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"Production of Biodiesel from Non Edible Vegetable Oils. A Review"

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Abstract

It is estimated that there are worldwide proven oil reserves for 53 years of production at its 2012 level where 32.8 billion of barrels of oil (bbp). On the other hand, it was mention about the negative environmental consequences of the use of fossil fuels and the few existing oil reserves, has led to the need to look for renewable alternatives to reduce these problems. For this reason, the production of biofuels is an alternative to minimize the use of fossil fuels and prolong existing reserves, in addition to contributing to reduce the emissions generated by conventional fuels. For this reasons, the generation of agro-energy processes has contributed that different countries seek to boost the production of biofuels because they represent benefits such as: i) a security in the energy supply; ii) reduction of dependence on fossil energy sources; iii) the reduction of greenhouse gas emissions; iv) soil protection through the use of biodegradable products; v) the minimization of the surplus of agricultural production. Nowadays edible and non-edible crops are used for this purpose, but almost 95 % is made of edible crops. This can cause different problems, because they are transforming food resources into automotive fuels, and this could bring global imbalance to the food supply and demand market. The aim of this review was to compare different non-edible crops as a raw material for biodiesel production.

Keywords—Biofuel, Biodiesel, Non-edible crops.

I. INTRODUCTION

The use of fuels obtained from petroleum in the current market is estimated to be exhausted before 2090. In addition to its overexploitation in its use has generated serious environmental problems such as global warming [1]. Another one is that the world's mobility depends on this type of fuel in more than 90%. Therefore, it is necessary to search for renewable alternatives of fuels to deal with such problems. Biofuels have appeared as an unexplored alternative and it is until recent years that there has been a growing interest in their study and use [2].

Biofuels are those fuels such as alcohols, ethers, esters and other chemical compounds, produced from natural sources known as biomass, which refers to all organic matter that has had its immediate origin in the biological processes of recently living organisms and includes products of both vegetable and animal origin [3]. These bioenergetics can be found in liquid, solid or gaseous state, and their purpose is to release the energy contained in their chemical components, through a combustion reaction. According to [4], there are different types of biofuels, which are usually classified in different ways: a) raw material, b) technology used for its preparation, c) intended use (bioethanol, biogas, bioturbosin, biodiesel), d) by its generation (first, second, third and fourth), among others [5].

II. GENERATION OF BIOFUELS

A. First Generation Biofuels

The first-generation biofuels are those of agricultural origin and are made up of food parts of the vegetables, which have a high content of starch, sugars and oils [6]. Biofuels are produced from these substances using conventional technologies such as fermentation, transesterification, and anaerobic digestion. Biofuels obtained from these processes are: bioethanol (from sugars), biodiesel (from oils), and biogas (mixture of methane and carbon dioxide, from organic waste). The advantage of first-generation biofuels is their ease of processing and their low greenhouse gas emissions and their disadvantage is that they have an impact on food security [7]. Some examples of materials used for the production of this biofuels are: sugarcane juice, corn grains, beet juice or beet, sunflower seed oil, soybean oil, palm oil, cottonseed oil, coconut oil, peanut oil or peanut, among others. Also used as inputs are animal fats, fats and waste oils from cooking and food processing, and organic solid waste [8].

B. Second Gneration Biofuels

On the other hand, second-generation biofuels distinguished from first generation biofuels in two aspects: they are obtained from vegetables that do not have a food function, and they are produced with technological innovations that allow to be more ecological, composed mainly of cellulose [9]. The main advantage of second generation biofuels is that there are no deviations of food from agriculture to the energy sector, but its disadvantage is that they do not reduce the emission of greenhouse gases during the processing of inputs. Some examples of raw material for its preparation are: sugarcane bagasse, corn stubble, wheat straw, sawdust, leaves and dry branches of trees, to mention a few examples [10].

C. Third Gneration Biofuels

Third-generation biofuels are based on the production of microbial species such as yeast, fungi and algae biomass [11]. It is currently in extensive research to improve both metabolic production and separation processes in biofuel production to eliminate non-combustible components and further reduce production costs [12]. The advantage of this type of biofuel is the algae biomass has no competition with agricultural food production and its disadvantage is the use of food cropland to plant algae [13].

