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EXPLORING THE POTENTIAL OF WASTE COOKING OIL AS A SUSTAINABLE FEEDSTOCK FOR BIODIESEL PRODUCTION THROUGH TRANSESTERIFICATION

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ABSTRACT

This research explores the possibility of utilizing waste cooking oil as a renewable feedstock for transesterification, which is a process of converting fats and oils into biodiesel by reacting them with alcohol and a catalyst. The research was carried out in Jhansi, India, with the objective of determining the availability of waste cooking oil, the frequency of its collection, and the opinions of individuals collecting it regarding the possibility of its conversion into biodiesel. 100 respondents were asked the source of the oil, how often it was collected, and if they thought biodiesel was practical, using standardized questionnaires. It emerged that the greatest sources of used cooking oil came from home kitchens (45%) and restaurants/hotels (35%), with the commercial and residential sectors each playing a big role in the collection process. A majority of the respondents (50%) collected used oil once every week, thus ensuring a source of reliable and steady supply for the production of biodiesel. There is much hope for biodiesel potential as an alternative source of renewable fuel since 60% of the respondents said that it was highly possible to produce it from used oil. The results show that spent cooking oil can serve as a low-cost and easily accessible feedstock for the production of biodiesel and highlight the need to encourage efficient collection systems to support waste minimization and renewable energy sources.

Keywords: *Biodiesel Production, Waste Cooking Oil, Transesterification, Alcohol, Catalyst, Feasible, Alternative Fuel, Low-Cost, Renewable Energy Solutions, Reduce Waste.*

1. INTRODUCTION

The growing energy demand worldwide and the increasing awareness of environmental degradation associated with the use of fossil fuels, biodiesel has received increasing attention as a potential renewable energy source. Biodiesel is obtained through transesterification, a chemical process that breaks down triglycerides into methyl or ethyl esters. Waste cooking oil is a by-product produced in large quantities by households, restaurants, and food processing industries, and it can be repurposed as a valuable resource instead of waste material, thus encouraging sustainability and minimizing the environmental impacts associated with its disposal.

Wastes cooking oil presents some advantages for biodiesel production because it is a readily available, free-to-cost raw material, which may also have otherwise gone to waste in much of the world, offering an economic alternative to the feedstocks that conventionally feed into biodiesel manufacturing and reduce waste with the only risk of potentially polluting landfills or waterways. Furthermore, waste oils for biodiesel can minimize the use of virgin vegetable oils. This will have a relieving effect on agricultural land and decrease its environmental footprint.

The process of transesterification is central in the conversion of waste oil from kitchen into biodiesel. In this conversion, triglycerides present in the waste oil combine with an alcohol, usually methanol or ethanol, catalyzed by a substance such as sodium hydroxide or potassium hydroxide. The reaction produces biodiesel (methyl or ethyl esters) and glycerol as a by-product.

The transesterification process has been improved significantly by researchers and industries to increase the yield and quality of biodiesel from waste cooking oil. In this respect, the generation of biodiesel from waste cooking oil can add value to waste and help in the circular economy model by reducing the environmental damage associated with waste collection.

2. LITERATURE REVIEW

Sadaf et al. (2018) focused on WCO-based transesterification to produce biodiesel. Although the tranesterification of waste oils may represent an attractive way of obtaining biodiesel very cheaply, the presence of a very large concentration of FFA significantly depresses the extent of the tranesterification. A measure of 5.5 mg KOH/g indicated high levels of acidity, i.e., FFA.

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Comparing the esterification reaction of WCO with HCl, H_2SO_4 and H_3PO_4 we have that process catalyzed by H_2SO_4 reduce FFA to as low as 88.8% at 60°C using a molar ratio methanol to oil 1:2.5. The transesterification with 1% catalyst of alkali (KOH) yielded FAME to the tune of 94% at 50°C. Calorie value, cloud point, pour point, specific gravity, iodine value, cetane number, acid value, and saponification value were some of the metrics used to characterised the biodiesel. There was also a Gas Chromatography (GC) examination of the biodiesel that was produced. The production of biodiesel from WCO was efficiently accomplished using alkali catalyzed transesterification, according to ASTM norms. The research showed that used cooking oils may be turned into biodiesel, which can reduce pollution and provide energy.

Yaqoob et al. (2021) analysed with an emphasis on combustion, performance, and emission parameters, as well as their influence on engine longevity. Researchers are always coming up with innovative methods to produce and use alternative, renewable, and dependable fuels because non-renewable conventional fossil fuel sources are running out at an alarming rate. Most forms of life on Earth have suffered greatly as a result of the severe degradation of the environment brought about by traditional technological practices. One of the greatest locally available alternative fuels to minimise emissions from compression ignition engines is waste cooking oil (WCO) biodiesel. Additionally, this study also reviews the economic and environmental implications. Combustion characteristics of WCO biodiesel are characterised by an increase in cylinder peak pressure value, a decrease in ignition delay period and heat release rate. There is a decline in braking power and torque, an increase in brake-specific energy consumption, and an increase in brake-specific fuel consumption when it comes to performance parameters. Because it produces 85% fewer hydrocarbon, SO_2, CO, and smoke emissions in the exhaust, WCO biodiesel is an excellent environmental savior. Nevertheless, in comparison to diesel, CO_2 and NO_x tend to rise. Also detailed are the broader monetary effects of production on this resource's use. Our research confirms that WCO biodiesel is a great choice for any diesel engine in terms of performance, cost, impact on the environment, and fuel efficiency.

