Experimental Investigation of Different Extraction Methods for Producing Biofuel from Jatropha Seeds and Castor Seeds

Mohammed Khalaf, Waleed Abdel-Fadeel, H. M. Abu Hashish, Daniel Eutyche Mbadjoun Wapet, Mohamed Metwally Mahmoud, Salama Abd Elhady, and Mohamed F. C. Esmail

1Faculty of Energy Engineering, Aswan University, Aswan 81528, Egypt
2Mechanical Engineering Department, National Research Centre, Giza 12622, Egypt
3National Advanced School of Engineering, University of Yaounde I, Yaounde 510, Cameroon

Correspondence should be addressed to Mohammed Khalaf; mohammed_khalaf@energy.aswu.edu.eg and Daniel Eutyche Mbadjoun Wapet; eutychedan@gmail.com

Received 9 November 2022; Revised 26 May 2023; Accepted 7 June 2023; Published 20 June 2023

Academic Editor: Abdurrahman Saydut

Copyright © 2023 Mohammed Khalaf et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

While energy production is highly dependent on fossil fuels, which consider the main source of global warming, biofuels would play a significant impact in diminishing such warming. In this paper, biooils were extracted from inedible seeds (Jatropha and Castor) using different continuous devices (solvents, screw presses, and hydraulic press-machines), aiming to achieve the highest oil’s yield of improved extraction properties at reduced time and energy. A wide range of engine speeds of 35, 60, 85, 110, and 135 rpm and preheating temperatures of 100, 125, 150, 175, 200, and 250°C were extensively studied to find their impact on the extraction properties. Results proved the ability of the screw press machine to extract the highest biooil yields from Jatropha and castor seeds. The optimum yield of Jatropha and castor were achieved at an extraction temperature range of 150-175°C at a motor speed of 135 rpm and a temperature range of 200-250°C at a motor speed of 35 rpm, respectively. Noteworthy, the yield of extracted castor oil is potentially solidified at low temperatures <100°C, leading oil samples to become like a dough. In contrast, lowering the temperatures of the Jatropha seeds improved the physical and chemical properties of the extracted oil. At a certain temperature (e.g., 100°C), the properties of both extracted and diesel oils are quite similar, which can be used directly in diesel engines.

1. Introduction

One of the most urgent global issues currently is the global energy crisis that is predominantly attached to the earth’s fast-depleting fossil fuel resources [1, 2]. As the transportation sector is almost entirely dependent on conventional fuels, especially petroleum-based fuels such as gasoline and diesel fuel, numerous nations have vigorously advanced the utilization of alternative fuels that are produced from agriculture [3, 4]. Compared with diesel fuel, biofuel reduces carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM) emissions. In addition, biofuel can be used successfully in railway locomotives, stationary agricultural equipment, and road transport, including long-distance trucks, garbage trucks, and school buses [5, 6].

Rudolf Diesel, the inventor of the diesel engine, first used vegetable oil and peanut oil in a diesel engine at the 1900 World Exhibition in Paris. He also confirmed that vegetable oil could be used in any diesel engine and that it could significantly improve agriculture [7, 8]. Many countries are moving to biodiesel production and use as a result of his prediction [9, 10]. The energy content of diesel fuel is almost similar to the energy content of safflower, Jatropha, sunflower, cottonseed, rapeseed, castor, and peanut oils; however, diesel engines have problems with atomization and vaporization when using these oils directly. This is mainly attributed to the higher density and
viscosity and lower caloric values of these oils compared with conventional diesel fuel. [11]. Since edible vegetable oils are more expensive, researchers are looking for nonedible vegetable oils like Jatropha and castor to produce biodiesel [12]. Biodiesel is a fuel made from vegetable or animal fats containing monoalkyl esters. Biodiesel fuels are widely used today and have a seal of benefits, including being a renewable energy source and lowering carbon monoxide, hydrocarbon, and particulate matter emissions [13]. Oil can be extracted mechanically using a press (ram, hydraulic, or screw) or chemically using organic solvents or water, using the three-phase partitioning extraction method or the supercritical extraction method [14].

Manual and relatively simple methods were used in the past to extract oil from seeds; however, these methods are no longer in use. Mechanically, Jatropha oil may be extracted by pressing the kernels. Oil expellers were used to extract oil from Jatropha seeds. Sundhara (or Sayari) oil expellers and Komet expellers are the most well-known types of expellers. Electrician expellers, such as the single screw Komet expeller, also extract oil from Jatropha seeds. It is critical to design the screw press to produce a higher yield while maintaining acceptable oil physical properties [15]. There are now modern approaches for aqueous enzymatic therapy, such as ultrasonication and the use of chemicals. The aqueous enzymatic process produces a maximum yield of about 74% [16]. Experiments were carried out to determine the effects of moisture content, cooking temperature, and cooking time on the yield of mechanically extracted oil from Jatropha seeds using a screw press expeller. When Jatropha seeds were conditioned to a dry basis moisture level of 9.69% and cooked at 110°C for 10 minutes, a maximum oil recovery of 73.14% was obtained [17]. The effect of extraction pressure and temperature, as well as moisture content, on oil yield for sesame, linseed, rapeseed, palm kernel, and Egyptian Jatropha, was examined. Oil yield increases as extraction pressure and temperature rise. The extraction rate increased with decreasing extraction temperature and moisture content [18].