D. Fourth Gneration Biofuels

Finally, there are biofuels of fourth generation or direct solar biofuels that are those that for their production uses the technology of solar energy that is an emerging field and is based on the direct conversion of solar energy into fuel using raw materials that they are inexhaustible, cheap and widely available [6].

In this work we will focus on the second-generation biofuels, specifically biodiesel produced from different vegetable oils from non-edible sources. The use of vegetable oils for the production of biofuels for use in internal combustion engines began in 1985 [14]. The first vegetable oil to be used for this purpose was peanut oil, but there is a great variety of species from which their oil could be used to make biofuels. The most used vegetable oils for the production of biodiesel are the following: soybean, rapeseed, sunflower, peanut (edible oils) Jatropha, Rubber seed, Pongam, Sea mango and Castor (non-edible) [15,16]. The main objective of using biofuels is to reduce greenhouse gas emissions that superheat the earth's surface and accelerate climate change [7].

III. Edible Crops And Non-Edible Crops

Vegetable oils (edible and non-edible) are rich in fatty acids which is one of the most important factor for the production of biodiesel, since these are the ones that act in the transesterification reaction. Once this reaction is carried out, the kinematic viscosity is determined, which is defined as the resistance of the liquid to flow and is the most important characteristic of the biofuel [17]. This viscosity affects the operation of fuel injection, formation of mixtures and combustion processes [18]. Another important factor is the flash point, which is the temperature at which the fuel will start to burn when it comes into contact with fire. This parameter is important from a security point of view. According to the ASTMD6751 standard, biodiesel has a flash point of not less than 120 °C and petroleum diesel of 71 °C [19].

Both edible and non-edible crops have suitable characteristics for the production of biodiesel, but non-edible crops have some advanteges like: they can grow almost everywhere like areas with low fertility, moisture demand, and poor and wastelands that are not suitable for food crops, because they have a great adaptability, and have a huge potential to restore degraded land and fixing. Also, these species does not compete with existing agricultural resources, because their oils can not be ingested by humans due to the presence of toxic components, and the surplus can be used to produce useful by-products. For example, the seed cakes of castor can be used to produce biogas. But the main advantages of non-edible oils are the availability, renewability, lower sulfur content, biodegradability and aromatic content [20].

The main species that are used for this pourpose are: soy, rice, sunflower, corn, palm (edible crops), Castor, Jatropha, Rubber seed and Pongam (non-edible crops) [16,20].

IV. Botanical Families Of Non-Edible Crops For Biodiesel Production

In this review it was found that 41 botanical families are used for biodiesel production with 108 different species and 77 Genus. The Euphorbiaceae family was the most used for this purpose: with 35 species, then Brassicaceae, and Apocynaceae with five species each, the Asteraceae, Malvaceae, and Meliaceae families with four species, the Clusiaceae, Sapindaceae, and Sapotaceae families with three species, the Achariaceae, Anacardiaceae, Calophyllaceae, Celastraceae, Combretaceae, Lamiaceae, Lauraceae, Moringaceae, Papaveraceae, Salvadoraceae, Simaroubaceae, and Urticaceae families with two species, and finally with one specie each the Balanitaceae, Basellaceae, Bombacaceae, Burseraceae, Cannabaceae, Cucurbitaceae, Fabaceae, Icacinaceae, Magnoliaceae, Malpighiaceae, Menispermaceae, Moraceae, Myristicaceae, Putranjivaceae, Rosaceae, Rubiaceae, Rutaceae, Santalaceae, and Solanaceae as shown in Table I [20- 53].

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Table1. Non edible crops for biodiesel production.

