REVIEW OF BIODIESEL PRODUCTION FROM TRANSESTERIFICATION OF ESTERIFIED Carica Papaya OIL (CSO)

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Abstract: As a result of global urbanization and modernization, the use of petroleum (fossil fuel) is on the increase and there are growing concerns among stakeholders in the oil and gas industry over the depletion rate of petroleum reserves and its rising cost. The conversion of readily available sources of biomass to produce different types of biofuels to address the future energy crisis is one of the preferred attractive choices. Biodiesel is generally produced by the transesterification reaction of vegetable oils, waste vegetable oil or animal fats in the presence of a suitable catalyst. The choice of biodiesel as a preferred renewable source of energy was based on its biodegradability, non-toxic, lower emissions, sulphur free, low levels of polycyclic aromatic hydrocarbons (PAHs) and their nitrated compounds. This alternative source of energy is environmentally friendly and could be used in the existing diesel engines with little or no modifications. This will reduce the world’s dependence on fossil fuels that are non-renewable with the attendant environmental benefits to mankind.

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However, the use of these edible vegetable oils will put pressure on the food uses of such oil which will result to fuel-food crisis in the future. This impending crisis can be readily averted by exploring non-edible crops/agricultural waste biomass that can be grown or harnessed domestically and capable of producing oils as valuable raw materials for the emerging industry. A free fatty acid (FFA) lower than 3% is necessary to carry out the base catalysed reaction to end.

For biodiesel production, the higher the acid value of the oil, the lesser the conversion efficiency hence the need for esterification process. Papaya seed contains 27.3% to 28.3% protein, 28.2% to 30.7% lipids, and 19.1% to 22.6% crude fibers, it is not economically used. The majority of seeds are produced as residues and discarded as agricultural waste during fruit processing, generating environmental issues. Oil is abundant in papaya seeds (13.9% to 40.0%), which is rich in monounsaturated fatty acids and beneficial phytochemicals as tocopherol, carotene, and phenolics. This provides information on how to reduce pollution and make waste seeds lucrative. As a result, the CPSO is receiving an increasing amount of attention.

**Key words:** Biodiesel, Esterified, Carica Papaya Oil (Cso).

**INTRODUCTION**

As a result of global urbanization and modernization, the use of petroleum (fossil fuel) is on the increase and there are growing concerns among stakeholders in the oil and gas industry over the depletion rate of petroleum reserves and its rising cost. In addition to the increased energy demand, global energy security and the contributions of emission from the use of petroleum and its derived products resulting to global increase in greenhouse gases (GHGs), the mitigation of climate change would not be achieved if the search for alternative source of energy is not keenly considered [1-3]. To tackle the issue of environmental degradation and energy security, the use of cost effective, renewable and sustainable energy in the future is important. The conversion of readily available sources of biomass to produce different types of biofuels to address the future energy crisis is one of the preferred attractive choices [4, 5]. In the last few years, efforts were intensified by researchers across the globe to determine the applicability of vegetable oils which include oil from soybean, rapeseed, sunflower, safflower, palm oil, chrysophyllumalbidium, and canola; waste cooking oil, animal fats and their derivatives as sources of fuels [2, 5-8]. This will reduce the world’s dependence on fossil fuels that are non-renewable with the attendant environmental benefits to mankind.

However, the use of these edible vegetable oils will put pressure on the food uses of such oil which will result to fuel-food crisis in the future [5-7, 9, 10]. This impending crisis can be readily averted by exploring non-edible crops/agricultural waste biomass that can be grown or harnessed domestically and capable of producing oils as valuable raw materials for the emerging industry.

