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Comparative Analysis of Biodiesel Production from Five Varieties of Castor Beans

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Authors' contributions

This work was carried out in collaboration among all authors. Author JKT designed and supervised the study. Author DKBM co supervised the study. Authors DTBD and MC performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. All authors managed the literature searches. The research was carried out at ACREST sponsored by author VK the CEO of the structure. All authors read and approved the final manuscript.

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ABSTRACT

A comparative study was conducted to estimate biodiesel productivity of five varieties of castor beans: *Ricinus communis zanzibariensis {white black}* (castor 1), *Ricinus communis sanguineus* (castor 2), *Ricinus communis carmencita* (castor 3), *Ricinus communis zanzibariensis {dark black}*

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(castor 4) and *Ricinus communis {black Tanzania}*(castor 5). The castor beans were preheated to a temperature between 22 and 33 ° C and then pressed with a manual hydraulic press, under 170 bars. The oil obtained was subjected to the transesterification reaction with methanol (99.98% pure) in a proportion of 5: 1 in the presence of sodium hydroxide as a catalyst (10,672g) for 02 hours at temperature between 60 and 70 °C. Purification was performed by reacting the methyl ester formed with heated water (55 °C) and acetic acid. The density, the kinematic viscosity at 21 ° C and the proportion of residual soap were determined later. The results for five castor varieties showed that the oil yields varied from 24 to 26.96 %; the volume of methyl ester was higher with castor 4 and lower with castor 5 but there was no significant difference in the biodiesel yields. Castor 2 has the best yield of biodiesel (93.5%), followed by castor 5 (92.5%), castor 3 (91%), castor 1 (90.75 %) and castor 4 (90%). Therefore castor oil 2 has a better potential for biodiesel production.

Keywords: Castor; biodiesel; Cameroon; methyl ester; transesterification; kinematic viscosity.

1. INTRODUCTION

Energy plays a major role in the growth and development of a country. Indeed, it is at the center of all human activities and is a key factor for sustainable development [1]. However, non-renewable fossil fuels (oil, coal and natural gas), the main sources of supply, are becoming increasingly scarce and more expensive. Their depletion in a few decades has been predicted [2]. In addition, the consumption of fossil oil is mainly at the origin of climate change, which plunges the international community into disarray [3]. Global emissions of greenhouse gases are increasing rapidly. This increase of carbon dioxide was 1.4% in 2012 thus reaching the historical threshold of 31.6 gigatonnes (Gt) [2]. In fact, fossil fuels account for nearly two-thirds of greenhouse gas emissions [4]. In Cameroon, there has been a significant decline in crude oil production over years [5], while its hydroelectric potential estimated at 294 TWh gives it the second-largest African ranking after the Democratic Republic of the Congo [6]. In fact, fossil fuels account for nearly two-thirds of greenhouse gas emissions [4]. With a growth rate of 2.6% of the Cameroonian population [7], an ever-increasing increase in the world population coupled with a strong demand for energy needs and paradoxically a shortage of fossil fuel reserves, there is need for the exploration of renewable energy resources especially those that can be produced and consumed on the spot without need for long distance transportation. The poor road infrastructures in many developing countries affect the distribution of petroleum products to the end users.

Produced from several sources of renewable energy, the main raw material used being vegetable oils, biofuels are presented as ecological alternatives to fossil fuels that can effectively contribute to meeting the aforementioned challenges. Biofuels are combustible materials directly or indirectly derived from biomass and commonly produced from plants, animals, as well as from organic wastes [8].

However, the production of biofuels as an alternative source of energy by food plants leads to a strong new demand for agricultural infrastructure such as land and machinery. In Cameroon, less than 10% of households in remote rural areas have access to electricity [9]. However, Cameroon has a high biofuel production potential because of its diversity in agro-ecological zones (lands that are not very productive and unsuitable for traditional food crops can be used). The use of castor oil for the production of biodiesel can significantly improve the living conditions of rural populations without access to fossil fuels and other forms of energy. In Cameroon as well as in many tropical countries, the castor plant grows in the wild and has very strong regenerative ability when transplanted, cut down or weeded off. It is the main weed disturbing agricultural activities in may farm lands. The grains as well as many other oil grains from other plants are simply abandoned to rot in the wild.

Based on this observation, this study aimed to propose the castor variety (*Ricinus communis L.*), the most suitable for the production of biodiesel as an alternative to fossil fuels in Cameroon. More specifically, it involved studying the physical characteristics of the grains, extracting oil from five locally available varieties of castor oil, producing biodiesel from each of the different extracted oils, and characterizing the biodiesel produced.

Such a study would provide scientific data useful for a successful biodiesel exploitation protocol

starting from variety selection through post-harvest handling and processing to oil treatment.

