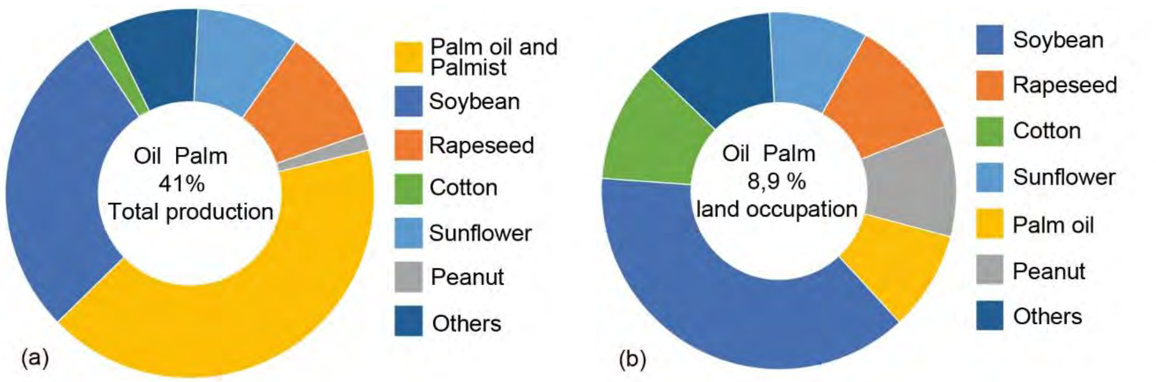


Fig 1. The importance of oil palm in terms of (a) land occupation and (b) oil production compared to other oilseed crops, (Zakaria et al., 2022; FAOSTAT)

### *2.1.2 Rapeseed (Brassica napus L.)*

Rapeseed, also known as canola, belongs to the Brassicaceae (Cruciferae) family. It is an annual or biennial plant cultivated as an oilseed plant in Asia, Europe, and Africa since ancient times. Advances in genetics and production technology have enabled the development of rapeseed varieties with low levels of erucic acid (less than 2%) and glucosinolates (less than 30 µmol/g of oil-free and dried meal air), making it suitable for human and animal consumption (Russo et al., 2021). Rapeseed has an oil content ranging from 38% to 46%, and it can yield approximately 1190 liters of oil per hectare per year (Anwar, 2021). Currently, rapeseed is the second most-produced oilseed globally, following soybeans (Tokel & Erkencioglu, 2021). Its oil, ranking third after palm oil and soybean oil, is the most widely consumed by humans in the world. Rapeseed is mainly produced in Canada (26%), the European Union (23%), China (19%), and India (12%) (USDA, 2020).

In recent years, there has been a noticeable and substantial increase in rapeseed cultivation, with an average annual growth rate of 4.9% (Wongsirichot et al. 2022). While rapeseed oil finds extensive use in the food industry, its utilization in biodiesel production, particularly in the European Union, has contributed significantly to the surge in cultivation (Di Fulvio et al., 2019). Around 37% of the total biodiesel produced is based on rapeseed oil (Yahya et al., 2022). This trend highlights the dual-use nature of rapeseed, serving as both a valuable food source and a feedstock for renewable energy production (Neupane, 2023).

### *2.1.3 Soybean (Glycine max L.)*

The soybean, a member of the Fabaceae family, is an annual oil-producing plant that was domesticated from a wild species called Glycine soybean. It thrives in a wide range of soil types, preferring neutral to slightly acidic conditions.