Family	Genus	Scientific name
Achariaceae [37]	Hydnocarpus	Hydnocarpus kurzii
		Hydnocarpus wightiana
Anacardiaceae [37]	Pistacia	Pistacia chinensis
	Toxicodendron	Toxicodendron succedaneum
Apocynaceae [21, 22, 36, 37, 39]	Calotropis	Calotropis procera
	Cerbera	Cerbera odollam
	Ervatamia	Ervatamia coronaria
	Thevetia	Thevetia peruviana
	Vallaris	Vallaria solanacea
Asteraceae [48-51]	Carthamus	Carthamus oxycantha
	Silybum	Silybum marianum
	Vernonia	Vernonia cinerea
	Xanthium	Xanthium sibricum
Balanitaceae [37]	Balanites	Balanites roxburghii
Basellaceae [37]	Basella	Basella rubra
Bombacaceae [24, 32]	Ceiba	Ceiba pentandra
Brassicaceae [23, 43, 44, 45, 46, 47]	Brassica	Brassica carinata
	Camelina	Camelina sativa
	Crambe	Crambe abyssinica
	Eruca	Eruca sativa
	Thlaspi	Thlaspi arvense
Burseraceae [52]	Canarium	Canarium commune
Calophyllaceae [24, 37, 39, 40, 41, 42]	Calophyllum	Calophyllum inophyllum
	Mesua	Mesua ferrea
Cannabaceae [37]	Cannabis	Cannabis sativa
Celastraceae [37]	Celastrus	Celastrus paniculatus
	Euonymus	Euonymus acanthocarpa
Clusiaceae [37]	Garcinia	Garcinia echinocarpa
		Garcinia indica
		Garcinia morella
Combretaceae [37]	Terminalia	Terminalia bellirica
		Terminalia chebula
Cucurbitaceae [52]	Momordica	Momordica dioica
Euphorbiaceae [24, 25, 26, 27, 28, 29, 30, 32, 37, 38]	Actinostemon	Actinostemon concolor
	Aleurites	Aleurites fordii
		Aleurites moluccana
		Aleurites montana
		Aleurites trisperma
	Croton	Croton floribundus
		Croton megalocarpus
		Croton nepetifolius
		Croton tiglium
	Euphorbia	Euphorbia acaulis
		Euphorbia antiquorum
		Euphorbia antisyphilitica
		Euphorbia caducifolia
		Euphorbia comosa
		Euphorbia geniculata
		Euphorbia helioscopia
		Euphorbia heterophylla
		Euphorbia hirta
		Euphorbia lactea
		Euphorbia lathyris
		Euphorbia neriifolia
		Euphorbia nivula
		Euphorbia royleana
		Euphorbia thymifolia
		Euphorbia tirucalli
		Euphorbia triogona

Family	Genus	Scientific name
Euphorbiaceae [24, 25, 26, 27, 28, 29, 30, 32, 37, 38]	Hevea	Hevea brasiliensis
	Jatropha	Jatropha curcas
	Joannesia	Joannesia princeps
	Mallotus	Mallotus phillippinensis
	Microstachys	Microstachys corniculata
	Ricinus	Ricinus communis
	Sapium	Sapium glandulosum
		Sapium sebiferum
	Stillingia	Stillingia trapezoidea
Fabaceae [24, 26, 31]	Pongamia	Pongamia pinnata
Icacinaceae [37]	Mappia	Mappia foetida
Lamiaceae [37]	Actinodaphne	Actinodaphne angustifolia
	Tectona	Tectona grandis
Lauraceae [37]	Litsea	Litsea glutinosa
	Neolitsea	Neolitsea umbrosa
Magnoliaceae [37]	Michelia	Michelia champaca
Malphigiaceae [37]	Hiptage	Hiptage benghalensis
Malvaceae [37]	Pachira	Pachira glabra
	Pterygota	Pterygota alata
	Gossypium	Gossypium hirsutum
Meliaceae [24]	Aphanamixis	Aphanamixis polystachya
	Azadirachta	Azadirachta indica
	Melia	Melia azedarach
	Swietenia	Swietenia mahagoni
Menispermaceae [37]	Anamirta	Anamirta cocculus
Moraceae [37]	Broussonetia	Broussonetia papyrifera
		Moringa oleifera

