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Bioprospecting Used Cooking Oil for Production of Bio-Diesel in Ethiope East nexus, Delta State

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Abstract
The growing population and waste from fossil fuels demand renewable, environmentally sustainable energy resources like biodiesel derived from used cooking oil (UCO), a promising alternative to fossil fuels. This study explores the viability of UCO as a potential raw material for biodiesel production in Ethiope East nexus, Delta State, Nigeria, a region with substantial UCO generation from domestic and commercial food operations.UCO samples were collected from restaurants, fast-food outlets, and households in Isiokolo, Eku, Okpara, and, Abraka. Samples were visually, filtered, heated, chemically pretreated, and transesterified using methanol and sodium hydroxide. Physicochemical analyses followed ASTM and AOAC standards. Data were analyzed using ANOVA at a 95% confidence level.Visual analysis showed that restaurant UCO was dark and viscous, fast-food UCO was slightly degraded, and household UCO was light and clear. Biodiesel yields were highest from household UCO (91.0%), followed by fast-food (88.0%) and restaurant UCO (85.0%), indicating that the quantity of produced biodiesel depends on the conversion state of start material. All biodiesel samples met ASTM D6751 specifications: viscosities ranged from 4.3–4.8 mm^2/s; flash points from 160–170 °C; densities from 0.86–0.88 g/cm^3; and acid values below 0.5 mg KOH/g. Heating values exceeded the minimum threshold (35 MJ/kg), peaking at 40.2 MJ/kg for household-derived biodiesel. Household UCO in Ethiope East nexus is a viable feedstock for sustainable biodiesel production, yielding high quantities and efficient fuel properties, conforming to international quality standards.

Keywords; used cooking oil; Transesterification; biodiesel; energy; wastes; environmental sustainability

Introduction
The rising demand for energy and the environmental concerns associated with fossil fuel use have driven global interest in renewable energy alternatives (Holechek *et al.*, 2022; Otobrise, 2013). Energy is an essential resources of human society and may be derived from renewable and non-renewable sources. The renewable energy resources are considered as a green and clean source of energy that replenishes naturally from solar, wind, biomass and geothermal while non-renewable energy resources are energy that cannot be

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replenished in a reasonable amount of time, examples are fossil fuel and nuclear energy (Güney, 2019). Currently, significant growth in population and change in lifestyle has led to increase in energy consumption with fossil resources as major source of this increase in energy demand (Khan *et al.*, 2021). Fossil fuels currently dominate in transportation energy, but their finite supply and high greenhouse-gas (GHG) emissions are driving interest toward alternative fuels. Despite Nigeria's abundant crude oil reserves, domestic refineries fail to meet demand, promoting importation. This shortfall, coupled with gas flaring, oil spills, community conflicts and illegal bunkering, exacerbates energy crisis (Bodo *et al.*, 2020; Monago *et al.*, 2013). According to Bodo *et al.*, (2020), it is believed that combustion of fossil fuels is the principal cause of global warming. Thus, to resolve the problem of fossil fuels depletion and increase in the price of energy due to high rate of demand, biofuel technology has been accepted as an alternative replacement for conventional fossil fuel (Anwar *et al.*, 2021).

Biodiesel, a fuel derived from vegetable oils or animal fats has emerged as a viable biofuel because it may be used in diesel engines with little modification and generally burns cleaner than petroleum diesel (Raman *et al*, 2019; Otobrise *et al.*, 2022). According to (Muhammad *et al.*, 2018), biodiesel holds great potential as an alternative energy resource that is renewable, economically feasible and friendly to the environment. In solving the problem of environmental/pollution crisis currently experienced all over the world due to energy generation, biodiesel production has been suggested as focus by many investigations because of its better quality of exhaust gas emissions, biodegradability and, no contribution to a net rise in the level of pollution through the release of carbon dioxide in the atmosphere (Choi *et al.*, 2019). Similarly, based on the findings of Cerón Ferrusca *et al*, (2023), biodiesel reduces CO_2 emissions by up to 80% compared to pure diesel. According to Igwebuike, (2023), biodiesel in Nigeria offers a sustainable alternative to imported diesel, reducing pollution and greenhouse gas emissions, while appropriate policies could spur growth of the local biodiesel industry. According to Chozhavendhan *et al.*, (2020), high yield and high-quality biodiesel may only be achieved through scientific assessment of production process. Biodiesel is produced from transesterification process which involves a chemical reaction between plant oil/animal fat and alcohol such as methanol in the presence of a catalyst such as sodium hydroxide (NaOH) or potassium hydroxide (KOH) to give biodiesel and glycerol.