Soybeans hold significant economic importance, accounting for nearly 60% of global oilseed production (Tokel & Erkencioglu, 2021). They also contribute to approximately 10% of the value of world agricultural trade (Gale & Valdes, 2019). The soybean market is primarily dominated by Argentina, the United States, and Brazil, which together supply two-thirds of the world's soybean consumption. China, heavily reliant on international markets, stands as the largest importer, responsible for 60% of global soybean imports (Gale & Valdes, 2019). In contrast, the European Union holds a marginal position in this trade. Soybeans are cultivated for their high protein content (30-38%) and oil richness (15-22 %) (Anwar, 2021). The average yield of soybean oil is approximately 446 L/ha/year (Anwar, 2021). Soy is utilized for both human and animal consumption, either in the form of whole seeds, oil, or meal. According to Neupane (2023), soybeans accounted for about 71.7% of biodiesel feedstock in 2020. In the United States, soybean oil remains the primary feedstock for large-scale biodiesel production (Pikula et al., 2020). This reliance on soybean oil as a feedstock highlights the important contribution of soybeans to the biodiesel industry and its role in meeting the growing demand for renewable fuels. The availability and established infrastructure for the cultivation and processing of soybeans make it a preferred choice for biodiesel production in many regions, particularly in the United States (Cui & Martin, 2017).

### *2.1.4 Sunflower (Helianthus Annuus L.)*

Sunflower, an annual plant belonging to the Asteraceae family, is native to the subtropical and temperate zones of North America. It was introduced to Europe in the 16th century by Spanish explorers (Adeleke & Babalola, 2020). Sunflower cultivation is widespread across various regions worldwide, adapting well to different climates and soil types, including sandy and clay soils (Ebrahimian et al., 2022). It is considered a sustainable crop with numerous technical and economic advantages (Debaele et al. 2017). Sunflower also serves as a beneficial rotation crop, enhancing soil quality for cereal production (Adeleke & Bbalola, 2020). Sunflower is grown extensively, with major producers including Ukraine (31%), Russia (27%), the European Union (18%), and Argentina (6%) (USDA, 2021). Sunflower oil, renowned for its nutritional value, is considered one of the four primary vegetable oils produced and consumed globally. It accounts for approximately 9% of total vegetable oil production worldwide. Sunflower seeds have a high oil content, ranging from 47% to 50%, making them an excellent raw material for biofuel production. Oil yields from sunflower seeds can reach up to 952 L/ha/year (Anwar, 2021). However, the higher quality and demand for sunflower oil in the food sector may impact the economic viability of producing biodiesel from this plant (USDA, 2021), which may vary depending on market dynamics and price competitiveness.

## 2.2 Inedible Oil Plants

### *2.2.1 Jatropha (Jatropha curcas L.)*

Jatropha curcas, a tropical species belonging to the Euphorbiaceae family, is a shrub native to tropical America. It has successfully spread to various tropical and subtropical regions of Latin America, Africa, India, and Asia (Openshaw, 2000).

Jatropha is an oil-producing plant well adapted to arid and semi-arid conditions, capable of withstanding prolonged periods of drought and light frost. Its unique pivot root system allows it to thrive in marginal soils that are infertile and unsuitable for conventional agriculture, making it advantageous for soil restoration and erosion control.

The primary use of Jatropha is as a hedge to demarcate farmers' plots and protect crops from animals. Additionally, it finds applications in traditional medicine, despite its effectiveness, as well as in the production of artisanal soap and other products (Openshaw, 2000).

Jatropha yields seeds ranging from 0.4 to 12 tons per hectare per year (Openshaw, 2000; Abobatta, 2021). These production rates vary depending on factors such as geographical origin, cultural practices, and environmental conditions (Ewunie et al., 2021; Openshaw, 2000; Lama et al., 2018). Although Jatropha exhibits great ecological adaptability, it often falls short of its production potential in arid and semi-arid areas (Achten et al., 2008). Yields in these regions have turned out to be much lower than expected, leading to the abandonment of plantations by many farmers (Lama et al. 2018). Furthermore, the oil content of Jatropha seeds is influenced by various biotic and abiotic factors. On average, Jatropha seeds contain 35-45% inedible oil, and the oil yield is approximately 1892 liters per hectare (Athar & Zaidi, 2020; Mohiddin et al., 2021).