Family	Genus	Scientific name
Myristicaceae [37]	Myristica	Myristica malabarica
Papaveraceae [37]	Argemone	Argemone mexicana
	Papaver	Papaver somniferum
Putranjivaceae [37]	Putranjiva	Putranjiva rosburghii
Rosaceae [37]	Princepia	Princepia utilis
Rubiaceae [37]	Meyna	Meyna laxiflora
Rutaceae [37]	Aegle	Aegle marmelos
Salvadoraceae [37]	Salvadora	Salvadora oleoides
		Salvadora persica
Santalaceae [37]	Santalum	Santalum album
Sapindaceae [34, 37]	Sapindus	Sapindus mukorossi
		Sapindus trifoliatus
	Schleichera	Schleichera oleosa
Sapotaceae [24, 35, 37]	Madhuca	Madhuca butyracea
		Madhuca indica
	Mimusops	Mimusops hexendra
Simaroubaceae [37]	Quassia	Quassia indica
Simmondsiaceae [53]	Simmondsia	Simmondsia chinensis
Solanaceae [36]	Nicotiana	Nicotiana tabacum
Urticaceae [37]	Holoptelea	Holoptelea integrifolia
	Urtica	Urtica dioica

V. Euphorbiaceae Family

The Euphorbiaceae family is one of the largest and diversified containing about 8,000 species in 300 Genus. The larger genera are: Euphorbia with about 2,000 species, Croton 700 species, Phyllanthus 500 species, Acalypha 430 species, Jatropha 175 species, Manihot 170 species, between others. It includes predominantly tropical species but also widely distributed in temperate zones [54].

From a biochemical point of view, it is a family very diverse since it contains alkaloids, cyanogenic glycosides, fatty acids, glucosinolates and terpenoids between others.

Due to the extension, diversity and wide range of applications of this family, many of its species were used by the most primitive societies. Currently, it is used is in the production of medicines, poisons, oils and fats, waxes, gums, rubber and components for paints, varnishes and other industrial products [55].

VI. Technologies of Biodiesel Production From Non-Edible Oils

There are many technologies that can be used for the production of biodiesel of non-edible crops like: pyrolysis, micro-emulsification, dilution, and transesterification [20]. Pyrolysis is a process to transform biomass into liquid (oil), gas and pyrolytic carbon in the absence of oxygen and in presence of a catalyst [56]. Micro-emulsification is defined as the colloidal equilibrium dispersion of optically isotropic fluid [57]. Dilution can be used to reduce the viscosity and improve the performance of the engine. Finally, transesterification which consists of reacting a vegetable oil or animal fat with a low molecular weight alcohol in the presence of a catalyst [58, 59] such as sodium and potassium hydroxide. This reaction is shown in Figure 1 [60].

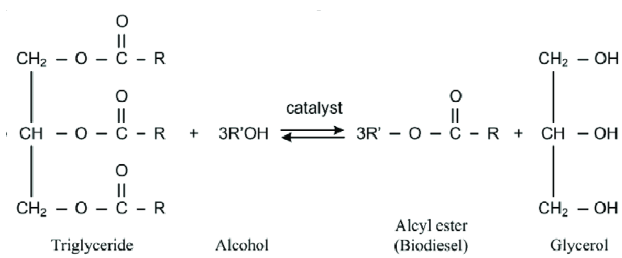

Figure 1. Transesterification reaction of triglycerides (TG) by methanol in basic medium; in the bibliography, it is usually specified as a meta-analysis.

VII. Discussion

Due that most of the energy worldwide is maintained from petrochemical sources, which generate pollution problems, each day are becoming less economically profitable and non-renewable raises, it is necessary to develop renewable energy sources and that have a lower environmental impact than currently used [61]. The utilization of biofuels is one of the many solutions because it generates lower emissions of greenhouse gases, which makes them more environmentally friendly than fossil fuels. The biodiesel also does not contain sulfur, carbon monoxide and the combustion of its emissions are lower than diesel oil [62].