According to Oyinlola et al. [19], the pressed cake contains 42–45% protein, 5–6% moisture, and 7–8% oil. Castor beans contain approximately 30-35% oil, which can be extracted using a variety of processes or a combination of processes such as hydrate presses, continuous screw presses, and solvent extraction. Supercritical carbon dioxide extraction (SCE) is a high-yielding oil extraction method that does not depend on organic solvents. In this method, the oil is dissolved in CO2 and extracted from the plant material. The SCE method yielded an actual extraction rate of 37.45%; the final oil product contained KOH (0.79 mg/g) and peroxide (3.63 meq/g). *Jatropha curcas* seeds were collected and powdered. The extraction pressure was 43 MPa, the extraction temperature was 47°C, the CO2 flow rate was 20 kg/h, and the extraction time was 80 minutes [20]. Nowadays, Soxhlet’s extraction is used as a reference method when evaluating conventional methods based on other principles. Most conventional methods display many similarities with the Soxhlet in that they are time consuming and require a large amount of solvents. On the other hand, because they are relatively simple in terms of performance and fundamentals, their development does not require the use of specialized personnel. Finally, these methods are inexpensive, which has greatly favored their widespread use, particularly in industries and laboratories. [21]. In Indonesia, Jatropha oil is typically extracted using a hydraulic press and a solvent method. Jatropha oil contains 40–60 g of oil per 100 g of Jatropha seed kernels. The hydraulic press method yields 47.2% of Jatropha oil at a maximum pressure of 20 bar, and the oil extraction is done twice. By extracting with hexane for three hours at room temperature, a yield of 43.80% oil was obtained; increasing the extraction time did not affect extraction efficiency [22].

Shah et al. [23] concluded that Jatropha seed kernels yielded 44 g of oil per 100 g. The oil yield from extracting *J. curcas* with petroleum ether (b.p. 40–60°C) in a solvent extractor was 46–48.6%. Su et al. [24] found that extracting Jatropha seed oil with n-hexane yielded 54.90%, methyl acetate yielded 55.92%, and ethyl acetate yielded 56.65%. To extract oil from seeds, various forms of technology are available. A study investigated by Ibrahim et al. [25] used a screw press to extract oil from Jatropha seeds. The maximum extraction yield from measurements is 19.83% at a screw speed of 20 rpm and extraction preheating temperature of 75°C. Raja et al. [26] investigated Jatropha oil extraction and its characterization by using hydraulic pressing. Seeds are placed on a sieve plate covered with fine wire mesh in a temperature controlled (30-100°C) pressing chamber with a definite diameter. Pressures up to 100 MPa are exerted by a hydraulic plunger, and this process yields about 10% of the oil extracted. According to Nangbes et al. [27], castor beans contain approximately 30-35% oil, which can be extracted using a variety of methods including cold press and solvent extraction. Furthermore, Kulikarni and Sawan [28] stated that the castor bean contains 35-55% oil by weight for high-yield breed types and has one of the highest viscosities among vegetable oils, with a molecular weight of 298. In Tanzania, Jatropha oil can only be obtained mechanically using a ram press or a screw press, both of which are small hand presses. The seeds are poured by applying pressure to the seeds using the ram press method. The extracted oil is dripped into a container. This press has a low extraction rate because the seedcake that remains after pressing contains some of the oil. 5 kg of seed is required to produce 1 L of oil, with a capacity of 1.5 L/h [29].

The extraction process affects oil yield, extraction time, and the physical and chemical properties of the oil produced. The extraction method affects engine performance and emissions. Oil was extracted from Jatropha and castor seeds using a stationary screw press with a cylindrical barrel and helical screw on a conical shaft supported by rotary shaft bearings. [30]. The seeds to be pressed are fed into the hopper, and the cake is passed from the barrel’s other end, with the oil discharging through small holes in the barrel’s bottom. The hopper feeds the seeds to be pressed into the cylindrical barrel to the screw, which then passes the cake to the other end of the barrel and discharges the oil through small holes in the barrel’s bottom. [30]. These oils cause atomization and vaporization problems when used directly in diesel engines. Blending, thermal cracking, emulsification, and transesterification can all be used to solve these problems [31]. In diesel engines, vegetable oils can be combined with diesel oil and checked. Transesterification is a reaction that produces esters (biodiesel) and
glycerol from triglycerides and alcohols (ethanol or methanol), and the catalysts used were potassium hydroxide (KOH) and sodium hydroxide (NaOH) [32].