The cultivation of Jatropha has gained popularity as an ideal raw material for biofuel production and a potential source of income (Dane et al., 2007). Singh et al. (2021) conducted a study on Jatropha biodiesel and found that it shares a similar density with diesel fuel. However, it has a higher viscosity and a lower calorific value compared to diesel. An important advantage of Jatropha biodiesel is its higher Cetane number, which is attributed to its significant content of unsaturated fatty acids. When used as an engine fuel, Jatropha biodiesel leads to reduced emissions compared to traditional diesel fuel. Specifically, it results in decreased emissions of hydrocarbons (HC), carbon monoxide (CO), and smoke as the blend percentage of Jatropha biodiesel increases. Furthermore, at higher temperatures, carbon monoxide (CO) emissions are converted into carbon dioxide (CO2) due to the high oxygen content present in Jatropha biodiesel (Singh et al., 2021). However, recent large-scale accelerated experiments have raised concerns about the profitability and economic viability of Jatropha cultivation for biofuel production due to low seed yields and high production costs (Kgathi et al., 2017).

### *2.2.2 Citrullus (Citrullus colocynthis L)*

Citrullus belonging to the cucurbitaceae family, is native to the arid sandy areas of West Asia, Arabia, tropical Africa, and the Mediterranean (Dane et al., 2007; Khan et al., 2023). Today, it is recognized as a promising oilseed crop cultivated in many countries worldwide. Citrullus bears inedible, potentially toxic fruits. This plant is known for its remarkable drought and saline tolerance, enabling it to thrive in arid and desert environments. Even under severe stress conditions, it can maintain its water content without wilting of the leaves or desiccation, making it well-suited to survive in dry climates (Nehdi et al. 2013). Citrullus can play a significant role in combating desertification and land degradation in arid areas. The average seed yield of Citrullus is approximately 2500-3500 kg/ha (Chavan et al., 2014). Citrullus seeds have an oil content ranging from 17% to 53% (Nehdi et al., 2013; Chouaibi et al., 2020; Alloune et al., 2018). This oil is rich in unsaturated fatty acids, constituting approximately 85% of the total fatty acid composition (Alloune et al., 2018). Due to its exceptional properties, Citrullus oil is highly prized in various industries, including cosmetics, fragrances, pharmaceuticals, and foods. It is known for its wide range of biological activities and holds significant value for its versatile applications (Khan et al., 2023). However, recent research offers new possibilities for its application as a biofuel. In a study conducted by Alloune et al. (2018), the performance of this biodiesel derived from C. Collocyntis was investigated within the context of a direct injection diesel engine. The evaluation involved comparing its performance with that of various fuels, including traditional diesel, B100, and B30. These experiments were conducted at an engine speed of 1500 RPM while varying power levels. Their results indicate that both B100 and B30 exhibit combustion characteristics that are similar to those of diesel fuel. Furthermore, both B30 and B100 demonstrated a substantial reduction in hydrocarbon emissions, with B100 achieving a remarkable 50% reduction. Additionally, they observed reduced emissions of nitrogen oxides and particulate matter as well (Alloune et al., 2018). The high inedible oil content of Citrullus seeds, combined with their drought and saline resistance, positions this plant as one of the most suitable inedible crops for potential use as a feedstock for biodiesel production (Ismail et al., 2019).

### *2.2.3 Castor (Ricinus communis L.)*

Castor is a shrub belonging to the Euphorbiaceae family, native to the tropics and subtropics. It was initially cultivated in Egypt, Ethiopia, and India, but today it is widely grown in many parts of the world due to the commercial value of its oil. India dominates the global castor bean market, accounting for approximately 70% to 80% of world production, followed by China and Brazil with shares of 18% and 8% respectively (Dumeignil, 2012; Pari et al., 2020).