As can be seen in this review, there are different non-edible species from which oil can be obtained for the production of biodiesel. It was decided to work with non-edible crops because they can grow almost everywhere like areas with low fertility, moisture demand, and poor and wastelands that are not suitable for food crops and these species does not compete with existing agricultural resources that can be used to produce edible products [20]. The species most used for this purpose correspond to the Euphorbiaceae family, where 35 species of 12 different Genus were found. This family is widely used because they do not need much care, and can be grown on soils that are not suitable for agriculture and the care needed to reproduce are minimal [16].

The development of more studies is required, using different species of the family Euphorbiaceae, because it is the family from which a greater number of species of non- edible crops have been obtained for the production of oil for the production of biofuel. In this way, these fuels can be produced using the most convenient species and obtain the highest efficiency and the best environmental benefits.

References

[1] SENER 2013. Prospectiva de Petróleo Crudo y Petrolíferos 2013-2027. https://www.gob.mx/cms/uploads/attachment/file/62951/Prospectiva_de_Petr_leo_y_Petrol_feros_2013-2027.pdf Consultado el 6 de febrero 2019

[2] Friedrich, S. (2003). A worldwide review of the commercial production of Biodiesel: a technological, economic and ecological investigation based on case studies. na.

[3] Rivas, A. G. V., Álvarez, M. G. D. L. R., Molina, C. E., & Castañeda, M. G. (2017). Optimización de la producción de enzimas aisladas de bacterias metilotróficas de pigmentación rosada (Ppfms) de suelo de jardín para la producción de biocombustibles. Jóvenes En La Ciencia, 2(1), 1801-1805.

[4] Maciel, C. Á. (2016). Biocombustibles: desarrollo histórico-tecnológico

[5] Ramos, F. D., Díaz, M. S., & Villar, M. A. (2016). Biocombustibles.

[6] Aro, E. M. (2016). From first generation biofuels to advanced solar biofuels. *Ambio*, *45*(1), 24-31.

[7] Salinas Callejas, E., & Gasca Quezada, V. (2009). Los biocombustibles. *El Cotidiano*, (157).

[8] Ho, D. P., Ngo, H. H., & Guo, W. (2014). A mini review on renewable sources for biofuel. *Bioresource technology*, *169*, 742-749.

[9] Petersen, A. M., Melamu, R., Knoetze, J. H., & Görgens, J. F. (2015). Comparison of second-generation processes for the conversion of sugarcane bagasse to liquid biofuels in terms of energy efficiency, pinch point analysis and Life Cycle Analysis. *Energy conversion and management*, *91*, 292-301.

[10] Cotana, F., Cavalaglio, G., Nicolini, A., Gelosia, M., Coccia, V., Petrozzi, A., & Brinchi, L. (2014). Lignin as co-product of second generation bioethanol production from ligno-cellulosic biomass. *Energy Procedia*, *45*, 52-60.

[11] Singh, A., Olsen, S. I., & Nigam, P. S. (2011). A viable technology to generate third-generation biofuel. *Journal of Chemical Technology & Biotechnology*, *86*(11), 1349-1353.

[12] Alam, F., Mobin, S., & Chowdhury, H. (2015). Third generation biofuel from algae. *Procedia Engineering*, *105*, 763-768.

[13] Behera, S., Singh, R., Arora, R., Sharma, N. K., Shukla, M., & Kumar, S. (2015). Scope of algae as third generation biofuels. *Frontiers in bioengineering and biotechnology*, *2*, 90.

[14] Muñiz, R. (2017). El biodiesel de microlagas. Una Alternativa Adecuada para el Sector Energético (P. 054-062). Tekhné, 20(1).

[15] Stratta, J. (2000). Biocombustibles: los aceites vegetales como constituyentes principales del biodiesel. Rosario, Argentina.

[16] Gui, M. M., Lee, K. T., & Bhatia, S. (2008). Feasibility of edible oil vs. non-edible oil vs. waste edible oil as biodiesel feedstock. Energy, 33(11), 1646-1653.

[17] Durham, S., & Wood, M. (2002). Biodegradable oils from alternative crops. Agricultural Research, 50(4), 22-23.