2. MATERIALS AND METHODS

2.1 Bean Preparation and Extraction of the Oils of the Different Varieties of Castor

2.1.1 Bean treatment

After harvesting the ripe fruits in the field the following operations were carried out: fruit drying, dehulling, sorting and selection of different varieties, cleaning with water and drying in a solar dryer. During the castor oil extraction phase, the drying in an electric dryer (at a temperature between 22 and 33 °C) was followed immediately by the pressing and finally the clarification.

2.1.2 Oil extraction from the beans

For each castor variety, 1 kg was taken from five measurement tests in order to obtain an average of the different quantities.

This phase was followed by extraction of the oil, using a manually operated hydraulic press. The oil was collected from the collector and clarified with a sieve of mesh 400 microns, before being used.

2.1.3 Détermination of extraction rate

The extraction yield (E_y) is the ratio between the quantity of oil obtained by extraction and the quantity of raw material worked. The extraction yield varies with the technique used and the quality of the raw material [10]. This definition translates to formula 1:

$$E_y(\%) = \frac{Oil\ weight\ obtained\ by\ extraction\ (g)}{Initial\ weight\ of\ pressed\ seeds\ (g)} \times 100 \quad (1)$$

2.2 Production of Biodiesel from Different Extracted Castor Oils

The production of biodiesel from pure vegetable oils (unrefined or SVO: straight vegetable oil) was done via a chemical reaction known as transesterification. This, also known as alcoholysis, is a chemical reaction between an oil or fat with an alcohol in the presence of a catalyst to form the esters and glycerol. Fig. 1 shows the transesterification reaction of a triglyceride with an alcohol.

According to [12], the transesterification of oil or greases for the formation of a high yield of biodiesel is typically a function of an optimum reaction of variables: the reaction temperature between 60 and 80 °C, the ratio molar oil / alcohol, catalyst concentration, and reaction time during the process.

For a transesterification reaction of 1 liter of vegetable oil, we need 200 ml of methanol [13,14]. A study by [15] shows that the amount of excess catalyst (NaoH) required for the transesterification of 20 liters of vegetable oil (castor oil, palm oil and soybean oil) must be 106.72 g with a vegetable oil / methanol ratio of 5:1. Once the transesterification reaction is complete, the mixture should be allowed to stand for about 24 hours to allow the separation of methyl ester (biodiesel) and glycerol before proceeding to the operation of purifying or washing biodiesel [13].

2.3 Reactor Assembly for Biodiesel Production

The reactor used for biodiesel production was originally designed by students at the University of Kentucky in the United States of America. The reactor is similar to that used by [16]. It consists of a 200-liter metal drum, inside which a channel has been introduced for the transfer of energy from the combustion source to the reactor as shown in Fig. 2.

When the mixture is introduced into the reactor, the vegetable oil mixture, 99.98% pure methanol and catalyst (NaOH), and in the presence of the temperature ranging from 60 to 70 °C., the methanol changes from the liquid state to the gaseous state then up through the pipe (1) and arrives at the radiator where it will condense and become liquid. The liquefied methanol flows down the line (2) to reach the reactor and the cycle begins again. This system makes it possible to homogenize the mixture during the reaction which takes place over a period of 2 hours.

The biodiesel production device thus mounted is shown in Fig. 2.

Galvanized and high-pressure rubber pipes (300 PSI) drive the evaporated methanol from the reactor to the radiator. A thermal probe allowed us to manually control the temperature via a thermocouple. The source of heat was wood energy. With 1 psi = 6.89 kPa.

2.4 Production of Biodiesel

Having obtained castor oil after extraction, we took 2 liters of each of the varieties and used for biodiesel production. The different steps as elucidated in Fig. 3 have been respected.

2.4.1 Purification of biodiesel

According to [17], to ensure the quality of biodiesel, it is essential to reduce as much as possible the total impurities that negatively affect the vehicle and the operation of the engine. The vinegar and glycerin solutions were more effective in reducing soap in biodiesel [15]. Thus, the biodiesel purification method used was that of the addition of hot water and acetic acid. We used vinegar with a percentage of acetic acid of 3%. The resulting mixture was heated to 55 ° C before being blended with biodiesel, then the whole homogenized and left to stand for 7 days, necessary time to separate unreacted oils or partly reacted mono- and di-glycerol from biodiesel formed. An infrared thermometer allowed us to control the temperature.