It is worth mentioning that the physical and chemical properties of oils extracted from Jatropha and Castor seeds depend on the tree’s growth conditions such as climatic parameters, soil properties, and tree growth treatments. In addition, based on our knowledge, studies on Jatropha and castor oil extraction methods from seeds under Egypt’s climatic conditions and selecting the best methods to extract the optimum oil yield with lower energy consumption and with acceptable physical and chemical properties are still missing in the literature. So, the main purpose of this research is to compare the different oil extraction methods from inedible seeds and select the best methods that increase the extraction yield of oil from Jatropha and castor seeds to make it commercially viable. The three methods of oil extraction investigated in this study are the screw press, hydraulic press, and solvent. The effects of extraction time, temperature, energy, and oil yield were all investigated. When these extraction processes are compared, the yield is higher, and the extraction time is shorter. The higher yield, shorter extraction time, and optimal physical and chemical properties of these extraction processes were compared.

2. Materials and Methods

Jatropha and castor’s fruits were collected from the Beheira farm in Nubaria, Egypt. The seeds are handpicked and, based on their brown skin, mature. Seeds were peeled by hand, and, after detoxification, seed peels and cakes were used as animal feed. *Jatropha curcas* is a plant belonging to the *Euphorbiaceae* family that produces a significant amount of oil from its seeds. This is a nonedible oil-bearing plant widespread in arid, semiarid, and tropical regions of the world. Jatropha is a drought-resistant perennial tree that grows in marginal lands and can live for over 50 years. The oil content in Jatropha seed is reported to be in the range of 30 to 50% by weight of the seed and ranges from 45 to 60% by weight of the kernel itself [26]. Since the oil is inedible, it has a bad taste. Jatropha oil can be used in many applications, including cooking, lubrication, paint binders, and lighting lamps. This oil is used to treat skin diseases as herbal medicine. Because of its lower density, viscosity, and higher calorific value, Jatropha oil can be used in a conventional diesel engine. Jatropha biodiesel can be made from Jatropha oil using oil pretreatment and used in diesel engines and oil burners. [33]. The castor oil plant, *Ricinus communis*, is a species of flowering plant in the spurge family, *Euphorbiaceae*. Castor is native to the south-eastern Mediterranean Basin, Eastern Africa, and India. Castor seed is the source of castor oil, which has a wide variety of uses. The seeds contain between 40 and 60% oil that is rich in triglycerides, mainly ricinolein [34]. Castor seed contains castor oil, which has a wide range of applications. Castor has a major advantage over Jatropha and Pongamia in that its growing season is much shorter, and farmers have much more information about its cultivation [35]. The sequence of oil extraction from the seed fruits into the final products is shown in Figure 1.

2.1. Solvent Extraction Method. The solvent is a chemical extraction method; the raw material is treated with hexane or petroleum ether in the solvent extraction process. The oil is then extracted by distillation from the miscella, which is a mixture of oil and solvent. The solvent dissolved in the cake is extracted by evaporation and condensation from miscella distillation. The solvent that is recovered is then used to extract oil. The higher solubility of oils and fats in hexane or petroleum ether, which has a boiling point of 67 C, is one of the main properties used in the solvent extraction process. The solvent is unable to penetrate the Jatropha and castor seeds’ hard shells. In a conical flask, petroleum ether was combined with powdered Jatropha and castor seeds for 24 hours, yielding a weight ratio of 1:1.5. Oil is combined with petroleum ether after 24 hours, and the mixture is filtered to remove residuals. In a conical flask, petroleum ether is added to powdered Jatropha seeds for a further 24 hours. To obtain petroleum ether purity, this method was repeated more than five times, as shown in Figure 2. The oil is then removed from the mixture which has been collected. The rotary evaporator is a system that evaporates solvents from samples in an effective and delicate method. In addition to distillates and extracts, rotary evaporators are used in molecular cooking. It was used to extract oil from a solution of oil and solvent. The rotary evaporator motor rotates at 115 rpm, has a temperature of 40°C, and has a pressure of 2 bar.

2.2. Hydraulic Press Method. The hydraulic press consists of three main parts, which are the piston base, the circular slats, and the cylinder in which the seeds are placed for squeezing. The cylinder is filled with seeds and the circular slices are placed after each appropriate amount of seeds to distribute the acting force on the seeds evenly to produce the largest amount of oil. The oil is collected through the holes in the body of the cylinder, and the squeezed oil is collected at the bottom of the cylinder. The production of oil using a hydraulic press is less than other methods because part of the oil is absorbed by the Jatropha seeds or castor after removing the force acting on it. Figure 3 shows the main parts of the hydraulic press.

