Tech-Sphere Journal of Pure and Applied Sciences (TSJPAS)
A Subsidiary of Tech-Sphere Multidisciplinary International Journal (TSMIJ)
Vol 1, Issue 1, 2024 Publication Edition

Extraction and Characterization of Biodiesel from Papaya Fibre Wastes

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ABSTRACT

The rising demand for renewable energy sources has prompted significant interest in biofuels. Biodiesel derived from renewable feedstock such as vegetables oils (both edible and non-edible) and animal fats, stands as a pivotal endeavour in the pursuits of sustainable energy solutions, it offers great environmental and economic advantages over conventional fossil fuel (diesel). In the production of biodiesel, oils is first extracted from the source and then transformed into biodiesel by trans-esterification. This paper seeks to extract and characterize biodiesels obtained from papaya fiber wastes sources. The method employs involved sourcing of the biomass, extraction of oil from the wastes using Soxhlet extractor, characterization of the oils, and production of biodiesel and its characterization. The results show that, oil extracted had the following characteristics; free fatty acid, peroxides value, acid value, saponification number, density, specific gravity, viscosity and iodine value of 2.29 mg/g, 8mol/kg, 4.58mgKOH/g, 78.54, 940kg/m3, 0.731, 0.56mm2/s and 121.1 respectively. An average of 37.7% of biodiesel was realized. The characterization of the biodiesel results indicated that the biodiesel had the following characteristics: 103°C, -5°C, 32J/kg, 3°C, 1.38 mg/g, 124.6, 92.56, 2.67mgKOH/g, 25.90, 0.43 mm2/s, 0.216 and 880kg/m3 for flash point, pour point, calorific value, cloud point, free fatty acid, iodine value, saponification number, acid value, cetane number, viscosity, specific gravity and density respectively. Some of the characteristics of the biodiesel compared well with that of diesel and in the range of ASTM specifications while others don't. The study conclude that papaya fibre oil is an ideal feedstock for biodiesel production due to its minimal fuel properties, which can be easily modified and improve for diesel engine application.

Keywords: Papaya Fibre, Extraction, Oil, Biodiesel, and Characterization.

1 Introduction

1.1 Background

As the global industrialization and transportation continue to rise daily, so are machines engines and automobiles; however, the fuel sources used in these engines are gradually declining if not getting to extinction [1]. The search for alternative, renewable, sustainable and eco-friendly fuel sources for diesel engines has been prompted by a number of factors including but not limited to; the depletion of the ozone layer, global warming, greenhouse gas emissions, limited supply of fossils fuels and the unhealthy global politics in economy. Thus, converting organic wastes into high-value product (fuel) offers a viable way to address those factors simultaneously [2]. Biodiesel is termed as either the ester or trans-ester of vegetable oils or animal fats [1, 3], biodiesel can also be defined as a fuel gotten from an easily biodegradable, renewable and non-toxic, biological sources with low emissions profile when compared with petroleum-based diesel [4]. Its environmental friendliness, its production from renewable resources and its ability to strike a balance between economic development, environmental preservation, and agriculture all play major roles in its appropriateness for applications [5, 6]. Vegetable wastes are in abundant (Papaya fibre for example) and often disposed and neglected. They are rich in lipid content which makes them a perfect source for biodiesel production, while at the same time addressing wastes management issues.

In the USA and Europe, biodiesel obtained from edible vegetable oils are already being in use, whereas the situation is different in Africa and other developing continents like Asia that import these edible oils, this is due to significant discrepancy between supply and demand of these oils. However, Jatropha curcas, a non-edible plant is now recognized as a novel source crop for renewable energy, with a host of exciting benefits. Africa's potential as a biodiesel exporter lies in its ability to grow and produce biofuel from these non-edible oils, particularly Jatropha curcas. [7].

Numerous sources of oils have been used in production of biodiesel, the most common among them may include and not limited to; soya bean oil [8, 9], Jatropha oil [4, 7, 8, 10-14], Palm kernel oil [15], Palm oil [16], Neem seed oil [17], Melon seed oil [18], Mango seed oil [19], Cotton seed oil [20], Tiger-nut [21], Baobab seed oil [22], and other Non-Edible Oil like Sapodilla seed oil [23] and Castor seed oil [2, 24, 25].

It is therefore, a subject of novelty to use Papaya fibre considered as waste, to produce biodiesel, which will immensely contribute to the fuel supply mix of the country thereby promoting the use of renewable energy as enshrined in the goal seven (7) of the United Nation (UN) Sustainable Development Goals (SDG) [26]. The research therefore aimed to produce biodiesel from papaya fibre, other objective includes, sourcing of the raw materials, extraction and characterization of oil from the source materials and production and characterization of the biodiesel. The study was limited to production and characterization of biodiesel obtained from papaya fibre wastes only.