There is a growing interest in biodiesel (fatty acid mono alkyl ester) because of the similarity in its properties to those of petroleum based diesel. The idea of using vegetable oils from seeds of plants for internal compression ignition engine is well known.
Rudolf Christian Karl Diesel championed the early development of diesel engine which he designed to run on vegetable peanut oil with a view desire to improve on the steam engines of the late 1800s [8,10]. However, its sustainability elements were considered challenging which were considered. Shortly after his death in 1913, crude oil became the primary source of energy particularly its refined product popularly called diesel. With the availability of cheaper crude oil, the diesel engine was redesigned to accommodate the properties of petroleum diesel [8]. Biodiesel is generally produced by the transesterification reaction of vegetable oils, waste vegetable oil or animal fats in the presence of a suitable catalyst. The choice of biodiesel as a preferred renewable source of energy was based on its biodegradability, non-toxic, lower emissions, sulphur free, low levels of polycyclic aromatic hydrocarbons (PAHs) and their nitrated compounds. This alternative source of energy is environmentally friendly and could be used in the existing diesel engines with little or no modifications [5, 11, and 12].

Currently, commercial biodiesel is produced from oil of first-generation vegetable plants (soybean, rape seed, sunflower, safflower, palm oil and canola which compete with food/pharmaceutical and cosmetic uses, resulting to the rising cost of such oils and high price of biodiesel and food [5-7,9,10]. The current research is focus on the use of second generation biomass whose oils are non-edible for the commercial production of biodiesel to avert the impending fuel-food crisis as most countries are net importer of edible vegetable oils [5, 6]. These non-edible oils are usually sourced from low-cost feedstock or freely available. The cost of biodiesel is reportedly 60-80% of the cost of feedstock [5, 7, and 9] and producing biodiesel from these non-edible oil feedstocks will ultimately reduce the challenges associated with food security. The most identified non-edible oils are rubber, jatropha, castor, linseed, cotton, Karanja, neem, waste used oil, waste used engine oil and tobacco. The main challenge of using non-edible vegetable oil is the presence of high free fatty acids (FFAs) that consume the homogeneous base catalyst during transesterification reaction hereby lead to soap formation (saponification). The use of esterified acid is therefore needed to reduce the FFAs of the oil.

In addition, homogeneous catalysts are difficult to separate from the reaction mixtures after reaction completion. Meanwhile, the conventional method uses homogeneous or heterogeneous catalysts depending on the FFAs and moisture content of the oil. The common conventional homogeneous catalysts for transesterification reaction are NaOH, KOH, carbonates and the alkoxides of Na and K. Acids such as H₂SO₄, HCl, H₃PO₄ and organic sulphonic acids are used for esterification (pre-treatment) process prior to transesterification (by alkalis) reaction for oils with high values of FFAs [5].

The homogeneous alkali-based transesterification is commercially used if the vegetable oil is substantially low in FFAs (<1% i.e. equivalent to 2 mg.KOH/g triglyceride) to prevent soap formation (saponification reaction) and allows easy separation of glycerol by-product. One of the sustainable non-edible oil whose waste is abundant on earth after consumption of the fruit is Carica papaya seed.

Literature on the fruit plant assessed total world production in 2020 was estimated at 13,894,705 metric tons, which is 1.9% higher than 2019 production. India is reported to be the leading producer of Carica papaya, accounting for over 43% of global production.

Based on report by FAOSTAT in 2020, production of Carica papaya globally is estimated to rise by 2.1 percent each year, up to 16.6 million tons in 2029. Furthermore, the reports from literature indicted that a single seed of Carica papaya account for 26-40% oil content, but depend solely on the ranges of the fruits [29].
This seed is non-edible oil, non-environmentally friendly, and in fact it has posed disposal problems, causing more death to aquatic animals, plants and domestic animals when discharged in water or land [13-16].

Utilization of the abundant *Carica papaya* seed in the world will reduce the dependence on fossil fuel as the main source of energy. This will reduce the prices of alternative sources of oil that is presently being used for commercial biodiesel production. Studies have shown that nano-catalysts such contain CaO, Al₂O₃, K₂O, SiO, and other compound derived from agricultural solid wastes are excellent heterogeneous base catalysts for the transesterification of oil to biodiesel [17-19].