2.4.2 Determination of biodiesel yield

The biodiesel yield is the ratio of the volume of biodiesel obtained after washing to the volume of vegetable oil used for the production. It was calculated using formula 2.

$$Biodiesel\ Yiel(\%) = \frac{Volume\ of\ biodiesel\ obtained\ after\ washing\ (ml)}{Volum\ of\ vegetale\ oil\ (ml)} \times 100 \quad (2)$$

2.5 Characterization of Biodiesel Product

2.5.1 The Jan Warnqvist Test

This is a quick Pass/Fail conversion test for biodiesel and works because biodiesel dissolves into methanol while triglycerides do not dissolve in it. It works with washed and dried, or unwashed biodiesel that is well settled. This test was carried out in order to verify the success of the transesterification process. Two 10 ml syringes, 3 ml of biodiesel were taken and added to 27 ml of 99.98% pure methanol contained in a burette. After homogenization of the mixture by stirring, a clear mixture with a slight coloration without phase differentiation after 10 minutes indicated successful and complete transesterification reaction. If, on the other hand, there was a phase separation after this period, it meant that the transesterification reaction was incomplete.

2.5.2 pHLip tests

This test which is of great importance gives a visual indication of the quality of biodiesel obtained, because of its sensitivity to pH. It indicates the purity of biodiesel. It consisted of adding the biodiesel to a solution of red phenolphthalein (0.02% red phenol indicator S25464A: colored indicator) in a bottle, followed by turning the mixture by half-turns (10 times) and allowing it to settle for 10 minutes. A very high quality ASTM B100 creates a “mirror” on the smooth interface of the fuel and indicator. According to [18], the following contingencies are possible in this test:

- If the fuel is slightly turbid and the indicator solution is transparent with a cherry color, we probably have a biodiesel still showing traces of glycerin.
- If the indicator becomes orange or yellow due to acid build-up, this may be out of test and should be tested.
- If the indicator solution is turbid, the presence of soap is suspected.
- If the colored indicator turns purple (purple red), then we have catalyst contaminants and it should not be used in the engine.

However the visual test was not enough to determine the suitability of the fuel for the engine. After having a visual appreciation, the amount of soap or impurities present were determined by performing the titration procedure on biodiesel.

2.5.3 Biodiesel Titration: Biodiesel Soap Identification Test

Biodiesel titration accurately determine the amount of residual soap in the biodiesel produced. This was done using 50ml of Isopropyl alcohol, 12 drops of bromophenol blue indicator with hydrochloric acid gradually being added to a beaker and on a magnetic stirrer. The solution being well homogenized, the hydrochloric acid is gradually and slowly added to the mixture until the change from blue to yellow.

Once the titration end point was reached, the addition of the volume of acid hydrochloric acid used to neutralize the soap was determined in order to calculate the amount of soap present in the biodiesel. Then, the 3 formula, was used to determine in ppm the amount of soap present in the biodiesel with the base (NaOH).

$$[(304.4\ for\ NaOH\ or\ 320\ for\ KOH) \times (0{,}01) \times (Volume\ in\ ml\ HCL)] = x\ ppm\ or\ (x) \times 10^{-4}\%\ of\ soap\ in\ biodiesel \quad (3)$$

2.6 Production Data Processing

The data was processed using the Microsoft Office Excel 2010 software that allowed us to graphically express our results, the GenStat Release 9.2 software for statistical analysis of the collected parameters.

3. RESULTS AND DISCUSSIONS

3.1 Collection and Description of Castor Beans Varieties

3.1.1 Origin and description of the castor beans used

From all the beans collected for the production of biodiesel, we selected five (5) castor varieties including four (4) of scientific names *Ricinus communis zanzibariensis white black* « castor1 *», Ricinus communis sanguineus, Ricinus communis carmencita* and *Ricinus communis zanzibariensis "dark black color",* and a fifth variety the *Ricinus communis Tanzania*. These different bean varieties were identified by castor 1, castor 2, castor 3, castor 4 and castor 5 and illustrated in Fig. 4.

Table 1 shows the color and average volume associated with different castor beans.

Five measurement of beans was taken in order to obtain an average volume of different castor.

This color difference is the response of the expression of the alleles contained in the genotype of each variety of bean and all castor beans are oblate spheroids.

3.1.2 Extraction of castor oil

The hydraulic cylinder press used to extract castor oil is shown in Fig. 5.

3.2 Oil Yield of Different Varieties of Castor

Extraction was within a room temperature range of 20 to 26 ° C and a bean temperature of 22 to 33 °C and 1 kg was taken from five measurement tests in order to obtain an average of the different quantities. Table 2 gives the average yield of oil obtained per kilogram of castor beans.

From this table, 3.5 kg of castor beans was used to obtain 1 litre of vegetable oil. The residue was used as an organic fertilizer and as a rodent repellant. It was also used as a feedstock in cogeneration systeme to produce biogas.

From statistical analysis using GenStat 9.2 software it was conclude that the oil yields are significantly different.