UCO, repurposed into biodiesel, offers a valuable, sustainable, low-cost, and eco-friendly renewable fuel. It is on the record that every year: many millions of tons of UCO are collected and utilized in a variety of ways throughout the world (Loizides *et al.*, 2019). In Nigeria, based on the findings of (Chukwujama, 2021) in a study note that Nigeria's palm oil use is about 1.4 million tons annually, and restaurants, hotels, and households generate substantial quantities of UCO yet, it represents a free or low-cost resource for fuel production. Currently, most of this UCO is discarded or burned, causing environmental nuisance (Foo *et al*, 2021).

Despite the notable relevance of waste cooking oil and biodiesel their knowledge remains yet unknown hence the study addresses/investigates this crucial gap to ascertain conversion or explores the viability of UCO as a potential raw material for biodiesel production in Ethiope East nexus, Delta State, Nigeria

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Materials and Methods

Study Area

This research was carried out in Abraka, located in Ethiope East Local Government Area, Delta State, Nigeria. The town is situated between latitude 5°45′N and longitude 6°05′E, and experiences a humid tropical climate characterized by high temperatures and heavy rainfall, including restaurants, fast-food outlets, and local street vendors, generates significant volumes of UCO making it a suitable location for biodiesel bioprospecting (Lopresto,2025).

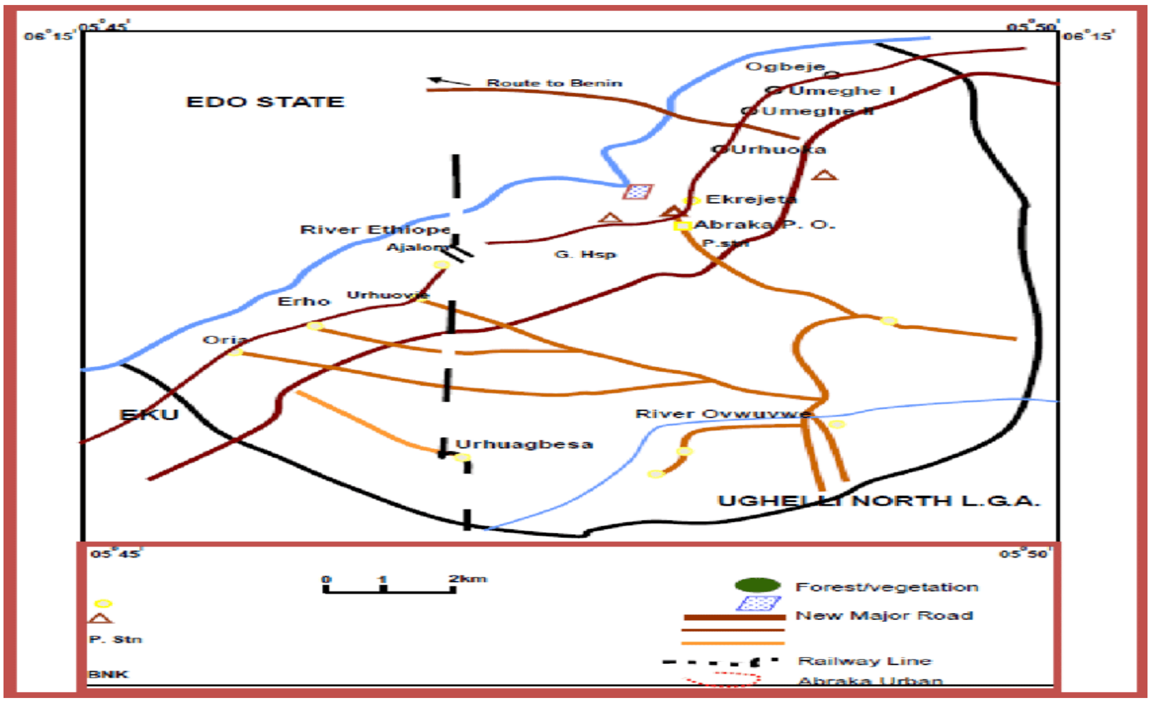

Figure. 1: Map of Abraka showing its several linear settlements.