**Biodiesel**

Researchers are searching for a viable replacement of petroleum-based fuels due to their high level of pollution to the ecosystem (land, air and sea) arising from their uses. Renewable energies (biomass, hydropower, solar, tidal waves, wind and geothermal) have been proposed as attractive preferences [20, 21]. However, biomass is considered as the cheapest source of renewable energy.
The earliest engine experimented by Rudolf Christian Karl Diesel were designed to run on vegetable peanut oils [8,10] which were later redesigned to accommodate the properties of petro-diesel when crude oil became abundant. The problem of atomization of high viscosity associated with vegetable oils did not allow the use of these oils in the newly redesigned diesel engines. The problem of high viscosity associated with oil from plant seeds can be alleviated by applying such methods as blending directly with petroleum diesel, micro-emulsification, pyrolysis and transesterification. Transesterification is the most viable method employed today for the production of biodiesel from vegetable oil, waste used oil and animal fats [22]. The transesterification methods for biodiesel production available in literature are conventional base-catalyzed process, in-situ process, enzymatic process, supercritical process, co-solvent process, ultrasonic assisted and microwave-assisted process [23].

**Feedstock’s employed for Biodiesel Production**
The feed stocks employed in biodiesel production are generally classified into vegetable oils, animal fats, and waste oils [24-27]. In recent times, several oils, including non-edible oils such as *Jatropha curcas* Linn, Oil palm (*Elaeisguineensis*), *Moringa oleifera*, Shea butter, Bitter melon, Kenaf, Kahalari Melon, palm kernel, animal fat, waste oils and Pumpkin (*Cucurbita maxima*) seeds have been used in the making of biodiesel [28-32].

Important consideration in selecting feedstock for biodiesel production includes: price, inconsistency in the quality and the chemical content feedstock, regular accessibility of the feedstock, elasticity to increases supply and cost of convey and pretreatment. The current production of animal fat and vegetables oils is not sufficient to completely replace fossil diesel fuel. In order to lower the costs of production of biodiesel and to widen its feedstock base, waste cooking oil can be used. Certain quantities of used cooking oil are available all over the world. These are generated locally wherever food is cooked or fried in oil, for example, hotels, restaurants, KFC, etc. Nigeria does not have statistical data about the amounts of feedstock available. Nevertheless, an educated presumption can be made for waste cooking oil discarded annually in Nigeria. This amount is about 32 million metric tonnes of waste annually.

Better disposal of used waste oil creates a significant challenge because of problems associated with dumping and possible pollution of water and land resources. Some of the used cooking oil is used for soap preparation and as an oil additive for fodder production. Nevertheless, major quantities of used waste oil are dumped illegally into landfills and rivers causing environmental pollution. [33–34] Used of waste used oil for biodiesel production to contribute to a reduction of greenhouse gases as well as eliminate the pollution of landfills and water.

**Advantages and Disadvantages of using Biodiesel**
The advantages of using biodiesel fall into three broad categories, environmental impact, energy security and economic impact. Concerning environmental impact, biodiesel from vegetable oil causes a 57% reduction in greenhouse gases compared to fossil diesel. Indeed, biodiesel from cooking oil has an 86% reduction in greenhouse gases compared to fossil diesel.
Some of the harmful exhaust emissions are positively affected in that biodiesel reduces particulate matter by 47% compared to fossil diesel [9]. Ultimately, biodiesel is renewable, it is plant based, and so when is used can be re-grown.

With reference to energy security, it is important to consider that fossil oil is a limited resource. On the other hand, biomass is a renewable resource and locally available in many countries. National dependence on fossil oil is reduced by production of energy from locally available sources such as biomass. Concerning economic impact, the bio-energy sector employed 2.8 million people globally in 2014. There is direct support for local agriculture: it is another way to support farmers. It has also been found that engine life is longer: biodiesel is a natural lubricant. Finally, biodiesel has a pleasant exhaust smell: When burned, the fuel emits a fried food or barbecue aroma.