2 Materials and Methods

2.1 Materials

The main sources of material used for the purpose of this study was Papaya Fibre wastes which was sourced partly from the nearby local farm and partly from the local road side fruit vendors, all within Ado-Ekiti Metropolis.

Reagents and Chemicals: The reagents and chemicals used include, Water, N-hexane, Methanol and Potassium hydroxide, all of analytical grade.

Apparatus and other equipment: these include, Soxhlet apparatus, weighing balance made in China by Dapeng, Pyrex glassware − measuring cylinders, magnetic stirrer, stop watch, bakers, conical flask, separating funnel, hot plate and thermometer.

2.1.1 Proximate Analysis

The Papaya fibre biomass sample was subjected to a proximate analysis test, to determine the moisture content, volatile matter, ash content and fixed carbon. The tests were performed in compliance with [1] Method and Practice ASTM D 346 of the American Society of Testing and Materials (ASTM) standard [1]. All result obtained were recorded as shown in Figure 1.0.

2.2 Production of Biodiesel

2.2.1 Extraction of Oil from Sample

After the material was sourced, it was first sun-dried for 72hours, sorted to get rid of any non-biodegradable materials before milling. Five batches of the sample weighing 10g, 20g, 30, 40g and 50g in mass, were measured. In order to prepare the first sample for oil recovery, it was mixed in 1:1 (i.e. g/mil) with water and then placed into the Soxhlet apparatus. N-hexane was the extraction solvent, and it took 240mins (4hours) to complete. This was carried out in compliance with the method of [27], [28] and [29]. The procedure was repeated for each other batches.

Percentage Oil Yield

The samples (the 1:1 mixture of the Papaya fibre and water) were weighed before extraction and this weight was referred to as theoretical oil yield. The extracted oil was weighed with the same weighing balance and this weight was referred to as actual oil yield.
Equation 1.0 was used to compute the percentage oil yield, which is displayed figure 2.0.

$$\%Oil\ yield = \frac{Actual\ oil\ yield}{Theoritical\ oil\ yield} \times 100 \quad \ldots\ldots 1.0$$

2.2.2 Characterization of Papaya Sample Oil

Density, specific gravity, iodine value, peroxide value, saponification value, acid value, free fatty acid and viscosity are among the physiochemical characteristic of the oil that was characterized. They standard procedure and method of [30] was applied. The result obtained is as presented in table 1.0.

2.2.3 Biodiesel Production from The Papaya Fibre Oil

In order to produce biodiesel, the trans-esterification process was adopted in which an aliquot of methanol and 0.5g of KOH pellet were mixed in a heat-resistance glass beaker. The mixture was vigorously stirred until KOH pellets dissolved and formed methoxide (KOCH3) a strong base. About 50ml of the Papaya oil was then poured into the reactor and heated gently at 65°C, in line with the method of [1] and the methoxide was added and the mixture was stirred vigorously for an hour to obtain a homogeneous mixture. The resulting mixture was separated using the separating funnel, settling for 24hours forming glycerine layers and biodiesel. The biodiesel was decanted, rinsed and drained before being heated at 105°C to remove the water and methanol residue left in it.

Percentage of Biodiesel Yield

The total oil extracted from each batch was weighed before the trans-esterification process and this weight was referred to as theoretical yield. The biodiesel produced from the total oil was weighed and this weight was referred to as actual yield.
Equation 2.0 was used to compute the percentage oil yield, which is displayed figure 2.0.

$$\%Oil\ yield = \frac{Actual\ biodiesel\ yield}{Theoritical\ biodiesel\ yield} \times 100 \quad \ldots\ldots 2.0$$

2.2.4 Characterization of the Biodiesel

Applying the same method of [30] in section 2.2.2 the physio-chemical characteristic of the biodiesel characterized include; density, iodine value, peroxide value, specific gravity, saponification value, acid value, free fatty acid and viscosity. The Pensky Martins apparatus of the ASTM D93 methods was used to determine the flash point while, the Hewlett adiabatic bomb calorimeter model 1242 was used to determine the calorific value as carried out by [1]. Cetane number was obtained numerically by the relation enunciated by [31]. Results obtained is as presented in table 2.0.
All pictures and other information not presented where present in the appendix of this work.