Source: https://www.researchgate.net/figure/Map-of-Abraka-Ethiope-East-LGA-Delta-State-Nigeria.

All experimental procedures, including oil pretreatment, transesterification, and biodiesel characterization, were conducted at the Microbiology Laboratory of Delta State University, Abraka.

Sample Collection

UCO samples were collected from restaurant, fast-food and household in Abraka, Nigeria to capture spatial variability in oil usage and waste characteristics. Approximately 500 ml of spent frying oil was drawn directly from the vendor containers into pre-cleaned amber glass bottles. To minimize contamination, each sample bottle was rinsed with the vendor's oil before collection, sealed immediately with screw caps, and labeled with date, time, and location. The sample was transported to the laboratory within two hoursfor further processing.The materials and equipment used were carefully sterilized and handled with care to prevent contamination. Sodium hydroxide (NaOH), methanol (99.8%), were used in the study of analytical grade.

Pretreatment of UCO

The UCO samples were filtered to remove food particles and heated at 110°C for 10–15 minutes to remove moisture. Samples with high free fatty acid (FFA) content (>2%) were subjected to acid esterification using

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methanol and H_2SO_4 in a 6:1 molar ratio to reduce FFA before base transesterification, following the procedure of (Hussain *et al.*,2022).

Physicochemical Analysis of Oil

Each oil sample underwent analysis to determine the suitability of UCO for biodiesel production Acid value, saponification value, iodine value, moisture content, specific gravity, and kinematic viscosity were determined using ASTM and AOAC standards, as described by (Zakaria *et al.,* 2022).

Transesterification of UCO

According to (Salaheldeen*et al.,* 2021), the core process of biodiesel production is based on the transesterification method, where triglycerides in the UCO react with methanol in the presence of a catalyst to produce methyl esters (biodiesel) and glycerol. Sodium hydroxide (NaOH) was used as the catalyst. 2.5 g of NaOH pellets were weighed accurately and dissolved in 50 ml of methanol within a conical flask. The solution was stirred until a clear sodium methoxide solution was obtained, indicating complete dissolution. 250 ml of the pre-filtered UCO was measured into a 500 ml beaker. A magnetic stirrer was inserted into the beaker, and it was placed on a shaker hot plate. The oil was continuously stirred and heated to a temperature range of 80°C to 110°C to reduce viscosity and enhance the miscibility of methanol with the oil. Once the desired temperature was attained, the sodium methoxide solution was slowly added to the heated oil while stirring continued. The reaction mixture was maintained at a steady temperature of approximately 110°C for 45–60 minutes to allow complete transesterification. The mixture was then left to cool to room temperature. After cooling, the mixture was passed through Whatman No.1 filter paper to remove soap residues, solid impurities, and any unreacted particles. The filtered mixture appeared as a homogenous fluid ready for separation. The filtrate was carefully poured into a clean separating funnel and allowed to stand undisturbed overnight. Two distinct layers formed: the upper biodiesel layer and the lower layer of crude glycerol. The pure biodiesel layer was carefully decanted into a clean container for analysis, while the glycerol was discarded appropriately.

Biodiesel Fuel Characterization

The obtained biodiesel was subjected to comparative tests alongside commercial diesel fuel to evaluate its physicochemical properties. Biodiesel fuel properties of waste cooking oil methyl esters (WCOME) were determined using standard test methods (ASTM D6751).The following fuel properties were measured experimentally: kinematic viscosity (ASTM D445), density (ASTM D4052) and flammability (flash point) (ASTM D93).

Viscosity Test

According to the ASTM D445 Standard Test Method for kinematic viscosity of transparent and opaque liquids, viscosity is determined by measuring the time it takes a fixed volume of liquid to flow through a calibrated glass capillary under gravity. A precise capillary viscometer and timing marks ensure reproducibility and allow calculation of kinematic viscosity (ν) in mm^2/s. In this study, 10 ml of each fuel sample of biodiesel and commercial diesel was measured into separate test tubes and a Duran tube was then dropped into each test tube simultaneously, and the time taken to sink was recorded using a stopwatch.