2.3. Screw Press Method. Mechanical press extraction is a high-yielding continuous extraction method. Jatropha seeds produce up to 25% of the seeds with a significant amount of oil, and castor seeds produce about 36% of the seeds with a significant amount of oil. This screw press is made up of three main components: the base (3 and 4), the housing (5), and the screw (7). After that, the screw is inserted into the housing, which supports the base. The seeds are fed into the swirling system or hopper (9) through circular holes in the base and housing. The oil is extracted through the housing’s holes (14). An electric motor (1) is attached to a gearbox (2) to reduce the rotational speed of the screw. A frequency inverter (10 and 13) controls the rotational speed, while a direction switch (11) controls the motor speed. The
seeds are preheated using heaters (6), and the temperature (8) is controlled using a wireless temperature thermostat (12). The screw press is a simple and efficient way to extract oil from Jatropha and castor seeds. Oil has been extracted from Egyptian nonedible seeds with high yields, and it has proven to be effective and efficient. For extracting oil with the desired properties, a higher yield and optimum screw operating conditions were achieved. The optimum condition for Jatropha seeds was a screw rotation speed of 135 rpm and a preheating temperature of 175°C, while the optimum condition for castor seeds was a screw rotation speed of 35 rpm and a preheating temperature of 250°C. A schematic diagram of the screw press and its sections is shown in Figure 4.

3. The Lovibond Scale

Figure 5(a) shows the Lovibond scale, often known as degrees Lovibond or abbreviated as L, which is a color measurement system invented by Joseph Lovibond in the 1860s. As shown in Figure 5(b), the sample is placed in a "Tintometer" that also contains many numbered tinted glass discs to determine color. The value assigned to the disc whose color most closely matches the sample is the Lovibond color. The Lovibond scale was developed to measure the colors of gases, but it has subsequently been expanded to include oils, chemicals, meals, and beverages.

4. Results and Discussions

After analyzing the three methods shown above, oil samples were extracted for each method, and the screw press method proved to be the most efficient method when compared to the other methods. A comparison was made between the three methods, and each of them was compared in terms of energy, time consumed, and quantity of oil produced for each of them, as well as an analysis of the density and
viscosity of the resulting samples. Table 1 shows a comparison between the three extraction methods. The pressing method has proven its effectiveness as it is the least energy- and time-consuming method used to extract the oil compared to the amount of oil extracted in each of them.

Because the seed cake must be removed after oil extraction, the hydraulic press is not a continuous method. A 1 kg sample of seeds was used to calculate the consumed time. 1 kg of seeds took more than 12 hours to press. The hydraulic press is powered by a 746 W motor that was turned on for about 1 hour, which is the total operating time for oil extraction from 1 kg of seeds. The hydraulic press’s total energy consumption is 746 Wh.

Because seeds must first be crushed and then mixed with solvent for one day, solvent extraction is not a continuous process. More than 5 days were required to extract oil from one kilogram of seeds. For solvent evaporation, a rotary evaporator with a 249 W motor, a 200 W vacuum pump, and a 500 W heater is used in the solvent extraction method (i.e., a total of 949 W). For oil extraction from one kilogram of seeds, the rotary evaporator evaporates the solvent in about 1.5 hours. As a result, the energy consumption of the solvent extraction method is 1423.5 Wh/kg seed.

A screw press is a method of continuous extraction. It produces a higher yield, extracting up to 25% of the oil from the seeds. The screw press is powered by a 370-Watt motor and a 640-Watt heater (i.e., a total of 1010 W). The screw press can press 1 kg of Jatropha seeds in 30 minutes, consuming 340 Wh of energy. While it takes about 25 minutes to press 1 kg of castor seeds, the energy consumption is nearly 400 Wh.

For the reasons stated above, this research will concern the screw press method and the effect of different temperatures and speeds on oil extraction, as well as the amount of energy and time required to extract the oil. Experiments were carried out for samples of Jatropha and castor seeds, with each sample weighing 100 grams. The screw press machine was used at five different speeds (35, 60, 85, 110, and 135) and extraction temperatures ranging from 100 to 250 degrees. The oil extraction yield was investigated for temperature and engine speed. The preheating temperature is limited to 250°C to prevent the undesirable fatty acids in the oil from increasing, and the higher the temperature, the oil color be darker.

4.1. Oil Yield as a Function of Temperature. The extracting machine, such as the screw press, was manufactured and modified by the authors to do a test on different seeds to determine the best temperature and speed for each one, which is able to produce the optimum extraction yield with lower energy and time consumption. So, every type of seed has extraction temperatures and speeds different from the other types. So Jatropha seeds need a lower temperature than castor seeds to prevent oil oxidization, unlike the castor seeds which need high temperatures because lower temperatures led to the solidification properties of castor samples, and they became like dough. Also, the type of seeds is different from one type to another at its shell; the hard shell of the Jatropha seeds needs higher speeds to enable it to be pressed and extract oil from it, unlike the soft shell of castor seed, which needs to use lower speeds to be pressed it.