3.3 Biofuel Yield from Different Castor Vegetable Oil

After purification of the methyl ester formed using vinegar with 3% acetic acid the product was left for 7 days. The quantities of biodiesel and soap formed after separation are illustrated in Fig. 6.

The soap formed here is a mixture of triglyceride and catalyst which did not reacted completely during the transesterification reaction and then residual vinegar.

From Fig. 6, it can be seen that the most productive variety of biodiesel is variety 2, which contains a quantity of soap slightly higher than that of variety 3. Despite the fact that the quantity of methyl ester of variety 4 was higher before the purification that all other varieties of castor, it however produces less biodiesel.

In addition, It can be seen that variety 4 contains more soap (impurities) than all other varieties of castor, which explains the sudden decrease in the amount of biodiesel obtained after purification. Then is followed by variety 1 which contains the highest amount of soap.

These results confirm that of [19], which showed that the variability of ricinoleic acid from 86.7 to 92.1% depending on castor varieties contributed to the disproportionality of the yields of biodiesel obtained.

After separation of the biodiesel and the soap, the residual methanol was extracted by distillation of the soap. The glycerol obtained is a feedstock used by saponification reaction for the manufacture of laundry soap.

The results obtained in Fig. 6 were used to calculate the percentage yields of biodiesel for each of the five castor varieties. The results of biodiesel yields are shown in Fig. 7.

According to Fig. 7, castor 2 has the highest yield of biodiesel at 93.5% while castor 4 has the lowest yield of 90%. This results are similar to those obtained by [16] which was 94% and [20] which was 94.5% in optimal condition.

From statistical analysis using GenStat 9.2 software it was conclude that there was no significant difference between the yields of purified biodiesel from different castor varieties and those obtained by [20]. Fig. 8 provides an overview of biodiesel from different castor varieties.

3.4 Physico-chemical Analysis of Biodiesel

3.4.1 Viscosity of the biodiesel of the five varieties

To measure the viscosity of the different biodiesels of volume 230 ml each, we used a steel ball of mass 19.5 g and diameter 17 mm, a radius of 8.5 mm and a volume of 2.5 ml and a mass volume of 7800 kg.m-3. The distance traveled by the ball was constant and equal to 212.7 mm or 0.2127 m. Table 3 below presents the results of the viscosity calculation.

From this table, the transesterification reaction considerably reduces the viscosity of the oils. A kinematic viscosity at 20 ° C of castor oil of 850-1100 $mm^2.s^{-1}$ [21] has been changed to a kinematic viscosity of variant biodiesel between 45-105 $mm^2.s^{-1}$ at almost the same temperature.

3.4.2 The jan warnqvist test

To ensure the success of the transesterification reaction, after having obtained methyl ester, for this test, for this, 5 test tubes of volume 50 ml each were used. After homogenization of the biodiesel and methanol mixture, and after a period of about 12 minutes, the mixture remained clear with a slight color without phase differentiation on all biodiesels from different varieties. This observation allowed us to confirm the smooth running of the transesterification reaction.

3.4.3 pHLip tests

From Fig. 9, we find that bottles B1, B2, B3 and B5 whose samples come from biodiesel made from the varieties castor 1, castor 2, castor 3 and castor 5 respectively have, after rest, an indicator having a color yellow. This color is due to the accumulation of free fatty acid in the indicator. This to be used requires additional testing such as determining the proportion of soap or glycerin present in the biodiesel as prescribed by the American standard ASTM-D6751.

In addition to the presence of suspected residual soap in each of the flasks, the presence of catalyst is suspected in the flask 4, which justifies its purple color. This biodiesel should not therefore be used in an engine. Because the residual catalyst can react with the internal components of the engine (injector, piston ...) and adversely affect the vehicle and the operation of the engine.

3.4.4 Biodiesel titration

Table 4 shows the amounts of hydrochloric acid (HCl) used to test each of the biodiesel samples obtained as well as the calculation result in ppm of the amount of soap present.

We can see from Table 4 that only the biodiesel obtained from castor 4 has a proportion of impurities (soap) greater than the requirements of ASTM-D6751 which is 41 ppm. This result can be explained by the fact that castor beans of this variety contain more impurities (the residual catalyst, the residual triglycerides which did not react completely during the transesterification reaction) than all the other varieties. The blackish color of the beans can also be the source of this abundance of biodiesel impurity or even the genotypic composition.