**Transesterification of Oils**

Transesterification or alcoholises of different types of oils, triglycerides react with alcohol, generally methanol or ethanol, to produce esters and glycerine. To make it possible, a catalyst is added to the reaction [35]. The overall process is normally a sequence of three consecutive steps, which are reversible reactions. In the first step, from triglycerides, diglycerides are obtained, the second step produced monoglycerides from diglycerides and in the last step, and from monoglycerides glycerine is obtained. In all these reactions esters are produced. The stoichiometric relation between alcohol and the oil is 3:1. However, an excess of alcohol is usually more appropriate to improve the reaction towards the desired product. This process has been widely used to reduce the viscosity of triglycerides. Transesterification is one of the reversible reaction processes and proceeds essentially by mixing the reactants. However, the presence of a catalyst (a strong acid or base) accelerates the conversion.

**Variables Affecting Transesterification Reaction**

The process of transesterification is affected by various factors depending upon the condition used. Factors such as: FFA and moisture content, catalyst and concentration type, molar ratio of oil/methanol ratio, temperature and reaction time and effect of mixing.

The effects of these factors are in this section.

**Effect of free fatty acid and moisture**

In transesterification process, free fatty acid and moisture content are input parameters for formative the feasibility of the vegetable oil. A free fatty acid (FFA) lower than 3% is necessary to carry out the base catalysed reaction to end. For biodiesel production, the higher the acid value of the oil, the lesser the conversion efficiency hence the need for esterification process. Both, in excess as well as low amount of catalyst may cause soap formation [36]. The initial materials used for base catalysed alcoholyses ought to convene certain specifications. The triglycerides should have lower acid value and all material should be substantially anhydrous. The addition of sodium hydroxide catalyst compensates for higher acidity, but the resulting soap causes an increase in viscosity or formation of gels that interferes in the reaction as well as with separation of glycerol [37].
The ester yields may be drastically reduced when the reaction conditions are not met. The methoxide and hydroxide of sodium or potassium ought to be maintained in anhydrous status. Prolonged contact with air, interaction with moisture and carbon dioxide will diminish the effectiveness of these catalysts.

**Effects catalysts and concentration type**

Catalysts used for the transesterification are classified as alkalis, acid, enzyme or heterogeneous catalysts, among which alkali catalysts like sodium hydroxide, sodium methoxide, potassium hydroxide, potassium methoxide are more effective [38]. For the oil with high FFA content and more water, acid catalysed is suitable. The acids could be sulphuric acid, phosphoric acid, hydrochloric acid or organic sulfonic acid. Metanalysis of beef tallow was studied with catalysts NaOH and NaOMe. The NaOH used as a catalyst was significantly better than NaOMe when compared [24]. Sodium methoxide causes formation of several by-products mainly sodium salts, which are to be treated as a waste. It was observed that there is a need for high quality of oil with this catalyst [22]. As a catalyst in alkaline metanalysis, most sodium hydroxide or potassium hydroxide have been used, both in concentration from 0.4 to 2% w/w of oil. A successive conversion can be reached when refined and crude oils with 1% either sodium hydroxide or potassium hydroxide. Metanalysis of soybean oil with the catalyst 1% potassium hydroxide has given the best yields and viscosities of esters [24]. Although chemical transesterification using an alkaline catalysis process gives high conversion levels of triglycerides to their corresponding methyl esters in short reaction times, several drawbacks can be seen in the reaction: glycerol recovery is difficult, it is energy intensive, alkaline waste water require treatment, the acidic or basic catalyst has to be removed from the product, free fatty acids and water interfere in the reaction. Enzymatic like lipases are able to effectively catalyse the transesterification reaction of triglycerides in either aqueous or non-aqueous systems, which can overcome the aforementioned problems [22]. In particular, the by – products, glycerol can be easily removed without any complex process, and also that FFA contained in waste oils and fats can be entirely converted to alkyl esters. On the other hand, the production cost of a lipase catalyst is significantly greater than of an alkaline one.

**Effects of molar ratio of alcohol to oil and type of alcohol.**

One of the most important variables affecting the yield of ester is the molar ratio of alcohol to triglyceride.