Flammability Test

According to (Tugyi *et al.,* 2024), the flammability test is the most important property that must be considered in analyzing the overall flammability. The gas stops burning when the flame is exposed to the Biodiesel vapor. Each biodiesel has a unique flashpoint. Many factors affect the change in biodiesel flashpoint, residual alcohol content is one of them (do Nascimento *et al.,* 2021). Moreover, flashpoint is influenced by several key factors, such as the chemical compositions of the biodiesel, including the number of double bonds and the number of carbon atoms (Álvarez *et al.,* 2019). The flashpoint of biodiesel is measured using the ASTM D93. The study of (Silitonga*et al.,* 2023) posited that the flashpoint is the temperature at which it ignites when the vapor is exposed to a flame or a spark. In this study, cotton wool was soaked in equal volumes of biodiesel and commercial diesel in separate setups. Each was ignited in a controlled environment, and the burning characteristics were observed.

Density Test

Density is an important parameter for the diesel fuel injection system. A higher density for biodiesel results in the delivery of a slightly greater mass of fuel since fuel equipment operates on a volume metering system. In this study, the density of each sample was determined by weighing 10 ml of each fuel in a test tube. The density of the oil sample at room temperature was determined using the formula below:

$$Density = \frac{mass}{volume}$$

Specific Gravity

Specific gravity was derived from the ratio of biodiesel density to water density. It provides a quick estimate of fuel weight and quality, consistent with methods by (Kwao-Boateng *et al.,* 2024).

Acid Value

Acid value was measured through titration with 0.1 M KOH solution. It indicates residual FFA, which could cause engine corrosion. Values were interpreted against ASTM standards (Andari *et al*., 2022).

Heating Value

The calorific value was determined using a bomb calorimeter. It represents the energy content per gram of biodiesel and is a key indicator of performance as a fuel (Musa & Folayan, 2020).

Safety and Ethical Considerations

All experiments were performed following standard laboratory safety protocols, wearing laboratory coats, gloves, and goggles, and methanol was handled in a fume hood. Ethical clearance was not required for this study, but verbal consent was obtained from local vendors during oil collection. Waste glycerol and water from biodiesel washing were disposed of according to local environmental regulations (Paladino *et al.,* 2021).

Statistical Analysis

Data obtained were subjected to descriptive statistical analysis, including mean range and percentage deviation.

Results and Discussion

The visual characteristics of UCO samples collected from three distinct locations in Abraka: a restaurant, a fast-food outlet, and a household kitchen are shown in Table 1. The restaurant UCO was observed to be dark brown and highly viscous, reflecting prolonged exposure to high frying temperatures and multiple reuse cycles. In contrast, the fast-food sample appeared slightly cloudy with a yellowish tint, indicating moderate degradation and possible mixing with fresh oil during daily operations. The household UCO, by comparison, was light yellow and clear, suggesting fewer heat cycles and cleaner usage conditions. Such variations can significantly influence subsequent biodiesel production, affecting both the efficiency of transesterification and the quality of the final fuel.

Table 1: Observation of UCO Samples Collected from Different Collection Sites

Collection Site	Visual Observation
Restaurant	Dark brown, viscous
Fast-food Outlet	Slightly cloudy, yellowish
Household Kitchen	Light yellow, clear

Biodiesel Yield after Transesterification

Table 2 shows the biodiesel yields obtained from the three UCO sources. The household UCO produced the highest biodiesel volume at 91 mL, corresponding to a yield of 91.0%. This superior performance is likely attributable to its lower free fatty acid content and minimal thermal degradation, which favor complete conversion to fatty acid methyl esters. Fast-food UCO yielded 88 mL of biodiesel (88.0% yield), reflecting intermediate oil quality with modest levels of oxidation products. The restaurant UCO delivered the lowest yield of 85 mL, or 85.0%, most likely due to its high viscosity and accumulated contaminants that can inhibit catalyst activity and saponify some fatty acids.