[18] Silitonga, A. S., Masjuki, H. H., Mahlia, T. M. I., Ong, H. C., Atabani, A. E., & Chong, W. T. (2013). A global comparative review of biodiesel production from Jatropha curcas using different homogeneous acid and

alkaline catalysts: Study of physical and chemical properties. Renewable and Sustainable Energy Reviews, 24, 514-533.

[19] García-Muentes, S. A., Lafargue-Pérez, F., Labrada-Vázquez, B., Díaz-Velázquez, M., & Sánchez del Campo-Lafita, A. E. (2018). Propiedades fisicoquímicas del aceite y biodiesel producidos de la Jatropha curcas L. en la provincia de Manabí, Ecuador. Revista Cubana de Química, 30(1), 142-158.

[20] Atabani, A. E., Silitonga, A. S., Ong, H. C., Mahlia, T. M. I., Masjuki, H. H., Badruddin, I. A., & Fayaz, H. (2013). Non-edible vegetable oils: a critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production. Renewable and sustainable energy reviews, 18, 211-245.

[21] Momin, M., & Deka, D. C. (2015). Fuel property of biodiesel and petrodiesel mix: experiment with biodiesel from yellow oleander seed oil. Biofuels, 6(5-6), 269-272.

[22] Lie, J., Rizkiana, M. B., Soetaredjo, F. E., Ju, Y. H., & Ismadji, S. (2018). Production of biodiesel from sea mango (Cerbera odollam) seed using in situ subcritical methanol–water under a non-catalytic process. International Journal of Industrial Chemistry, 9(1), 53-59.

[23] Costa, E., Almeida, M. F., Alvim-Ferraz, C., & Dias, J. M. (2019). The cycle of biodiesel production from Crambe abyssinica in Portugal. Industrial Crops and Products, 129, 51-58.

[24] Mardhiah, H. H., Ong, H. C., Masjuki, H. H., Lim, S., & Lee, H. V. (2017). A review on latest developments and future prospects of heterogeneous catalyst in biodiesel production from non-edible oils. Renewable and sustainable energy reviews, 67, 1225-1236.

[25] Adebayo, G. B., & Ameen, O. M. (2017). Physico-chemical properties of biodiesel produced from Jatropha curcas oil and fossil diesel. Journal of Microbiology and Biotechnology Research, 1(1), 12-16.

[26] Ruhul, A. M., Kalam, M. A., Masjuki, H. H., Shahir, S. A., Alabdulkarem, A., Teoh, Y. H., ... & Reham, S. S. (2017). Evaluating combustion, performance and emission characteristics of Millettia pinnata and Croton megalocarpus biodiesel blends in a diesel engine. Energy, 141, 2362-2376.

[27] Cabral, M. R., dos Santos, S. A., Stropa, J. M., Rogério, C. D. L., Cardoso, C. A., de Oliveira, L. C., ... & Simionatto, E. (2016). Chemical composition and thermal properties of methyl and ethyl esters prepared from Aleurites moluccanus (L.) Willd (Euphorbiaceae) nut oil. Industrial Crops and Products, 85, 109-116.

[28] Azad, A. K., Rasul, M. G., Khan, M. M. K., Sharma, S. C., Mofijur, M., & Bhuiya, M. M. K. (2016). Prospects, feedstocks and challenges of biodiesel production from beauty leaf oil and castor oil: A nonedible oil sources in Australia. Renewable and Sustainable Energy Reviews, 61, 302-318.

[29] Henkel, C., Muley, P. D., Abdollahi, K. K., Marculescu, C., & Boldor, D. (2016). Pyrolysis of energy cane bagasse and invasive Chinese tallow tree (Triadica sebifera L.) biomass in an inductively heated reactor. Energy conversion and management, 109, 175-183.

[30] Razak, Z. K. A., Kamarullah, S. H., Khazaai, S. N. M., & Maniam, G. P. (2018). synthesis of alumina-cao-ki catalyst for the production of biodiesel from Rubber seed oil. Malaysian Journal of Analytical Sciences, 22(2), 279-285.