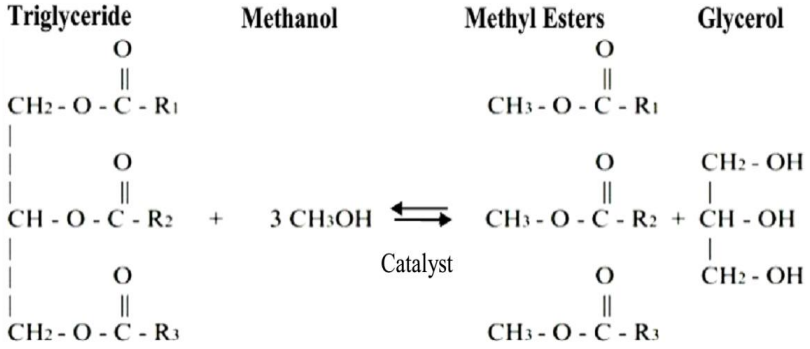
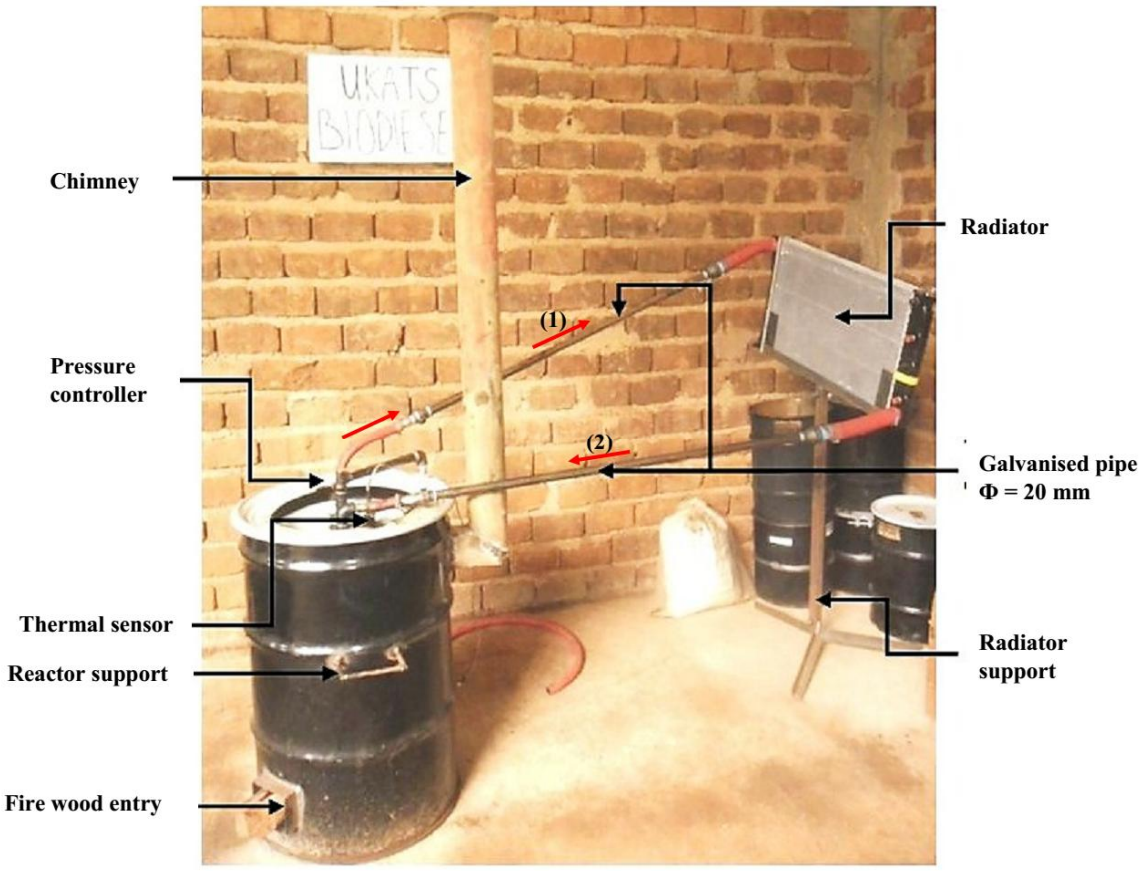
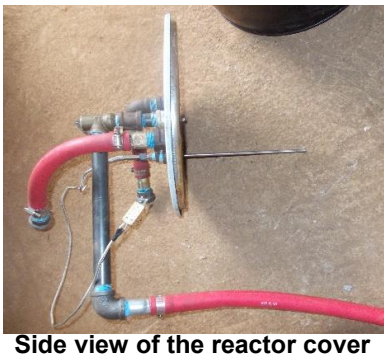


Fig. 1. Transesterification reaction of a triglyceride with an alcohol [11]