The oil yield from castor seeds ranges from 350 to 900 kg per hectare (Mubofi, 2016). Castor beans contain approximately 40% to 55% inedible oil (Pari et al. 2020; Carrino et al., 2020), with the main constituent being ricinoleic acid, a monounsaturated fatty acid that accounts for about 90% of the total fatty acids in the oil (Carrini et al. 2020). This unique composition compared to other vegetable oils gives castor oil significant added value in various fields, including pharmacology, cosmetology, the chemical industry, and more recently, the production of biofuels (Dumeignil, 2012; Mubofi, 2016). Castor is a hardy plant that thrives in a wide range of ecosystems, exhibiting good resistance to salinity and drought while requiring minimal inputs. Additionally, castor has the potential for phytoremediation of heavy metals and organic pollutants (Carrino et al., 2020). Castor is considered a high-potential raw material that can contribute up to 60% of the inedible oil required for biodiesel production (Osorio-Gonzalez et al., 2020). Arunkumar et al. (2019)'s study revealed that using a B20 blend of castor biodiesel and diesel in a dynamo engine caused a 4% increase in Specific Fuel Consumption (SFC) and 2.2% reduction in Brake Thermal Efficiency (BTE). Despite these drawbacks, the switch led to substantial reductions in greenhouse gas emissions, including an 8.6% drop in carbon monoxide (CO), an 8.1% decrease in hydrocarbons (HC), and similar reductions in nitrogen oxides (NOx). On the downside, B20 resulted in a 4.3% increase in smoke levels compared to diesel (Arunkumar et al., 2019). One notable advantage of castor is its adaptability to various climates and its ability to thrive on marginal lands without competing with conventional agriculture. Therefore, it is crucial to highlight that castor can be considered as an economically viable alternative for the supply of second-generation biodiesel.

### 2.2.4 Moringa (*Moringa oleifera L.*)

Moringa is a plant native to sub-Himalayan regions of northwest India, Africa, Arabia, Southeast Asia, the Pacific, Caribbean Islands, and South America, belonging to the Moringaceae family. Nowadays, it is spreading in tropical and subtropical lands impacted by drought (Leone et al., 2016). Moringa oleifera is a plant with numerous medicinal applications and notable nutritional value (Leone et al., 2016; Rashid et al., 2008). The seeds contain 30 to 42% of vegetable oil (Boukandoul et al., 2017), suitable for both human consumption and commercial purposes (Leone et al., 2016). With its rapid growth and ability to thrive in arid and less fertile regions, Moringa offers an attractive alternative to food crops for sustainable biofuel production. The plant's capacity to tolerate poor soils and drought conditions makes it well-suited for cultivation in challenging environments, providing a promising source of biofuel that does not compete with food production. A recent survey of 75 non-traditional oils derived from indigenous plants in India identified M. oleifera oil, along with others, as having great potential for biodiesel production (Rashid et al., 2008). In the study conducted by Ramalingam and Mahalakshmi (2020) on Moringa oleifera biodiesel, the B20 blend reached its peak Brake Thermal Efficiency (BTE) at 33.49%. This BTE value is slightly lower (0.47%) than that of conventional diesel but slightly higher (0.73%) than that of B100 biodiesel.

However, it is essential to note that B20 showed higher carbon monoxide (CO) emissions compared to other blends and conventional diesel. In contrast, B100 achieved the lowest CO emissions at just 0.01% volume.

### *2.2.5 Camelina (Camelina sativa L.)*

Camelina is an herbaceous plant belonging to the Brassicaceae family, originally from Western Asia and Northern Europe. It has been introduced to Australia and various regions in Africa and America, including Canada, Argentina, and Uruguay (Sydor et al., 2022). Initially, Camelina was introduced to these countries as a contaminant in flax seeds or other cultivated plants. Later, it was domesticated as an oilseed crop (Agarwal et al., 2021). The seeds of Camelina are small-sized and have an oil content ranging from 35 to 45% by weight. Camelina is a hardy plant resistant to pests and adapts well to various environmental conditions, including cold and semi-arid climates. It grows naturally in meadows, cereal fields, flax fields, alfalfa fields, and road edges. Camelina thrives with minimal inputs and can grow well in diverse soil conditions. Camelina exhibits good tolerance to drought, salinity, and frost (Agrawal et al. 2021). Recently, Camelina sativa has been recognized as a promising non-food oil crop that can be efficiently converted into renewable biofuel (Blume et al., 2020; Mupondwa et al., 2016). Camelina oil methyl esters demonstrate potential as a source for biodiesel production, yielding low emissions of carbon monoxide (CO), carbon dioxide (CO2), and hydrocarbons (HC). The Camelina biodiesel can be successfully employed as a substitute for diesel fuels in unmodified engines, leading to decreased exhaust emissions and supporting environmental cleanliness (Oni & Oluwatosin, 2020).

