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Views & Comments

Oil Crops: A Potential Source of Biodiesel

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1. Introduction

Oil crops such as soybeans, sunflower, canola, rapeseed, and peanuts play a vital role in the agricultural economy, second only to food crops in terms of area and yield. Vegetable oil is known for its high energy density, containing approximately 2.25 times more calories per unit mass than carbohydrates or protein. Therefore, vegetable oil is an important source of energy and provides a variety of fatty acids necessary for human health. With the increase in global population and the acceleration of industrialization, global development is facing two major problems: energy shortage and environmental pollution. The gradual depletion of fossil fuels has accelerated investigations into alternative sources of energy. As a potential substitute for fossil fuels, renewable sources of energy are becoming increasingly important and are capable of meeting some energy demands [1]. Among the various types of renewable energy sources, biodiesel—a diesel-equivalent alternative fuel derived from biological sources such as edible and nonedible oils, animal fats, and waste cooking oils through appropriate processing methods—has superior characteristics that include an environmentally friendly process, a competitive price in comparison with fossil fuels, and technical feasibility. Furthermore, biodiesel can be used in conventional diesel engines with no need for fundamental transformations [2]. The first diesel engine, which was presented by Rudolph Diesel at the World Fair in Paris in 1900, ran using peanut oil as fuel. Due to the fuel shortage during World War II, peanut oil was widely used as an alternative to conventional fossil fuels. Since then, biodiesel has attracted numerous researchers across the world, and remarkable achievements have been obtained in its development and applications.

The main objective of this article is to summarize the production of biodiesel from oil crops as a renewable source of energy and to explore ways to increase the production of oil crops in the future.

2. The necessity and feasibility of biodiesel production from oil crops

Studies report that global biodiesel production increased by 357.14% from 2005 to 2010. As shown in Fig. 1 [3], global biodiesel production almost doubled between 2011 and 2021, reaching 1.5 exajoules (EJ; equal to 10^{18} J, where 1 EJ is equivalent to 45 billion liters of biodiesel) [4]. The global demand for biodiesel is estimated to reach 10.5 EJ by 2050 [5]. Investigations based on life-cycle assessments have shown that the greenhouse gas emissions from biodiesel are 20%–80% less than those from petroleum diesel [6]. The key to biodiesel production is the availability of raw materials, which is the main factor determining the price of biodiesel, accounting for 67% of the total cost. As oil reserves continue to be depleted, biodiesel can play a crucial role in reducing the global energy demand. Moreover, biodiesel is an attractive renewable alternative to fossil fuels due to its availability and environmental friendliness [7].

Almost all vegetable oils are in the form of triacylglycerols, which can be converted into methyl esters. Vegetable oil has a similar structure to petroleum hydrocarbons and to glycerol, and has wide applications in chemistry and the food industry. Currently, biodiesel is mainly obtained from high-yielding soybeans in the United States, rapeseed oil (also known as canola oil) in European countries, castor oil in Brazil, and jatropha and palm oil in Southeast Asia. It is worth noting that oil crops with a high oleic acid content have better oxidative stability than oils that are rich in polyunsaturated fatty acids. With the selection of low-cost sustainable non-food feedstocks, improved production processes to improve quality, and low production costs, oil crops are already a valuable source of biofuel, with tremendous potential for increased utilization. Although biofuel cannot provide the final solution for increasing energy demands, it appears to be a notable stopgap solution [8].

3. Oil crops of the future

Agricultural production faces enormous challenges, including a variable climate, extreme weather, low production efficiency, and high costs. Accordingly, it is necessary to use modern breeding and biotechnology methods to improve the oil yield of oil crops (Fig. 2). For example, a 1% increase in the oil content of rapeseed, with 1.314×10^7 hm^2 being planted in China, is equivalent to an increase in the output of 3.0×10^5 hm^2 of rapeseed oil [9]. There are many potential targets that could be manipulated to increase the oil content in seeds, and previous attempts have targeted source (i.e., photosynthate and fatty acid biosynthesis) and sink

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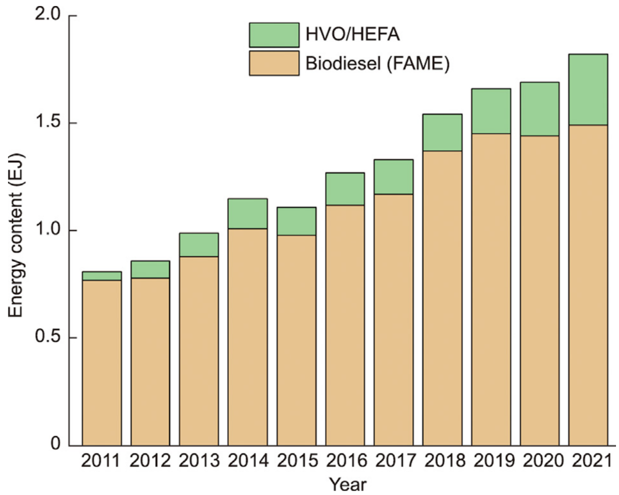

Fig. 1. Global production of biodiesel with a fatty acid methyl ester (FAME) structure and with hydrotreated vegetable oil/hydroprocessed esters and fatty acid (HVO/HEFA) from 2011 to 2021 [3].