Figure 6 shows the comparison between the oil yield as a function of temperature in the case of Jatropha and castor seeds. Jatropha oil yield by a mechanical expeller can extract more than 80% mass fraction of oil in comparison with the reference Soxhlet method. The Soxhlet extraction method is ideal because it can extract 95 to 98% mass fraction of available oil in Jatropha seeds [26]. The maximum extraction yield from
Egyptian Jatropha by Soxhlet is only about 25%. Egyptian Jatropha contains little oil as a species in the carapace of seeds from other origins [36]. According to Figure 6(a), the maximum available oil yield for Jatropha seeds is about 25% and has been obtained at a motor speed of 60 rpm and a preheating temperature of 100°C, while the oil yield from castor seeds is about 36% and is obtained at a motor speed of 35 rpm and a preheating temperature of 250°C as shown in Figure 6(b). It is noticeable that the optimum castor yield is obtained at high temperatures, which exceed 175 degrees, because low temperatures lead to the solidification properties of castor samples, and it became like dough. This is because castor seeds have high viscosity compared to Jatropha, so it needs an appropriate amount of heat with low speeds until the seeds are squeezed. So, pressing seeds using a motor speed range from 35 to 60 rpm gives optimum yield with lower energy and time and with good-quality production oil. This is agreed with Ref. [37]. This proves that the present screw press is efficient and well-designed for getting a good oil extraction yield from Jatropha and castor seeds. However, at these extraction conditions, much time is consumed associated with higher motor power and torque.

4.2. Oil Yield as a Function of Speed. Figure 7 illustrates the relationship between the oil yield as a function of speed in the case of Jatropha and castor seeds. The optimum available oil yield for seeds is obtained by decreasing the speed of the screw machine, for Jatropha seeds the maximum yield is obtained at a motor speed of 60 rpm and a preheating temperature of 100°C as shown in Figure 7(a), while the maximum oil yield from castor seeds is obtained at a motor speed of 35 rpm and a preheating temperature of 250°C as shown in Figure 7(b). In both cases, pressing seeds at a lower speed produces more yield but consumes more time and energy than higher speed [25]. For castor seeds, pressing seeds using a lower speed and temperature leads to the oil being solidified, and it became like dough. This is because castor seeds have high viscosity compared to Jatropha, so it needs an appropriate amount of heat with low speeds until the seeds are squeezed. So, pressing seeds using a motor speed range from 35 to 60 rpm gives optimum yield with lower energy and time and with good-quality production oil. This is agreed with Ref. [37]. This proves that the present screw press is efficient and well-designed for getting a good oil extraction yield from Jatropha and castor seeds. However, at these extraction conditions, much time is consumed associated with higher motor power and torque.

4.3. Extraction Time as a Function of Temperature. Figure 8 shows the time consumed in pressing Jatropha and castor seeds about temperature. Extraction time increases as temperature decreases and also with lower screw speeds. Jatropha seeds consumed more time than castor seeds, and they consumed almost twice the time as castor seeds. This is because Jatropha seeds have a harder shell than castor seeds and due to the nature of castor seeds, which is characterized
by being softer compared to Jatropha seeds. Using a lower screw speed produced more yield but consumed more time; this is clearly shown by using 35 rpm which produced optimal yield and energy but consumed more time. The extraction time is approximately the same for both seeds at temperatures between 200°C and 250°C. Figure 8(a) shows the best time to get an optimum yield of Jatropha seeds at 135 rpm and preheating temperature of 175°C, while Figure 8(b) shows the best time for extracting castor seeds at 60 rpm and a temperature of 250°C.

4.4. Extraction Time as a Function of Speed. Figure 9 shows the relation between the time and the speed of the screw machine for the castor and Jatropha seeds. Extraction time increases as temperature decreases and also with lower screw speeds. In both seeds, the time consumed at lower speed is more than at high speed, castor seeds consumed lower time than Jatropha seeds, and it consumed about half the time than Jatropha seeds. This is due to the nature of Castor seeds, which are characterized by being softer compared to Jatropha seeds. Using a lower screw speed produce more yield but consumed more time, a speed of 35 rpm in both cases produces optimum yield and energy but consumed more time. The optimum time for Jatropha seeds ranges from a speed of 85 to 135 rpm as shown in Figure 9(a), while Figure 9(b) shows the optimum time for castor seeds which ranges from a speed of 35 to 60 rpm because increasing speed for castor seeds leads to decreasing yield and the samples being solidified.