Top view of reactor



Side view of the reactor cover

Pressure Controller

Thermocouple used for controlling temperature in reactor

Fig. 2. Simple biodiesel production device mounted

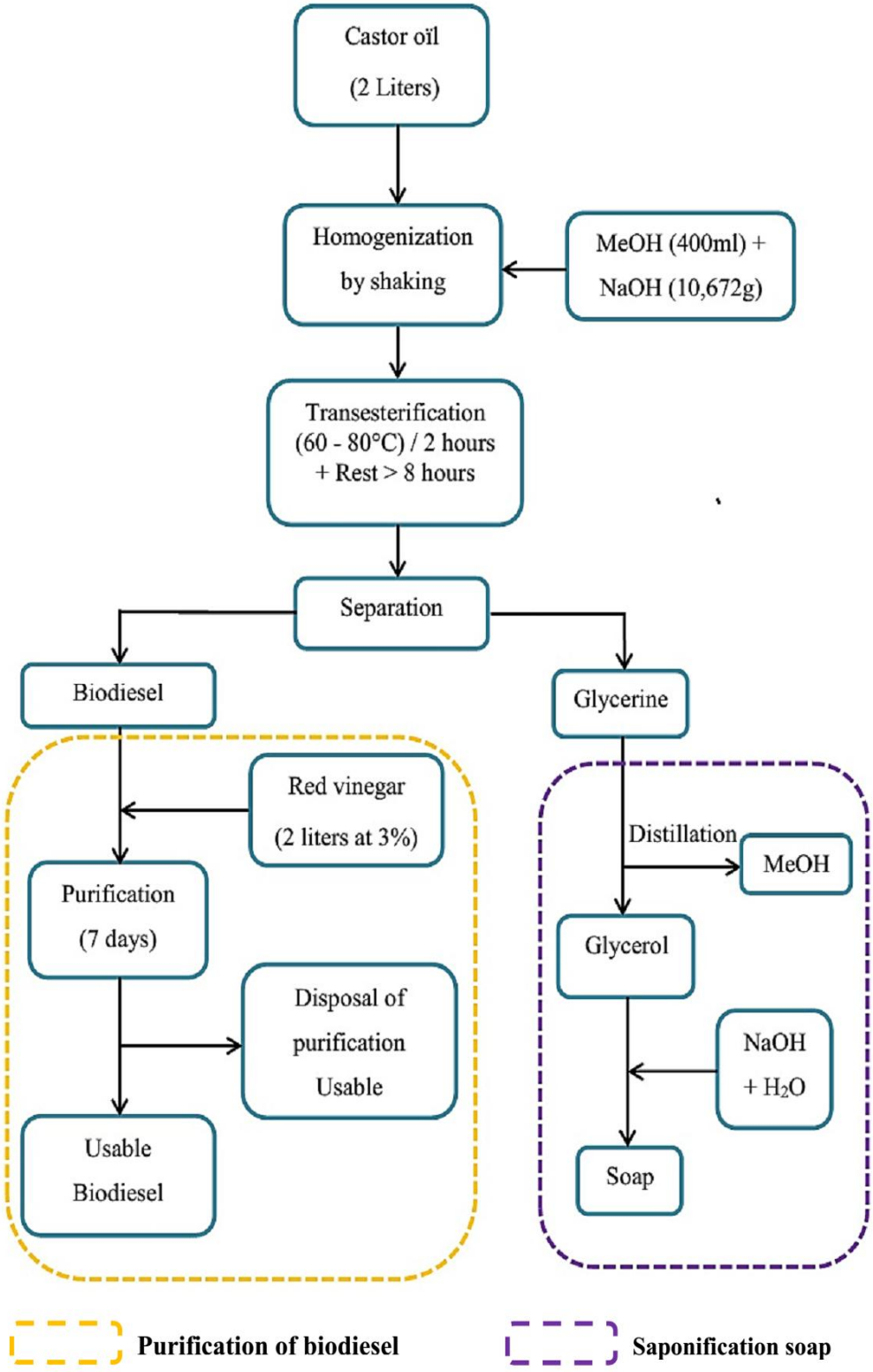


Fig. 3. Synoptic diagram of the biodiesel production process

(a) - R. c. zanzibariensis- « **castor 1** »

(b) - R. c. sanguineus **« castor 2 »**

(c) - R. c. carmencita **« castor 3 »**

(d) - R.c. zanzibariensis **« castor 4 »**

(e) - R. c. tanzania **« castor 5 »**

Fig. 4. Different varieties of castor beans studied

Table 1. Colors and volume associated with each castor beans

	Castor 1	Castor 2	Castor 3	Castor 4	Castor 5
Colors	Black and white stripes	Dark red	Stripes Red, black and white	Dark black	Small black, white and dark red striped beans
Average volume in Cm^3	10,344	9,484	5,809	11,247	1,389