[31] Verma, P., & Sharma, M. P. (2016). Comparative analysis of effect of methanol and ethanol on Karanja biodiesel production and its optimisation. Fuel, 180, 164-174.

[32] Kibazohi, O., & Sangwan, R. S. (2011). Vegetable oil production potential from Jatropha curcas, Croton megalocarpus, Aleurites moluccana, Moringa oleifera and Pachira glabra: assessment of renewable energy resources for bio-energy production in Africa. Biomass and Bioenergy, 35(3), 1352-1356.

[33] Rashid, U., Anwar, F., Ashraf, M., Saleem, M., & Yusup, S. (2011). Application of response surface methodology for optimizing transesterification of Moringa oleifera oil: Biodiesel production. Energy Conversion and Management, 52(8-9), 3034-3042.

[34] Mathiarasi, R., & Partha, N. (2017). Transesterification of soap nut oil using novel catalyst. Journal of Saudi Chemical Society, 21(1), 11-17.

[35] Behera, S. S., & Ray, R. C. (2019). Forest bioresources for bioethanol and biodiesel production with emphasis on Mohua (Madhuca latifolia L.) flowers and seeds. In Bioethanol Production from Food Crops (pp. 233-247). Academic Press.

[36] Maisashvili, A., Bryant, H. L., & Richardson, J. W. (2016). Economic feasibility of tobacco leaves for biofuel production and high value squalene. International Food and Agribusiness Management Review, 19(4), 145-162.

[37] Patel, N. K., Nagar, P. S., & Shah, S. N. (2013). Identification of non-edible seeds as potential feedstock for the production and application of bio-diesel. *Energy Power*, *3*(4), 67-78.

[38] Patan, S. S. V. K., Bugude, R., Sake, P. K., & Randall G, T. (2018). Use of Euphorbia sp.(Euphorbiaceae) as biofuel feedstock for semi-arid and arid lands. *Biofuels*, 1-11.

[39] Sousa, L. V., Santos, A. P. B., Souza, L. D., Santos, A. G. D., & Beatriz, A. (2018). Evaluation of the properties of calotropis procera oil aiming the production of biodiesel. *Orbital: The Electronic Journal of Chemistry*, *10*(2), 147-152.

[40] Bernabé-Antonio, A., Álvarez, L., Salcedo-Pérez, E., Toral, F. L. D., Anzaldo-Hernández, J., & Cruz-Sosa, F. (2015). Fatty acid profile of intact plants of two different sites and callus cultures derived from seed and leaf explants of Calophyllum brasiliense Cambess: A new resource of non-edible oil. *Industrial Crops and Products*, *77*, 1014-1019.

[41] Dash, S. K., Lingfa, P., & Chavan, S. B. (2018). An experimental investigation on the application potential of heterogeneous catalyzed Nahar biodiesel and its diesel blends as diesel engine fuels. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *40*(24), 2923-2932.

[42] Das, R., Shelke, R. G., Rangan, L., & Mitra, S. (2018). Estimation of nuclear genome size and characterization of Ty1-copia like LTR retrotransposon in Mesua ferrea L. *Journal of Plant Biochemistry and Biotechnology*, *27*(4), 478-487.

[43] Brock, J. R., Dönmez, A. A., Beilstein, M. A., & Olsen, K. M. (2018). Phylogenetics of Camelina Crantz.(Brassicaceae) and insights on the origin of gold-of-pleasure (Camelina sativa). *Molecular phylogenetics and evolution*, *127*, 834-842.

[44] Basili, M., & Rossi, M. A. (2018). Brassica carinata-derived biodiesel production: economics, sustainability and policies. The Italian case. *Journal of cleaner production*, *191*, 40-47.

[45] Tavares, G. R., Massa, T. B., Gonçalves, J. E., da Silva, C., & dos Santos, W. D. (2017). Assessment of ultrasound-assisted extraction of crambe seed oil for biodiesel synthesis by in situ interesterification. *Renewable energy*, *111*, 659-665.