4.5. Energy as a Function of Temperature. Figure 10 shows the energy consumed by the screw press machine as a function of temperature. The energy consumption increases at lower screw speeds as the extraction temperature rises. Motor energy increases as the extraction temperature increases at lower speeds, this agrees with Ref. [25]. The energy consumption for extracting oil from castor seeds is lower than from Jatropha seeds. It is approximately equal to half the energy consumed.
with Jatropha seeds. The reason is that the Jatropha seed’s shell is very hard, so it needs energy to release oil from it. Also, the nature of castor seeds, which is characterized by being softer compared to Jatropha seeds, enables castor seeds to consume less energy than Jatropha seeds. For Jatropha and castor seeds, maximum energy was obtained at a speed of 35 rpm and an extraction temperature of 250°C. For temperature range from 150°C to 175°C, the optimum yield with optimum energy was obtained in the case of Jatropha seeds as shown in Figure 10(a), while for castor seeds, the samples were solidified and became like dough, so the temperature was increased to range from 200°C to 250°C because of the nature of the seeds and the highest viscosity of the production oil as shown in Figure 10(b).

4.6. Energy as a Function of Speed. Figure 11 shows the energy consumed by the screw press machine as the function of screw speed. Energy increases with decreasing extraction speed for Jatropha and castor seeds. For both seeds, maximum energy was obtained at a screw speed equal to 35 rpm. Extracting oil from Castor seeds consumes less energy than extracting oil from Jatropha seeds. It is approximately half the amount of energy that Jatropha seeds consume. Jatropha seeds have hard shells, so they require energy to release their oil. In addition, since castor seeds are softer than Jatropha seeds, they consume less energy than Jatropha seeds. Figure 11(a) shows that the optimum energy for Jatropha seeds was obtained, ranging from a speed of 110-135 rpm and an extraction temperature of 150-175°C, while Figure 11(b) shows the optimum energy for castor seeds which was obtained at a speed of 35 rpm and an extraction temperature of 250°C. Decreasing the speed for both seeds leads to much energy consumed. Decreasing the preheating temperature of castor seeds decreases energy consumption but causes solidification in samples, and they became like dough. For Jatropha, seeds increasing speed with increasing temperature decreased energy consumption, but the oil was oxidized.
4.7. Effect of Temperature on Oil Density. Figure 12(a) shows the variations in densities of Jatropha and castor oil extracted by a screw press machine at various temperatures. Results show that the temperature of oil extraction has a major effect on the density of the extracted oils. At a temperature equal to 25°C, the measured density for Jatropha oil by test method “American Standards for Testing Materials” (ASTM) D-1298 was 905 kg/m³, whereas, for Castor oil, the measured density was 935 kg/m³, as compared to just 825 kg/m³ for conventional diesel oil. Oil densities decrease as the temperature rises. The measured results show that the density is inversely proportional to the oil temperature, with a linear connection. Density correlations at different temperatures can be used to predict and calculate densities for extracted oil from Egyptian Jatropha and castor seeds with different methods of extraction [37]. For the extraction process, the density can be associated in a linear relationship with oil temperature. By preheating Jatropha and castor oil at a temperature near 100°C, the density for both oils would be near the density of conventional diesel oil.

4.8. Effect of Temperature on Oil Viscosity. Figure 12(b) shows the differences in viscosities of Jatropha and castor oil at different temperatures. The results reveal that oil temperatures have a significant effect on the viscosity of the extracted oils. Castor oil has a significantly higher viscosity than Jatropha oil. At 25°C, the measured value of dynamic viscosities by ASTM D-445 for Jatropha oil was 7.5 Cp, but for Castor oil, the measured values are 19.5 Cp, compared to only 1.35 Cp for diesel oil at the same temperature. The viscosity is inversely proportional to the oil temperature as a linear relationship as obtained by the measured results.
Correlations of viscosities at different temperatures help predict and calculate viscosities [38]. Preheating biooil fuel is one approach for solving the problems caused by increasing oil viscosity in diesel engines. As the temperature of the oil rises, the viscosity decreases as a power function [37]. By preheating Jatropha and castor oil for temperatures near 100°C, the viscosity for both oils would be near the viscosity of conventional diesel oil.

4.9. The Lovibond Scale as a Function of Temperature and Screw Speed. Figure 13 shows the relation between the Lovibond scale as a function of temperature and screw speed. The temperature at which the oil is extracted affects the color and, therefore, the quality of the oil. The Lovibond number is used to represent the color of the oil extraction. As shown in Figure 13(a), the maximum Lovibond number for Jatropha oil was 13, while Figure 13(b) shows the maximum Lovibond number for castor oil was 7. The quality of production oil for Jatropha ranges from 100°C to 150°C at a speed equal to 60 rpm, while castor oil was range from 200°C to 250°C at 60 rpm. Chemical and physical properties are influenced by extraction temperature. The color of the oil varies depending on the extraction conditions; the lower of extracting temperature and the motor speed, the oil color tends to be lighter, but if the temperatures and motor speeds increase, the oil’s color tends to darken as a result of the oil’s oxidation as part of the extraction process. Castor oil has a lower Lovibond number, although it was pressed at high temperatures. The temperatures at which the castor seeds were pressed have almost the same Lovibond number. For a single sample, the higher the speed, the less time needed to press, and, thus, the less exposure of the exposed seeds to heat. This improved the chemical and physical properties of the resulting oil and its inability to oxidize.