The stoichiometric ratio for transesterification requires three moles of alcohol and one mole of triglyceride to yield three moles of fatty acid alkyl esters and one mole of glycerol. However, transesterification is an equilibrium reaction in which a large excess of alcohol is required to drive the reaction to the right. For maximum conversion to the ester, molar ratios of 6:1 need to be used. The molar ratio has no effect on acid, peroxide, saponification and iodine value of methyl esters [39]. However, the high molar ratio of alcohol to vegetable oil interferes with the separation of glycerine because solubility increases. Equilibrium shift to the left when glycerine remains in solution, lowering the yield of the esters.

The base catalysed formation of ethyl ester is difficult compared to the formation of methyl esters.
Specifically, the formation of stable emulsion during ethanolysis is a problem. Methanol and ethanol are immiscible with triglycerides at ambient temperature, and the reaction mixtures are mechanically stirred to enhance mass transfer. During the course of reaction, emulsions usually form. In the case of metanalysis, these emulsions quickly and easily break down to form a lower glycerol rich layer and methyl ester rich layer. In ethanolysis, emulsions are easily stable and severely complicate the separation and purification of esters [37]. The formation of monoglyceride and triglycerides as intermediates products shows that both has polar hydroxyl group and non-polar hydrocarbon chains. These intermediate are strong surface active agents. In the process of alcoholysis, the catalyst, NaOH/KOH is dissolved in polar alcohol phase, in which triglycerides must transfer in order to react. The reaction is initially mass – transfer controlled and does not conform to expected homogeneous kinetics. At critical level of higher concentration of the intermediates, emulsion form. The concentration of both intermediates will be very low when the emulsion becomes unstable. Hence, the reaction must be complete as much as possible in order to reduce the concentration of the mono and diglycerides.

Effects of reaction time and temperature
As the reaction time increases, the conversion rate increases. The transesterification of peanut, cotton-seed, sunflower and soybean oil under the condition of methanol/oil molar ratio 6:1, 0.5% sodium methoxide catalyst and 60 °C was carried out by [40]. The conversion was almost the same for the four oils after an hour 93 – 98% (w/w). [41] Studied the effect of reaction time on transesterification of beef tallow with methanol. The reaction was very slow during the first minute due to mixing and dispersion of methanol into beef tallow. The reaction proceeds faster from the first 5 min and the production were at maximum level as the reaction reach 15 min. It has been observed that the optimum reaction time reported by different authors was 7 h [42-45]. Transesterification takes place at any different temperatures depending on the type of oil used. [46] Studied the production of biodiesel from crude Neem oil feedstock and its emissions from internal combustion engines. The optimum reaction temperature for the oil yield was at 60 °C, [47] studied the application of response surface methodology for the optimizing transesterification of Moringa oleifera oil and recorded the optimum temperature to be 55°C, while optimization of the transesterification reaction from cottonseed oil using a statistical approach was done by [45]. The maximum temperature for highest oil yield was 65°C which mean the temperature clearly influenced the reaction rate and the yield of esters.

Effects of mixing/agitation
Since the oil is immiscible with NaOH - methanol solution, mixing is very important in the process of transesterification reaction. Once the two phases mixed, agitation is no longer needed [41] studied the effect of mixing on transesterification of beef tallow. No reaction was observed without mixing and when NaOH - MeOH was added to the melted beef tallow in the reactor while stirring, stirring speed was significant. Reaction time was the controlling factor in determining the yield of methyl esters. This suggested that the stirring speeds investigated exceed the threshold requirement of mixing.
Effect of FFA and Oil preheating
Because of nature and long chains present in the triglyceride, there is always a need to determine the FFA of the oil. The FFA ≤ 1.5 is only applicable to base catalyst transesterification process. Values higher ≥ 1.5 will need two steps approach (Acid first, then base catalysts). Apart from this factor that affects the biodiesel production, the preheating time of the oil is also important. Oil must be preheated for a particular time before being used for the biodiesel production.