## 2.3 Used cooking oil

The use of animal fats and waste cooking oils as feedstocks for biodiesel production has gained significant importance due to their potential as low-cost alternative raw materials (Yussuf et al. (2021). Additionally, these feedstocks are readily available in large quantities (Dey et al., 2021; Chen et al., 2020). By valorizing and recycling these waste materials within the context of a circular economy, there are significant environmental and socio-economic advantages, especially when addressing the direct environmental and socio-economic constraints caused by their accumulation (Lee et al., 2019). This approach can play a vital role in sustainable energy production, and waste management, and contributing to a greener, more sustainable future.

# 3. CURRENT STATE IN ALGERIA

Algeria is particularly vulnerable to the impacts of climate change, which are already evident and expected to intensify over time, given the country's susceptibility to desertification (INDC, 2015). In response to these challenges, Algeria has committed to supporting the global community in its efforts to reduce greenhouse gas emissions (GHGs). However, this commitment is compounded by the complexities of the national economic context, exacerbated by population growth and increasing energy demands, along with a significant decline in hydrocarbon prices. It is important to note that Algeria heavily relies on energy exports, with natural gas and oil accounting for approximately 95% of its exports and 60% of its national budget (Serradj, 2023).

To address these challenges, the Algerian government has prioritized the promotion and development of renewable energies. To achieve this, they have adopted the National Renewable Energy and Energy

Efficiency Development Plan, which aims to install 22,000 MW of power-generating capacity from renewable sources by 2030, with an ambitious target of exporting 10,000 MW (MEM, 2011). The program focuses on harnessing various renewable energy sources, including photovoltaic, concentrated solar power (CSP), geothermal, wind, biomass, and cogeneration. Solar energy holds particular significance in the program due to Algeria's abundant solar potential, with average annual sunshine estimated at approximately 3000 hours (Stambouli et al., 2012).

In contrast to the significant potential of renewable energy sources like solar and wind, Algeria's capacity for biomass energy is relatively modest. The country's biomass energy potential encompasses the recycling of waste generated from various human activities, including urban and agricultural waste, and is estimated at 1.33 million tons of oil equivalent (Mtoe) per year (Abada & Bouharkat, 2018). The amount of this generated waste increases in line with population growth, economic development, and urbanization. Despite this considerable quantity of biomass waste, it remains largely under-utilized in the country. The untapped potential of biomass waste is noteworthy, as it can be effectively converted into energy and serve as raw materials for producing various high-value products.

Edible oilseed production in Algeria has faced limitations and has not played a significant role in the country's agricultural landscape. Several factors, including unfavorable climatic conditions and the traditional preference for cereal production with fallow periods, have contributed to this situation. As a result, the cultivation of oilseed crops such as rapeseed, peanuts, and sunflower has been cultivated on a small scale, yielding only a few thousand tons over several decades (Rastoin & Benabderrazik, 2014). The rapeseed species B. napus, extensively grown in northern Europe, is not found in Algeria (Sydor et al., 2022). Instead, it is the rapa species (*Brassica rapa*) that thrives in the country with various cultivated and wild forms, some of which have a long history of being used for culinary and forage purposes.

Moreover, some non-edible oilseeds, as well as used cooking oils (Danane et al., 2022), have been explored for biodiesel production including Jatropha, Moringa, Citrullus, and Castor oil seeds (Ahmia et al., 2014; Alloune et al., 2012; Amouri et al., 2023; Danane et al., 2022). These oilseeds are being considered for their adaptability to local climates and their potential yields in biodiesel production. These plants have been subject to biodiesel production, but mainly at the experimental scale. Some cultivation trials of these plants have been conducted to assess their potential as raw material sources for biodiesel production. However, large-scale biodiesel production from these plants in Algeria is still in its early stages.