Table 2: Biodiesel Yield from UCO Samples

Source of UCO	Volume of Oil (mL)	Volume of Biodiesel (mL)	Yield (%)
Restaurant	100	85	85.0
Fast-food	100	88	88.0
Household	100	91	91.0

Properties of the Biodiesel

Table 3 shows the key physicochemical properties of the biodiesel samples derived from restaurant, fast-food, and household UCO, benchmarked against ASTM D6751 standards. Figure 2 is compares the biodiesel properties from the three sources. All three samples exhibited viscosities within the acceptable range of 1.9–6.0 mm²/s, with values of 4.5, 4.8, and 4.3 mm²/s respectively, indicating suitable fluidity for engine injection systems. Flash point ranged from 160-170 °C, which was above the ≥130 °C minimum, confirming adequate safety margins for storage and handling. Densities ranged from 0.86 to 0.88 g/cm³, comfortably within the standard 0.86–0.90 g/cm³ limits, and specific gravities of 0.87–0.89 align with typical biodiesel fuel characteristics. Acid values, indicative of residual free fatty acids, were low across the board (0.30–0.42 mg KOH/g), remaining below the maximum of 0.5 mg KOH/g. Finally, heating values increased progressively from restaurant (38.1 MJ/kg) to household (40.2 MJ/kg), all exceeding the ≥35 MJ/kg threshold, reflecting efficient energy content.

Table 3: Comparison of Properties of Biodiesel Samples to ASTM D6751 Standards

Parameter	Restaurant	Fast-food	Household	Mean	Range	Deviation (%)	ASTM D6751 Limit
Viscosity (mm²/s)	4.5	4.8	4.3	4.53	0.50	11.03	1.9 – 6.0
Flash Point (°C)	160	165	170	165.00	10.00	6.06	≥ 130
Density (g/cm³)	0.88	0.87	0.86	0.87	0.02	2.30	0.86 – 0.90
Specific Gravity	0.89	0.88	0.87	0.88	0.02	2.27	–
Acid Value (mg KOH/g)	0.42	0.39	0.30	0.37	0.12	32.43	≤ 0.5
Heating Value (MJ/kg)	38.1	39.0	40.2	39.10	2.10	5.37	≥ 35