Catalysts
Many chemical reactions involved the use of one or more catalysts for reaction to reach completion. The type of catalyst used in a particular reaction depends solely on the reaction conditions and the nature of reactants involved. Although catalysts are not to be consumed in the reaction, its presence speeds up or limits reaction rate, and itself recover at the end of product formation. Nowadays, industries such as pharmaceuticals, polymers, petroleum, electronic, environmental treatment, chemical, and agrochemical industries employ the use of catalysts to achieve the end products. Also, the use of catalysts occupies an important place in academic research. A recent report revealed that the worldwide marketplace price of catalysts stood at USD 26.1 billion in 2019, and is anticipated to increase by 4% in 2020, and 4.5% progress (https://www.grandviewresearch.com/industry-analysis/catalyst-market. Retrieved date: November 12th, 2022) rate in 2025 according to Compound Annual Growth Rate (CAGR). This makes it a value-added income for the financial sustainability of all nations if biomass waste can be employed. However, catalysts are primarily divided into four categories; homogeneous catalyst, heterogeneous catalyst, heterogenized-homogeneous catalysis, and biocatalysts. Homogeneous catalysis involved the operation of the mixture in the same phase, the possible reactant and the catalyst exhibit a high uniform phase due to high reactivity and selectivity. Most oxidation, carbonylation, hydrogenation, esterification, and hydrocyanation are homogeneous catalysis in reaction. However, this nature of catalyst usage comes with its shortcoming, which includes among others recoverability problem, highly toxicity, and high cost, especially in esterification (bio-fuel production) case [22].

Heterogeneous Catalyst
Heterogeneous catalysis, on the other hand, involved the mixture that exists in different phases; the catalyst usually solid support or bulk form does not dissolve in the reactant, yet exhibit high reactivity. The advantages include ease of recoverability and reused, non-toxic, and of low cost [22]. These have made many industries such as hydrocarbon produced company (Fischer process), ammonia synthesis company (Haber-Bosch process), sulphury acid company (Contact process), soap making company (Saponification process), and petroleum company (transesterification process) to adhere to the use of this catalysts, apart from these advantages, heterogeneous catalysts produce in smaller particle size increase its activity due to surface phenomenon. The smaller the particles size the larger the surface area of catalysts during the reaction.
Heterogenized-homogeneous catalysis
Heterogenized-homogeneous catalysis is the mixture of the heterogeneous and homogeneous catalysts together. The homogeneous catalyst is embedded onto the solid supports to prepare the heterogenic analogy. However, these catalysts are difficult to produce due to complexity, less selectivity, reactivity, and covalent bonding between the polymer chain and the surface atoms (grafting) [20].

Biocatalysts
Biocatalysts are usually referred to as enzymes or ribozymes catalysts obtained from plants, microbes, or Goat tissue, which are used to catalyst reaction that takes place outside the living cells. This type of catalyst is on high industrial usage and has been considered an alternative to most industrial conventional catalysts due to the advantages such as mild reaction conditions, high selectivity, high efficiency, and non-toxic. Companies such as, dairy, baking, detergent, leather, textile, and biofuel utilized this catalyst for their production. Its major drawbacks are inability to convert a cellular catalyst into a bioprocess, difficulty in recoverability (brewing process) sustainability in harsh environmental conditions during culture (high temperature, extreme pH, high salt concentrations, organic solvent), instability in aqueous media (protein), cofactor dependability (non-protein chemical compound), possibility of an allergic reaction, and inactivation through inhibition [16].

Carica papaya oil (CSO)
Carica papaya belongs to a family Caricaceae is a tropical plant that grows wild throughout the tropics. It has a lot of biologically active chemicals in it. Candy, jam, jelly, and pickles are all made from papaya, Because of the nutritional and functional elements found in papaya seeds, which account for about 20% of the total weight of the fruit [60], they could be potentially helpful. The tree's high concentration of natural self-defense chemicals makes it extremely resistant to insect and disease invasion.