Jatropha was introduced in Algeria as a crop within the framework of the European project JATROMED. Research and pilot projects have been conducted to evaluate Jatropha's potential for biodiesel production, with a specific focus on its oil yield and overall feasibility as a sustainable feedstock (Papazoglu et al.).

Regarding Moringa, in recent years, several farmers in southern Algeria have chosen to cultivate this plant to diversify their crops. This plant is particularly attractive due to its fast growth, evergreen nature, and drought resistance. Moringa can be used for reforestation and restoration of degraded areas, helping to prevent desertification in the region (Boulal et al., 2019). Its ability to improve soil fertility and water retention makes it a valuable resource for restoring fragile ecosystems in areas affected by land degradation. By promoting the growth of Moringa, farmers are contributing to the preservation and regeneration of land in arid regions, thereby combating desertification. Citrullus is another biodiesel-potential plant that displays remarkable resistance to adverse conditions and has become widespread in arid and semi-arid areas of Algeria (Alloune et al., 2018).

Used cooking oils, classified by the National Waste Agency (AND) as fatty and non-hazardous waste, encompass used vegetable oil that originates from cooking food. In 2018, the National Waste Agency

(AND) reported a staggering 450,519,000 liters of waste cooking oil generated across the nation, and this substantial volume is projected to increase to approximately 550 million liters by 2027 (Boulal et al., 2019), as depicted in Figure 2. Furthermore, waste cooking oil from food establishments and households is recorded at an average of 4.12 liters per restaurant per day and 0.61 liters per inhabitant per month, respectively (Danane et al., 2022).

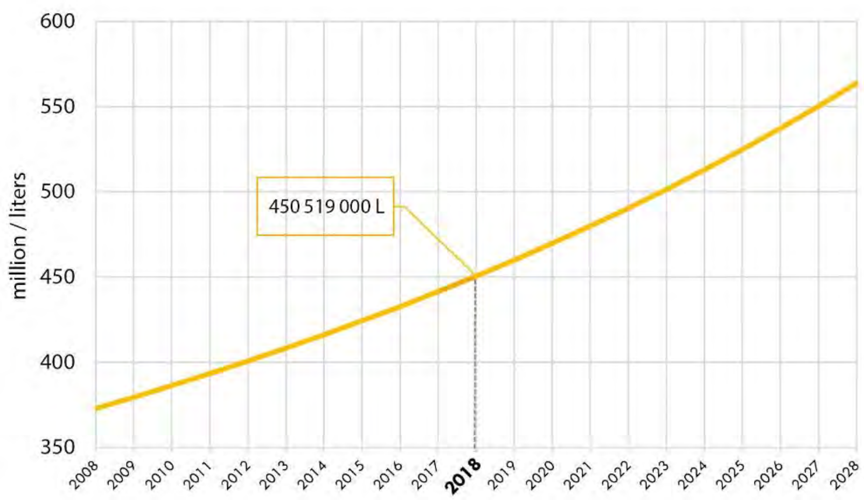


Fig 2. Waste cooking oil generated across the nation

Currently, collectors approved by the Ministry of the Environment export used cooking oils to some EU countries as a raw material for biodiesel production. However, there is a lack of available data concerning the quantities collected and exported (MEER).

The significant amount of used cooking oil generated in Algeria presents both challenges and opportunities. While this waste poses environmental and health concerns, it also represents a potential source of valuable raw materials for various applications, including biodiesel production and the development of bio-based products.

## 4. CHALLENGES AND PERSPECTIVES

Biodiesel production faces several challenges, including feedstock availability, environmental sustainability, and economic competitiveness. However, Biodiesel production presents numerous prospects for development.