4.10. Physical and Chemical Properties of Jatropha and Castor Oil. The physical and chemical properties of Jatropha, castor oil, and diesel fuel are shown in Table 2. The availability of heat to produce engine power was determined by the calorific value of the fuel. As a result, calorific values are essential in selecting an alternative fuel for diesel engines to improve engine performance. Jatropha, castor, and diesel oils have heating values of 40.6, 39.8, and 43.3 MJ/kg, respectively. Cetane number is a measure of a fuel’s combustion quality in diesel engines, and it is related to fuel volatility and ignition delay time. Engine performance, cold starting, warm-up, and combustion roughness are all affected by ignition quality and cetane number. A higher cetane number results in a shorter ignition delay and a decrease in engine performance. The cetane numbers for Jatropha, castor, and diesel oil are 56, 59, and 53, respectively. For safe fuel handling and storage, the flash point temperature is critical. Because the flash points of Jatropha and castor oil are higher than those of diesel oil, these oils are less hazardous to handle and store than diesel fuel. The flash points of Jatropha, castor, and diesel oil are 165, 190, and 85°C, respectively. The pour point is the lowest temperature at which the oil

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Density (kg/m³)</th>
<th>Viscosity (Cp)</th>
<th>Heating value (MJ/kg)</th>
<th>Cetane number</th>
<th>Flash point (°C)</th>
<th>Pour point (°C)</th>
<th>Lovibond number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jatropha oil</td>
<td>903</td>
<td>7.3</td>
<td>40.6</td>
<td>56</td>
<td>165</td>
<td>-7</td>
<td>6</td>
</tr>
<tr>
<td>Castor oil</td>
<td>935</td>
<td>11.85</td>
<td>39.8</td>
<td>59</td>
<td>190</td>
<td>-3</td>
<td>7</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>825</td>
<td>1.68</td>
<td>43.3</td>
<td>53</td>
<td>85</td>
<td>-9</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 2: Physical and chemical properties of Jatropha oil, Castor oil, and diesel fuel.
Figure 14: Continued.
is observed to flow and approximates the lower limit at which fuel oil can be pumped from storage as the temperature drops. This parameter shows the lowest temperature at which oil can be pumped without heating the storage tank. The Jatropha, castor, and diesel oil pouring points at which oil can be pumped without heating the storage tank. The Jatropha, castor, and diesel oil pouring points are -7, -3, and -9°C, respectively. The obtained results potentially indicate that castor and Jatropha oil might be decently substituted for diesel engines, where the latter is promising in the near future.

4.11. Optimal Extraction Yield and Energy. Screw speeds of 35, 60, 85, 110, and 135 rpm, as well as extraction temperatures of 100, 125, 150, 175,200, and 250°C, were studied. The maximum extraction yield for Jatropha seeds is 25% when the screw speed is 60 rpm and the extraction preheating temperature is 100°C, but the maximum extraction yield for castor seeds is 36% when the screw speed is 35 rpm and the extraction preheating temperature is 250°C. As screw speed and temperature were increased, motor energy, extraction time, and extraction yield all decreased. The extraction yield was higher with lower screw speeds and a medium extraction temperature because all samples that had been done under temperature ranges of 100 to 150°C had been solid in the case of castor seeds. At a screw speed of 135 rpm and a temperature of 250°C, the minimum extraction yield for Jatropha seeds is 16.3%, while the minimum extraction yield for Castor seeds is 5.35% at a screw speed of 110 rpm and a temperature of 150°C. Higher screw speeds and higher extraction temperatures resulted in lower extraction yield for Jatropha seeds, but higher screw speeds and lower extraction temperatures resulted in castor oil solidification. Figure 14 shows the different comparison between different extracting conditions as a function of temperatures and screw speed; increasing the screw speed from 35 to 135 rpm and increasing the extraction temperature from 100 to 250°C reduced extraction Jatropha yield by 21% while increasing extraction castor yield by 40%.

For Jatropha seeds, condition 1 (N = 60 rpm and T = 100°C) and condition 2 (N = 135 rpm and T = 175°C), the time consumed for condition 2 is nearly 3 times less than that for condition 1. Moreover, the motor power and torque are also much less, which gives the maximum yield for a little difference of yield of 80%. This means that condition 2 is more effective and preferable to condition 1. For castor seeds, in condition 1 (N = 35 rpm and T = 250°C) and condition 2 (N = 60 rpm and T = 250°C), the time consumed for condition 1 is one and a half that for condition 2, which gives the maximum yield but consumed twice the energy than condition 2. Moreover, the motor power and torque are also much less. This means that condition 2 is more effective and preferable to condition 1, which gives the maximum yield for a little difference of yield of 85%. Jatropha oil is extracted at a motor speed of 135 rpm at a temperature of 150°C to 175°C and at a motor speed of 35 rpm at a temperature of 200°C to 250°C to extract castor oil. The present study’s observations are extremely important.