CONCLUSIONS
In conclusion, papaya seed is edible and can be used as a substitute for black pepper because of its fiery flavor. Papaya seed, in fact, contains 27.3 percent to 28.3 percent protein, 28.2 percent to 30.7 percent lipids, and 19.1 percent to 22.6 percent crude fibers; nonetheless, it is not economically used. The majority of seeds are produced as residues and discarded as agricultural waste during fruit processing, generating environmental issues. Oil is abundant in papaya seeds (13.9 percent–40.0 percent), which is rich in monounsaturated fatty acids and beneficial phytochemicals as tocopherol, carotene, and phenolics. Furthermore, Carica papaya seed oil (CPSO) is discovered to be resistant to oxidation and can be produced into a new form of cooking oil with higher health benefits in the food business [36]. This provides information on how to reduce pollution and make waste seeds lucrative. As a result, the CPSO is receiving an increasing amount of attention.
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**Apstrakt:** Kao rezultat globalne urbanizacije i modernizacije, upotreba nafte (fosilnog goriva) je u porastu. Postoji sve veća zabrinutost između zainteresovanih strana u industriji nafte i gase zbog stope iscrpljivanja rezervi nafte i njene sve veće cene. Konverzija lako dostupnih izvora biomase u proizvodnju različitih vrsta biogoriva za rešavanje buduće energetske krize je jedan od poželjnih atraktivnih izbora. Biodizel se generalno proizvodi reakcijom transesterifikacije biljnih ulja, otpadnog biljnog ulja ili životinjskih masti u prisustvu odgovarajućih katalizatora. Izbor biodizela kao poželjnog obnovljivog izvora energije bio je zasnovan na njegovoj biorazgradivosti, netoksičnosti, nižim emisijama, bez sumpora, niskim nivoima policikličnih aromatičnih ugljovodonika (PAH) i njihovih nitratnih jedinjenja. Ovaj alternativni izvor energije je ekološki prihvatljiv i mogao bi se koristiti u postojećim tipovima dizel motora uz male ili nikakve modifikacije. Ovo bi smanjilo svetsku zavisnost od fosilnih goriva koja nisu obnovljiva sa pratećim ekološkim prednostima za čovečanstvo.

Međutim, upotreba ovih biljnih ulja izvršiće pritisak na upotrebu takvog ulja u ishrani, što će dovesti do krize sa hranom u budućnosti. Ova predstojeca kriza može se lako spreći istraživanjem nejestivih useva ili biomase poljoprivrednog otpada koji se mogu gajiti ili iskoristiti za proizvodnju ulja kao vredne sirovine za industriju u nastajanju. Slobodna masna kiselina (FFA) niža od 3% je neophodna da bi reakcija katalizacijom (bazom) bila završena. Za proizvodnju biodizela, što je veća kiselinska vrednost ulja, to je manja efikasnost konverzije, stoga je potreban proces esterifikacije.

Semenka *Carica Papaya* (Papaja) sadrži 27,3% do 28,3% proteina, 28,2% do 30,7% lipida i 19,1% do 22,6% sirovih vlakana, ne koristi se ekonomično. Većina semenki u proizvodnji ulja su ostaci i odbacuju se kao poljoprivredni otpad tokom prerade, što dovodi i do evidentnih ekoloških problema. Ulje *Carica Papaya* (Papaja) (sadržaj 13,9% do 40,0%), je bogato mononezasičenim masnim kiselinama i korisnim fitohemikalijama kao što su tokoferol, karoten i fenoli. Ovo pruža informacije o tome kako smanjiti zagađenje i učiniti otpadno seme unosnim. Kao rezultat toga, seme *Carica Papaya* (CPSO) dobija sve veću pažnju.

**Ključne reči:** biodizel, esterifikovano, *Carica Papaya* ulje (CSO).

**Prijavljen:**
**Submitted:** 22.12.2023.

**Ispriavljen:**
**Revised:** 22.01.2024.

**Prihvaćen:**
**Accepted:** 05.02.2024.