3 Result and Discussion

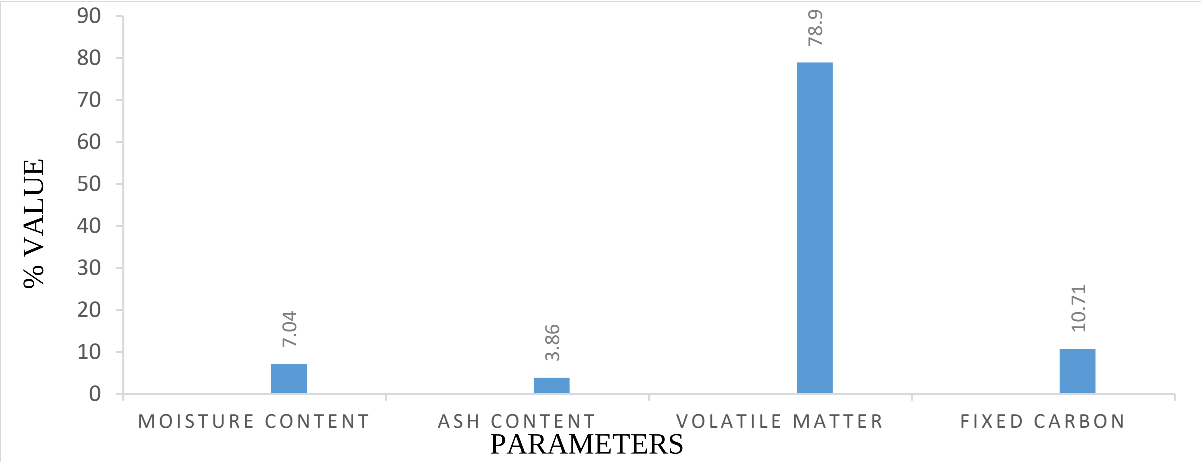

Figure 1: Proximate Analysis of the Papaya fibre Sample

The proximate composition of papaya fibre waste is as shown Fig. 1.0. It composes of 7.04% Moisture content, 3.86% Ash content, 78.9% Volatile Matter and 10.71% Fixed carbon. These values are consistent with [30] and other studies reported by [1], [8], and [31] on vegetable wastes.

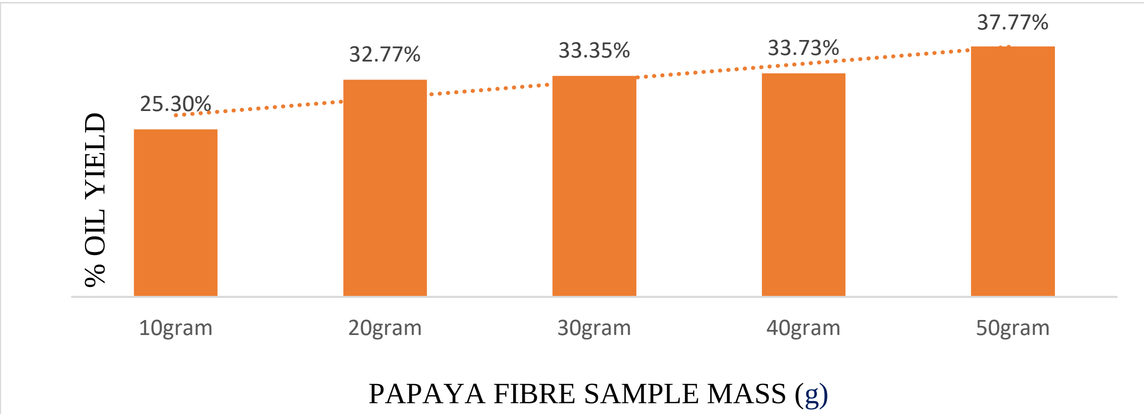

Figure 2: Percentage (%) Oil Yield from each Batch of Papaya Fibre Sample

The percentages of oil yield from each batch of papaya fibre as shown in figure 2.0. Five batches containing 10, 20, 30, 40 and 50g of the papaya fibre biomass were used and the resulting oil yield were approximately 25.30, 32.77, 33.35, 33.73 and 37.70% respectively. This is consistent with the work of [1], [27], [17] and others; that the more sample there was, the more the quantity of the oil produced. An average of 32.57% of oil was yielded from all the five batches of the sample.

The determined properties of the biodiesel produced were compared to the properties of conventional fossil fuel diesel and that of the America Society of Testing and Materials (ASTM) specifications sated by [1] and [10], as presented in Table 2.0.

Table 1: Characterization of Papaya Oil Extract

S/No.	Properties	Value
1	Specific gravity	0.731
2	Density (kg/m3)	940
3	Viscosity @ 400C mm2/s	0.56mm2/s
4	Free Fatty Acid mg/g	2.29
5	Saponification Value	78.54
6	Iodine Number	86.8
7	Peroxides Value (mol/kg)	8
8	Acid Value (mgKOH/g)	4.58

Table 2: Characterization of the Biodiesel

S/No.	Properties	Biodiesel	Diesel	ASTM EN14214:2012 Standard Value
1	Specific gravity	0.216	NA	0.86 -0.90
2	Density (kg/m3)	880	850	875 – 900
3	Viscosity @ 400C mm2/s	0.43mm2/s	2.6	0.9 – 6.0
4	Free Fatty Acid mg/g	1.38	NA	NA
5	Saponification Value	92.56	NA	176 -187
6	Iodine Number	88.5	NA	NA
7	Acid Value (mgKOH/g)	2.67	0.3	0.4 – 4.0
8	Flash Point 0C	103	70	>1010C
9	Cloud Point 0C	-5	NA	NA
10	Pour Point 0C	3	-20	NA
11	Cetane No.	25.90	46	51.0
12	Calorific Value J/kg	32	NA	NA

Tables 1.0 and 2.0 shows that following trans-esterification, which yields its biodiesel, the specific gravity of the papaya fibre oil reduced from 0.731 to 0.216, which is lower than the ASTM standard when compared.