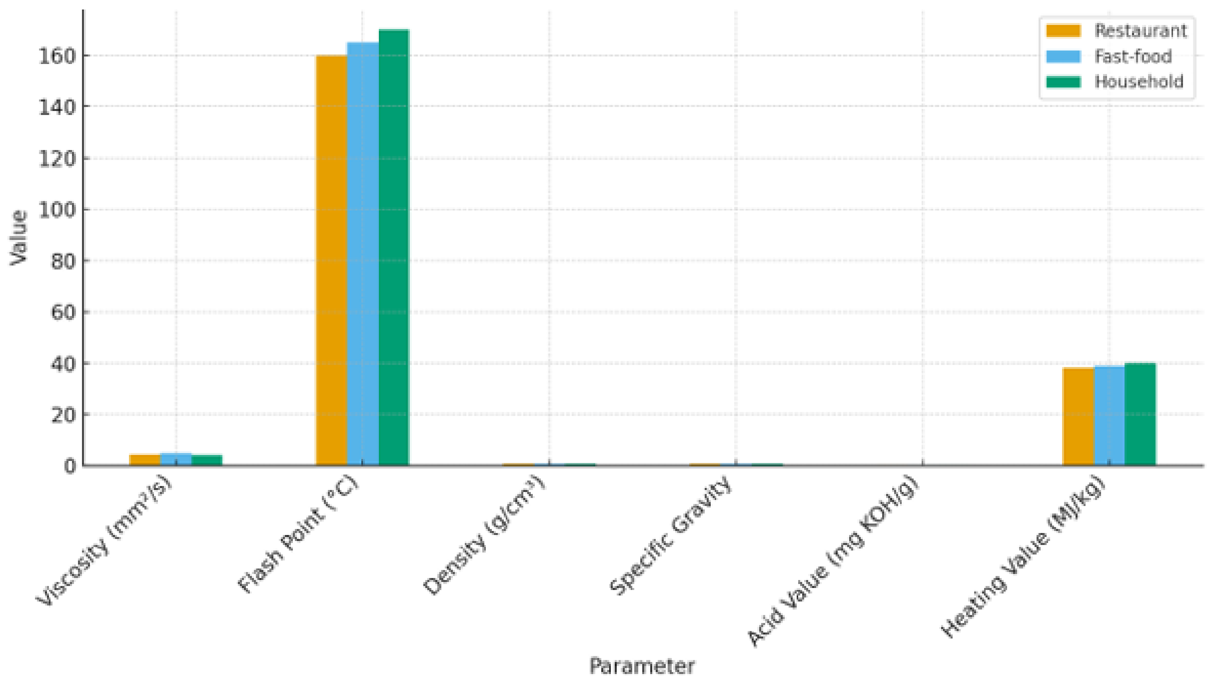

Figure 2: Comparison of biodiesel properties from the three sources

The biodiesel yields obtained, 91.0 % from household used cooking oil, 88.0 % from fast-food used cooking oil, and 85.0 % from restaurant used cooking oil, are consistent with the 84–97.5 % range typically reported by Miyuranga *et al.*, (2023) for base-catalyzed transesterification of waste cooking oils. Chanphavong, (2023) in a study achieved a 91.3 % yield using KOH and methanol at 60 °C for 30 minutes, while Pooja and Sukhneet, (2020) in a review of biodiesel production from UCO worldwide notes yields spanning 84.0–97.5 % under varied conditions. The results also agree with Elgharbawy *et al.* (2021) who reported even higher conversions, up to 98 %, when optimized catalysts or reaction parameters were used such as 9.5:1 methanol-to-oil ratio, 1 wt % KOH at 50 °C in 20 min). The slightly lower yields of 88.0% and 85.0 %

observed for fast-food and restaurant oils in the study likely reflect their higher free-fatty-acid contents and thermal degradation products, which are known to inhibit base-catalyzed reactions unless pretreated as reported by Farouk *et al.,* (2024) who in a study reported lower yields of 71.2%. Kinematic viscosities of 4.3–4.8 mm^2/s align with EN 14214 and ASTM limits (3.5–6.0 mm^2/s) and closely match the 4.0–5.0 mm^2/s typical for UCO biodiesel reported by Corach *et al.,* (2021).The flash points of 160–170 °C in this study exceed the ASTM D6751 minimum (≥130 °C) and are within the 140–180 °C range reported in similar investigations by Ferreira*et al.,* (2021) with a range of 152-167 °C. Density values of 0.86–0.88 g/cm^3 and specific gravities of 0.87–0.89 also conform to the 0.86–0.90 g/cm^3 window noted by Pooja and Sukhneet, (2020). Acid values (0.30–0.42 mg KOH/g) fall below the 0.5 mg KOH/g threshold, matching that reported by Farouk *et al.,* (2024) who achieved 0.2–0.5 mg KOH/g after proper pretreatment. Heating values (38.1–40.2 MJ/kg) exceed the ASTM minimum of 35 MJ/kg and parallel the 37–42 MJ/kg range frequently cited for waste-oil biodiesel by Pooja and Sukhneet, (2020).

Conclusion

The study demonstrate the potential usage of cooking oil (UCO) as a viable and sustainable raw material for biodiesel production. With the ever-increasing global demand for clean, renewable, and economically viable energy alternatives, especially in developing countries, this research provides crucial insight into the practical conversion of waste oil into eco-friendly biofuel. Among the samples analyzed, household-used oil gave the highest biodiesel yield, followed by oil from fast-food outlets and then restaurants. This difference is likely due to the frequency of oil reuse and the extent of degradation in restaurant oils, which are often subjected to high-temperature cooking for prolonged periods. This study By provides a practical approach to recycling waste into biodiesel, addresses both environmental pollution and the energy crisis in a single solution. Additionally, the research supports global Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 12 (Responsible Consumption and Production).The consistent performance of the biodiesel suggests it can be blended with diesel or used as a standalone fuel, especially for generators, farm machinery, or even public transportation in the future. Therefore, this work sets a foundational platform for more comprehensive biodiesel initiatives within and beyond Abraka. Educating communities through workshops, media, and school outreach programs can encourage proper collection, storage, and donation of UCO for biodiesel production.Secondly, the government and local authorities should support the establishment of small-scale biodiesel processing units within the community. stimulate employment and promote energy self-sufficiency regulations and policies should be developed to encourage restaurants and food service providers to properly dispose of their used cooking oil. Incentives can be given to vendors who supply UCO for biodiesel production, while penalties can be imposed for improper disposal. This ensures both environmental protection and the steady availability of raw materials. Finally, collaboration between universities, NGOs, and private sectors should be encouraged to create a circular economy model around waste cooking oilwhere waste is collected, converted, and reinvested into the community as fuel and income.

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Conflict of interest

None declared.

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