(i.e., triacylglyceride assembly) steps in the biological process to increase oil production in order to meet the growing demand for vegetable oils from consumers and industry. Promising areas that have received less attention are outlined below:

(1) **Domestication and breeding of perennial oil crops.** Perennial crops have less nutrient loss compared with annual crops, have higher energy efficiency, and increase soil carbon sequestration. For example, in Sweden, *Lepidium campestre*, a hardy biennial cruciferous plant with an oil crop yield of 5 $t \cdot hm^{-2}$, is undergoing domestication as an oilseed crop. This product is an appropriate choice in northern temperate regions; it can be cultivated to diversify agroecosystems and increase global vegetable oil production [10].

(2) **Manipulating the autophagy pathway.** The autophagy pathway, which is a catabolic pathway necessary for eukaryotic growth and development, can be manipulated to improve the adaptability of crops under changing climate conditions. Alternative tools for the manipulation of autophagy in plants include molecular breeding and the application of autophagy regulatory compounds [11]. So far, two autophagy-related approaches have been identified to improve lipid production in plants: the manipulation of hunger-induced lipophagy and the enhancement of basal autophagy flux in nutrient-adequate plants. Given recent advances in chemical biology, these tools may become available in the near future.

(3) **Accumulation of stored oil in non-seed/fruit tissues.** The biomass of various non-seed tissues such as skins, tubers, stems, and leaves, originating from the accumulation of triacylglycerol, is usually much greater than that of seeds. Due to the systematic regulation of plant oil synthesis, with the ultra-rapid development of high-throughput technologies such as modern plant modification technology, genomics, proteomics, and metabolomics, oil crops can be tailored to meet energy demands by using the gene modification multi-gene engineering strategy, which can induce lipid accumulation in genetically modified (GM) crops [12].

4. Conclusions

The decrease in the world's oil resources and the drastic fluctuation of oil prices are challenges that threaten the development of human society in the 21st century. Biodiesel is one of the potential alternatives to fossil fuels for solving the global energy crisis. Oil-based crops will be one of the main sources of biodiesel long after fossil resources are exhausted. Meanwhile, modern breeding and biotechnology methods can be used to improve the oil content and adjust the proportion of fatty acids in vegetable oils to reach high proportions of monounsaturated fatty acids (16:1 and 18:1), low proportions of polyunsaturated fatty acids (18:2 and 18:3), and appropriate amounts of saturated fatty acids (16:0 and 18:0), thereby providing a new strategy to increase the yield of oil crops. The development of efficient, reliable, environmentally friendly, low-carbon, and cheap catalysts and green production processes are the main challenges presented by the industrialization of biodiesel.

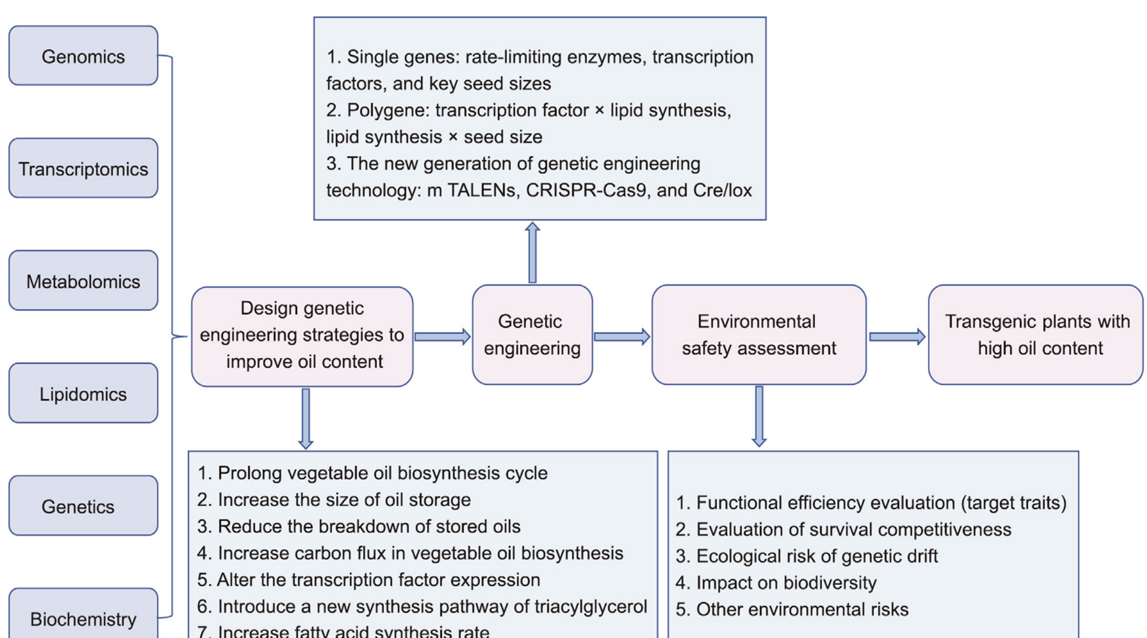

Fig. 2. Tools and strategies for the genetic engineering of oil content in plant seeds. m TALENs: mitochondrion transcription activator-like effector nuclease; CRISPR-Cas9: clustered regularly interspaced short palindromic repeats (CRISPR)—CRISPR associated 9 (Cas9); Cre/lox: cyclization recombinase/locus of X.

Acknowledgments

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