Viscosity is one of the important factors used in evaluating a diesel. The viscosity of papaya fibre oil before trans-esterification was 0.56mm2/s, but reduced to 0.43 mm2/s after trans-esterification as observed in Table 1.0 and Table 2.0 respectively. This value is low when compare to diesel and the ASTM standard. High viscosity in biodiesel is responsible for poor injection and atomization performance which may lead to operational issues like engine deposits. [1] and [17]. However, biodiesel offers more protection and lubricating power for engine moving parts than diesel. [1] and [32].

The papaya oils free fatty acid and acid value significantly reduced from 2.29mg/g and 4.58mgKOH/g as indicated in Table 3.0, to 1.38mg/g and 2.67mgKOH/g as indicated in Table 4.0 respectively. However, ASTM specifications doesn't recommend a standard value for free fatty acid of a biodiesel as it expressed, that decrease in FFA of an oil when converted to biodiesel shown an effective trans-esterification procedure in producing the biodiesel [1]. It should be noted that the acid value of the biodiesel directly measures its FFA content [19]. As shown in Table 4.0, the acid value of biodiesel is significantly higher than that of diesel and falls comfortably within the range of ASTM specifications. It also helps to indicate the fuels corrosive nature tendency to clog filters and water content. It can also be used to measure freshness of the biodiesel [1]. According to [19], the fuel quality decreases with increasing acid value. For vehicle fuel, an acid value of less than 0.5mgKOH/g is ideal. Thus, it is safe to classify the biodiesel made from papaya fibre oil as being of high quality.

The peroxide value of the papaya fiber oil was found to be 8mol/g as presented in Table 3.0

The saponification values of the papaya fibre oil were found to be 78.54 and that of its biodiesel was found to be 92.56 as shown in Table 3.0 and 4.0 respectively. The low saponification value of the papaya fibre oil as compared to that of its biodiesel contradict the previous work of [1], [19], [28] and [31], as it is believed that oil is a normal triglyceride and trans-esterification would have help to reduce the triglyceride. However, the saponification value obtained for the biodiesel produced is lower than the ASTM standard range when compare as shown in table 4.0.

The oil's iodine value was determined to be 86.8, and while that of the biodiesel's was found to be 88.5. A high iodine value indicates a high degree of oil unsaturation [13] and [1]. This means that the oil and biodiesel have low unsaturation due to their iodine values.

The cloud and pour point are two crucial factors to take into account when operating an engine in a colder or denser environment [9]. Table 4.0 displays the determined values for the cloud and pour points of biodiesel, which are -5 and 3, respectively. This is fairly high when compared to standard diesel.

Biodiesel's higher flash point enhances storage and transportation safety, preventing auto-ignition and fire hazards at high temperatures emphasizing the importance of recognizing flash. [10] and [16]. The flash point of the biodiesel produced was determined to be 103°C which is higher than that of diesel and within the ASTM standard range, as shown in Table 4.0

In table 4.0 the cetane number of the biodiesel was found to be 25.90, which is extremely low when compared to the values of regular diesel and the ASTM standard, which are 46 and 51 respectively. High cetane number shortens the engine delay period and promotes smooth combustion [33]. Therefore, it is evident that the biodiesel generated has a low cetane number. Also, in table 4.0 shows the net calorific value of biodiesel, which was determined to be 32J/Kg.

4 Conclusion

The study focuses on the extraction and characterization of oil from papaya fibre waste, which was then used to produced biodiesel. The result shows that papaya fibre oil is as suitable feedstock for biodiesel production, as it has minimal fuel properties that can be modified for use in diesel engines

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Appendix

Appendix A shows the pictures of the progress of the research from Plate I -VIII

I

II

III

IV

V

VI

VII

Adopted from [1]

PLATES	DESCRIPTIONS
Plate I	Weighting of the batch samples of papaya,
Plate II	Extraction stage of the oil using Soxhelt apparatus
Plate III	Extract residue after leaching
Plate IV	Weighing of the oil yield from the batch papaya fiber sample
Plate V	The Extract from the Papaya sample
Plate VI	Biodiesel production from the Papaya oil extract
Plate VII	Funnel separation of biodiesel from the glycerol residue