Fig. 5. Manual press with hydraulic cylinder

Table 2. Average oil yield per kilogram of castor beans measured

Parameters	Repetitions	Castor 1	Castor 2	Castor 3	Castor 4	Castor 5
oil mass[a]	m1	275± 2,7	245± 2,5	250± 3,0	260± 0,6	240± 8,5
	m2	278± 4,2	225± 7,5	225± 9,5	270± 5,6	250± 3,5
	m3	260± 9,6	255± 7,5	255± 5,5	264± 2,6	280± 11,5
	m4	265± 4,6	235± 2,5	260± 8,0	255± 1,9	260± 1,5
	m5	270± 0,4	240± 00	230± 7,0	245± 6,9	255± 1,0
Average oil mass[a]	m	269,6± 7,30	240± 11,18	244± 15, 57	258,8± 9,47	257± 14,83
oil quantity[b]	v1	305 ± 1,3	280 ± 4,3	292± 7,5	295± 2,0	265± 12,2
	v2	310 ± 3,8	255 ±8,2	245± 16,0	305± 7,0	292± 1,3
	v3	295 ± 7,4	295± 11,8	293± 8,0	300± 4,5	300± 5,3
	v4	300 ± 2,4	262± 4,7	295± 9,0	295± 2,0	295± 2,8
	v5	302 ± 0,4	265± 3,2	260± 8,5	260± 15,5	295± 2,8
Average oil volume[b]	v	302,4±0,55	271,4± 1,60	277± 2,38	291± 1,78	289,4± 1,39
mass of residue[a]	r1	725± 2,4	755± 2,5	750± 3	740± 0,0	760± 8,9
	r2	722± 3,9	775± 7,5	775± 9,5	730± 5,0	749± 3,4
	r3	738± 8,2	745± 7,5	745± 5,5	735± 2,5	720± 11,1
	r4	734± 4,2	765± 2,5	740± 8,0	740± 0,0	738±2,1
	r5	730± 0,2	760± 0,0	770± 7,0	755± 7,5	744± 0,9
Average mass of residue[a]	r	729,8±6,49	760± 11,18	756± 15,57	740± 9,35	742,2±14,80
Extraction rate[c]	E_{rate}	26.96	24	24.4	25.88	25.7
Oil density[d] at 17.3°C		891,5343	884,3036	880,8664	889,3470	888,0442

[a] Mass of oil g. [b] Volume oil in ml, [c] Oil yield obtained in %, [d] density in kg.m^{-3}