5. Uncertainty Analysis

Measurement errors result from various causes such as instrument calibrations, the data set finite statistics, and the methods used. We do not know the exact value of the measured parameters. There are two main types of errors; systematic error and random error. The main difference between systematic and random errors is that random errors lead to fluctuations in the measured value of the instrument around the true value. Systematic errors lead to predictable and consistent deviation from the true value due to a problem related to equipment calibrations [39].

Uncertainty analysis helps in describing the interval about the measured value within which we suspect that the true value must fall with a stated probability. Uncertainty analysis is the process of identifying, quantifying, and combining the errors [39].

\[ V = M \pm (X) \pm P\% \]  

where \( V \) is the variable, \( M \) is its best value, \( U(X) \) is the uncertainty, and \( P \) is the confidence level. In general, uncertainty analysis can be expressed using the following equation:

\[ U(X) = \sqrt{\left( \frac{\Delta X_1}{\Delta X} U(X_1) \right)^2 + \left( \frac{\Delta X_2}{\Delta X} U(X_2) \right)^2 + \cdots + \left( \frac{\Delta X_n}{\Delta X} U(X_n) \right)^2} \]  

\[ (2) \]
For oil extraction, the seeds had been dried in a solar drier at a temperature of 80°C for 6 hours. Then, they are subjected to an engine-driven mechanical screw-press continuous machine. Once the machine runs, the seeds are fed by a conveyor within the feeder, which has a variable-speed controller which had an accuracy of about ±10 rpm to regulate the seed flow during press-loading. Then, the seeds are passed through a preheater for efficient extraction. Its temperature is controlled by an (RKC, REX-C100) temperature controller which had an accuracy of about ±5°C. The energy consumption in the reheater was measured by using an electricity usage monitor multifunction electrical power consumption Watt meter with an accuracy of ±1%. After that, the extracted oil is released along the cage, drained into the base, and deliver to the lab. Meanwhile, the solid material within the press discharges to the removal bag.

6. Conclusion

Biooil is being accepted as a future resource that can be used to replace crude oil fuels. However, this field still has very limited scope for large-scale research and production. This study was covering the aspects of producing the best oil from oilseeds. There are many techniques to extract oil such as the screw press method, hydraulic press method, and solvent method. This study compared the different oil extraction techniques to extract oil from inedible seeds (Jatropha and castor seeds). To select the best method, many considerations were taken such as the oil yield extraction % age, the consumption of energy and time, and the chemical and physical properties of the extracted oil.

The screw press extraction is a continuous extraction method and, hence, has a higher yield. Mechanical screw presses typically recover 86–92% of oil from oilseeds. Oil recovery can be enhanced by suitable pretreatment of the oilseed, such as cleaning, conditioning, decorticating, cracking, flaking, cooking, extruding, and drying to optimal moisture content. The cooking or drying conditions for oilseed preparation to screw presses are one of the most important factors that influence screw-press performance. The main conclusions are stated as follows:

1. The screw press machine was effective and reliable in extracting oil from Egyptian Jatropha and castor seeds with the maximum yields compared to other methods. The maximum oil yield obtained from Jatropha seeds is about 25%, while the maximum oil yield obtained from castor seeds is about 36%

2. Reducing the extraction temperature and screw speed of Jatropha seeds increases oil yield but also increases extraction time and energy. While the oil yield of castor seeds increases with higher extraction temperatures and lower screw speeds, extraction time and energy consumption increase

3. Temperature and speed limits for Jatropha seeds of 150-175°C and 135 rpm are essential to get optimum oil yield with good chemical and physical properties, while for castor seeds, the temperature and speed limits of 200-250°C and 35–60 rpm are essential to get oil with a higher yield and to prevent oil samples to be solidified or dough. According to this study, the maximum extraction temperature and screw speed for Jatropha oil extraction are 175°C and 135 rpm, and for Castor seeds, extraction is 250°C and 35 rpm

4. Physical and chemical properties of the extracted oils using screw press machines are similar to the physical and chemical properties of diesel fuel, allowing them to be used directly in diesel engines. As the temperature increased, the densities and viscosities of the extracted oil decreased. The flash points of extracted Jatropha oil and castor oil are higher than those of diesel oil, and handling and storing these oils is less hazardous than handling and storing diesel fuel. Jatropha oil and castor oil have very similar calorific values, and these values are comparable to diesel fuel

5. Conventional diesel engines are not suitable to burn 100% vegetable oils, so diesel engines fueled with vegetable oils should be equipped with an automatically controlled fuel preheater by exhaust to adjust the fuel viscosity to be similar to that of conventional diesel fuel. However, we recommend a preheating temperature of about 90°C, since the engine performance and emission concentrations are within values obtained for diesel fuel

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References