[46] Altendorf, K., Isbell, T., Wyse, D. L., & Anderson, J. A. (2019). Significant variation for seed oil content, fatty acid profile, and seed weight in natural populations of field pennycress (Thlaspi arvense L.). *Industrial Crops and Products*, *129*, 261-268.

[47] Bateni, H., & Karimi, K. (2016). Biorefining of Eruca sativa plant for efficient biofuel production. *RSC Advances*, *6*(41), 34492-34500.

[48] Sabzalian, M. R., Saeidi, G., & Mirlohi, A. (2008). Oil content and fatty acid composition in seeds of three safflower species. *Journal of the American Oil Chemists' Society*, *85*(8), 717-721.

[49] Fadhil, A. B., Ahmed, K. M., & Dheyab, M. M. (2017). Silybum marianum L. seed oil: a novel feedstock for biodiesel production. *Arabian journal of Chemistry*, *10*, S683-S690.

[50] Tong, D., Hu, C., Jiang, K., & Li, Y. (2011). Cetane number prediction of biodiesel from the composition of the fatty acid methyl esters. *Journal of the American Oil Chemists' Society*, *88*(3), 415-423.

[51] Chang, F., Hanna, M. A., Zhang, D. J., Li, H., Zhou, Q., Song, B. A., & Yang, S. (2013). Production of biodiesel from non-edible herbaceous vegetable oil: Xanthium sibiricum Patr. *Bioresource technology*, *140*, 435-438.

[52] Azam, M. M., Waris, A., & Nahar, N. M. (2005). Prospects and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. *Biomass and bioenergy*, *29*(4), 293-302.

[53] Canoira, L., Alcantara, R., García-Martínez, M. J., & Carrasco, J. (2006). Biodiesel from Jojoba oil-wax: Transesterification with methanol and properties as a fuel. *Biomass and Bioenergy*, *30*(1), 76-81.

[54] Aworinde, D. O., Nwoye, D. U., Jayeola, A. A., Olagoke, A. O., & Ogundele, A. A. (2009). Taxonomic significance of foliar epidermis in

some members of euphorbiaceae family in Nigeria. Research journal of Botany, 4(1), 17-28.

[55] Correal Castellanos, E., & Pascual Villalobos, M. J. (1992). La familia Euphorbiaceae como fuente de aceites vegetales para la industria tecnoquímica. Grasas y aceites, 43(1), 39-44.

[56] Fermoso, J., Pizarro, P., Coronado, J. M., & Serrano, D. P. (2017). Advanced biofuels production by upgrading of pyrolysis bio‐oil. Wiley Interdisciplinary Reviews: Energy and Environment, 6(4), e245.

[57] Jain, S., & Sharma, M. P. (2010). Prospects of biodiesel from Jatropha in India: a review. Renewable and Sustainable Energy Reviews, 14(2), 763-771.

[58] Benavides, A., Benjumea, P., & Pashova, V. (2007). El biodiesel de aceite de higuerilla como combustible alternativo para motores diesel. *Dyna*, *74*(153).

[59] Salihu, B. Z., Gana, A. K., & Apuyor, B. O. (2014). Castor oil plant (Ricinus communis L.): botany, ecology and uses. *International Journal of Science and Research*, *3*(5), 1334-1341.

[60] Maneerung, T., Kawi, S., Dai, Y., & Wang, C. H. (2016). Sustainable biodiesel production via transesterification of waste cooking oil by using CaO catalysts prepared from chicken manure. Energy Conversion and Management, 123, 487-497.

[61] Medipally, S. R., Yusoff, F. M., Banerjee, S., & Shariff, M. (2015). Microalgae as sustainable renewable energy feedstock for biofuel production. BioMed research international, 2015.

[62] Imdadul, H. K., Masjuki, H. H., Kalam, M. A., Zulkifli, N. W. M., Alabdulkarem, A., Rashed, M. M., ... & How, H. G. (2016). Higher alcohol–biodiesel–diesel blends: an approach for improving the performance, emission, and combustion of a light-duty diesel engine. Energy Conversion and Management, 111, 174-185.