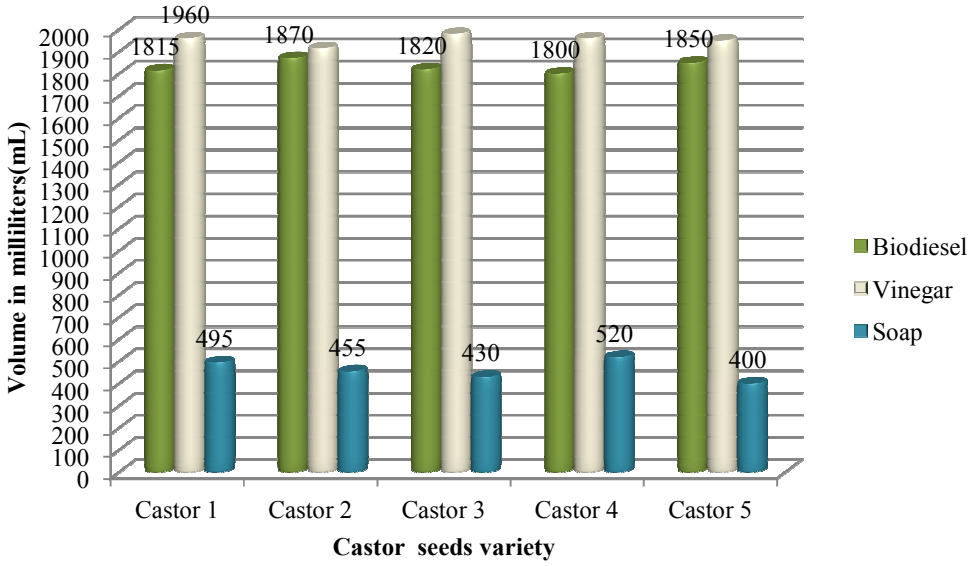


Fig. 6. Biodiesel and soap yield after purification

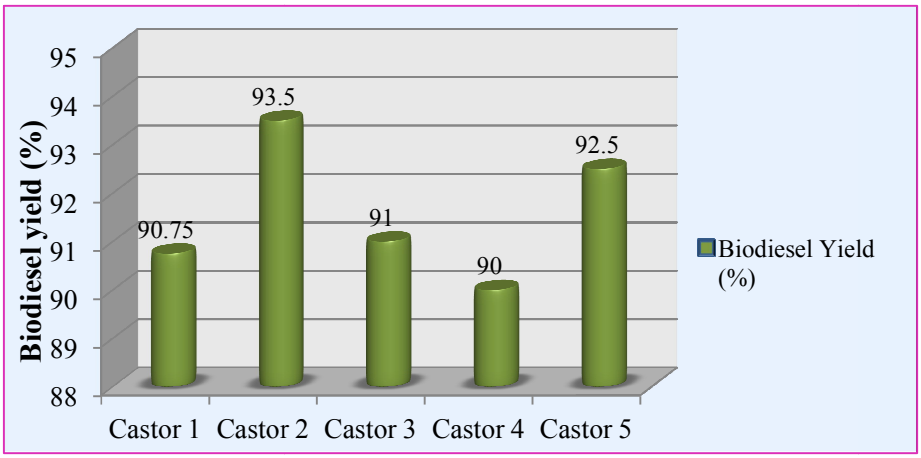


Fig. 7. Biodiesel yield (%) of different castor varieties

Table 3. Results of the calculation of the biodiesel viscosity[1] of the different varieties of castor 1 to castor 5

Settings	Castor1	Castor2	Castor3	Castor4	Castor5
Temperature[a]	22	21.8	21.8	21	21
Masse of biodiesel[b]	0.198	0.199	0.192	0.175	0.198
Quantity of biodiesel[c]	230×10^{-6}	230×10^{-6}	230×10^{-6}	230×10^{-6}	230×10^{-6}
Biodiesel density[d]	860.869	865.217	834.782	760.869	860.869
Dynamic viscosity[e]	0.6423	0.5135	0.386	0.781	0.5138
Kinematic viscosity[f]	74.611	59.351	46.339	102.76	59.689

[a]Temperature in °C, [b]Biodiesel mass in kg, [c]Quantity of biodiesel in m^3, [d]Density of biodiesel in $kg.m^{-3}$, [e]Dynamic viscosity in Pa.s, [f]Kinematic viscosity in $mm^2.s^{-1}$

[1] *Viscosity determined from the settling velocity of a sphere in the liquid*

Fig. 8. Overview of different biodiesel produced from different castor oil

Fig. 9. Overview of the red phenolphthalein test of different biofuels

Table 4. Results in ppm of the proportions of soap contained in biodiesel

Different varieties	Castor1	Castor2	Castor3	Castor4	Castor5
Mass of biodiesel[a]	10	10	10	10	10
Volume (HCl) of hydrochloric acid used[b]	5	9	6	16	7
Quantity of soap[c]	15,22	27,396	18,264	48,704	21,308
Quantity of soap[d]	0,001522	0,0027396	0,0018264	0,0048704	0,002130

[a] Mass in g, [b] Volume of hydrochloric acid used in ml, [c] Quantity of soap in ppm,[d] Quantity of soap in %

4. CONCLUSIONS

At the end of our study, based on field data following our methodology and analysis, we can draw the following conclusions:

1. There is a significant difference at a 95% confidence interval and a coefficient of variation of 5.7% between the oil yields obtained from each of the castor beans varieties. Castor 1 has the highest oil yield which is 26.96 % while castor 2 has the lowest oil yield which is 24 %.
2. After purification of the methyl ester formed during the transesterification reaction, by addition of hot water and acetic acid (vinegar at 3% concentration), a greater yield of biodiesel was observed which was 93.5%? This is followed by the castor 5 (92.5%), castor 3 (91%), castor 1 (90.75%) and castor 4 (90%). There was no significant difference at a 95% confidence interval between purified biodiesel yields from different castor varieties.
3. The highest kinematic viscosity at 21-22 °C is observed with the biodiesel of castor 4 (102,760 $mm^2.s^{-1}$), followed by castor 1 (74,611 $mm^2.s^{-1}$), castor 5 (59.689 $mm^2.s^{-1}$), castor 2 (59.351 $mm^2.s^{-1}$) and castor 3 (46.339 $mm^2.s^{-1}$). The transesterification reaction considerably reduces the viscosity of the oils;
4. The soap is higher in biodiesel from the beans of castor 4 with 48,704 ppm. This concentration is much higher than the requirements of ASTM-D6751 with a recommended margin of 41 ppm. Other biodiesel had soap proportions that met the standard. That is 15.22 ppm for castor 1, 27.396 ppm for castor 2, 18.264 ppm for castor 3 and 21.308 for castor 5.

Thus, the production of biodiesel from castor beans was not proportional to the amount of starting oil, it could also depend on the biochemical composition of oil and to a certain extent the ecological conditions of growth. Of all these analyzes on the five tested varieties, castor oil 2 gives better results and presents itself as the variety best indicated for the production of biodiesel.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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