Feedstock availability is a significant challenge for the biodiesel production value chain. Biofuels are categorized into different groups depending on the source of feedstock used in their production (Mupondwa et al., 2016; Yusuff et al., 2021). The first generation is mainly produced from food crops such as soybeans, canola oil, and palm oil. These crops are already widely cultivated for food and animal feed and have well-established markets, technologies, and infrastructure for their conversion into biofuels. Over 95% of biodiesel is derived from these edible oil crops, highlighting their dominance in the biofuel industry (Topare et al., 2021; Jeswani et al., 2020). However, the extensive utilization of these first-generation biofuels raises important concerns regarding competition with food production (reducing potential food supplies and increasing global food prices) and associated social and environmental impacts (Mahlia et al., 2020).

On the contrary, second-generation biofuels are produced from non-food crops, agricultural residues, and waste. Unlike first-generation biofuels, these feedstocks do not directly compete with the food supply and are often considered more sustainable options (Vickram et al., 2023), because they exploit readily available non-food crops that can thrive in adverse environments, such as arid or saline lands, where food crops are struggling to grow. Cultivating these marginal and degraded areas can contribute to combating desertification and supporting reforestation efforts in arid and semi-arid ecosystems.

However, the production of second-generation biofuels involves more advanced technologies, which are still in the research and development, pilot, or demonstration phase (Jeswani et al., 2020; Mahlia et al., 2020). These technologies target to overcome the limitations and drawbacks of first-generation biofuels by utilizing non-food feedstocks and improving the efficiency of the conversion process. However, further progress and investment are needed to bring these technologies to commercial viability. These significant efforts are currently focused on improving varietal selection, increasing crop yields, enhancing resilience to climate change, and optimizing energy efficiency in production processes. These advancements will contribute to the sustainable and economically viable production of second-generation biofuels (Topare et al., 2021; Mahlia et al., 2020; Cavelius et al., 2023; Pinzi et al., 2009).

Nevertheless, despite the promising solutions offered by second-generation biofuels, they alone are not plentiful enough to satisfy the current global energy demand (Cavelius et al., 2023; Atabani et al., 2013). The transition toward a sustainable biofuel industry requires continuous efforts and investments in research, development, and innovation. By incorporating diverse feedstocks, advanced technologies, and a comprehensive approach, we can strive towards achieving economic viability, and environmental sustainability, and meeting the growing global energy demand.

Economic competitiveness is another challenge for the biodiesel industry (Jeyaseelan et al., 2023), as the economic aspects of production are influenced by various factors that affect production costs. These considerations include feedstock costs, production scale efficiencies, processing and equipment expenses, transportation logistics, government incentives, market dynamics, research and innovation efforts, and environmental compliance. Feedstock costs are particularly significant, typically representing 75% to 85% (Mahlia et al., 2020; Kargbo, 2010) of total expenses and susceptible to fluctuations that influence overall costs. Strategies such as achieving economies of scale and optimizing resource utilization are essential for cost management and ensuring the economic viability of biodiesel production.

Biodiesel production in Algeria is still in its early stages, requiring additional research, investment, and policy backing to maximize its potential and align it with the national energy strategy. Although specific data on potential biodiesel production in Algeria is currently unavailable, assessing this potential involves evaluating various factors. These factors include identifying available raw materials, estimating oil or lipid yields, assessing cultivable land area, and projecting crop yields per hectare. A comprehensive assessment in these areas can help chart the course for biodiesel production development in Algeria.

## 5. CONCLUSION

Biodiesel production is a promising alternative to fossil fuels due to its renewable nature and environmental benefits. However, according to the literature, biodiesel production faces several challenges, particularly regarding feedstock availability and sustainability. To address these challenges, different biodiesel generations, such as second-generation and third-generation biodiesel, are being developed.

To achieve a sustainable biofuel industry, a continuous commitment to research, development, and innovation is necessary. It is crucial to explore diverse feedstocks and employ advanced technologies to ensure economic viability, and environmental sustainability, and to meet the growing global energy demand. This requires investing in the optimization of production processes, improving feedstock selection, and promoting holistic approaches that consider the entire biofuel supply chain. By taking these measures, we can pave the way for a greener and more sustainable energy future.

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