Innocenzi and Prisciandaro (2021) performed employing hydrodynamic cavitation, may set a new standard for industrial-scale uses. For biodiesel manufacturing to become a competitive process while reducing environmental effect, new and creative methods are needed. Because oil

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and alcohol are inherently incompatible as raw materials, the mixing process has a significant effect on the total process cost and operates as a bottleneck. This study presents the results of a process analysis for a biodiesel production scheme that uses virgin oil and used cooking oil as feedstocks. In the first, we model the conventional process flow; in the second, we swap out the biodiesel reactor for a hydrodynamic cavitation one. In this study, we compare the old and new processes using the life cycle costing method. This gives us a professional tool for process analysis, and it also gives us some pointers on how to apply technology in the industrial sector. The use of hydrodynamic cavitation cuts energy usage by almost 40% compared to the old method, which is an important consideration. When starting with waste cooking oil as feedstock, the costs decreased by about 60%, down to 290-300 €/t (innovative and traditional process, respectively), compared to when using virgin oil as feedstock, which ranged from 820-830 €/t.

Nayab et al. (2022) carried out in this paper to emphasize different facets of biodiesel, including biodiesel feedstocks, production methods, biodiesel qualities and characteristics, issues with and possible solutions to using vegetable oil, pros and cons of biodiesel, economic feasibility, and lastly, biodiesel's future. There needs to be research into alternative fuels to replace fossil fuels because their supply is dwindling, which could lead to an energy crisis in the future. Among the most promising new resources, biodiesel stands out. Some of the materials that have been investigated as potential feedstocks include microalgae and genetically modified plants like poplar and switchgrass; others are non-edible oils like Jatropha curcas and Calophyllum inophyllum. Diluting, pyrolyzing, micro emulsifying, and trans esterifying are some of the production processes that have been covered, along with their similarities and differences. When comparing various methods, the transesterification process stands out as the most cost-effective and productive. Transesterification methods, both catalytic and non-catalytic, provide the most environmentally friendly biodiesel production options. The catalytic potential of many catalysts, including mixed, enzymatic, homogeneous and heterogeneous acid/basic, and others, has been studied in relation to trans esterification.

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3. RESEARCH METHODOLOGY

A quantitative, descriptive research design was adopted in the study. The study involved 100 participants in Jhansi who collected used cooking oil through structured surveys. The practicality of producing biodiesel was determined by analyzing the data using frequency analysis and descriptive statistics and visualizing the results with frequency tables and graphs.

3.1. Research Design

The research design utilized here is the descriptive type for which this study investigates the feasibility of the usage of used cooking oil as sustainable feedstock in producing biodiesel. The main study of this kind intends to explore whether spent cooking oil originates, its frequency in being collected, and respondents' attitudes towards using such oil as an alternative source of feedstock for the manufacturing of biodiesel. It uses a quantitative method whereby the data is collected through surveys and analyzed using frequency distribution and descriptive statistics. The design allows for an in-depth understanding of the existing processes, attitudes, and challenges surrounding used cooking oil collection and its use in the production of biodiesel.

3.2. Data Collection

Structured questionnaires were employed as a tool of data collection on this study across participants collecting the used cooking oils for the production of biodiesel. The following crucial areas were intended to be covered by the survey questionnaire:

- **Source of waste cooking oil:** The respondents were asked to indicate if the oil came from street sellers, restaurants/hotels, industrial canteens, or home kitchens.
- **Frequency of oil collection:** The frequency of waste oil collection was indicated by the respondents, who may choose between daily, weekly, or monthly.
- **Perception of biodiesel feasibility:** Respondents said whether they thought it was highly feasible, moderately feasible, or not viable to produce biodiesel from used cooking oil.

A total of 100 respondents who actively participate in the collecting of waste cooking oil were given the survey.

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3.3. Sample Size

The study's sample size consisted of 100 respondents that were chosen from Jhansi. These respondents were specifically targeted because they were involved in the collection of used cooking oil from various sources. The sample contained diverse respondents who ensured that information was collected from different locations, including homes, eateries, workplace canteens, and street vendors. As such, due to the diverseness of the sample, a complete understanding of the various waste oil collection modes and sources in the region is achieved.

3.4. Research Area

The survey was conducted in the northern Indian city of Jhansi. This city was selected because of its diversified commercial, residential, and industrial activity. This city is a best location to test the feasibility of utilization of waste cooking oil to prepare biodiesel as there are wide sources in this city, including restaurants, industrial canteens, and kitchen areas in residential apartments. The objective of this research is to understand the dynamics of the supply chain of waste cooking oil in this region.

3.5. Data Analysis

The data collected was analyzed by making use of frequency analysis and descriptive statistics. With the help of frequency analysis, the number and percentage of respondents in each category were determined for each variable. These variables include the source of waste oil, the frequency of oil collection, and opinions regarding the viability of biodiesel. With summaries in frequency tables, clarity is further enhanced with bar charts and pie graphs (Figures 1, 2, and 3). Such data would then become readable with clear indication of trends and patterns, and the trends and patterns are all significant towards the understanding of viability in biodiesel production from used cooking oil.

4. DATA ANALYSIS AND INTERPRETATION

Table 1 and Figure 1 presents the four primary sources of used cooking oil that are collected for biodiesel production. These include: home kitchens, eateries and lodging facilities, industrial

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canteens, and street sellers. A bar graph illustration of these ratios is presented while a table for the frequency and percentage distribution for each source can be seen as well.

Table 1: Origin of Used Cooking Oil

Source	Frequency (n)	Percentage (%)
Household Kitchens	45	45%
Restaurants/Hotels	35	35%
Industrial Canteens	15	15%
Street Vendors	5	5%
Total	**100**	**100%**

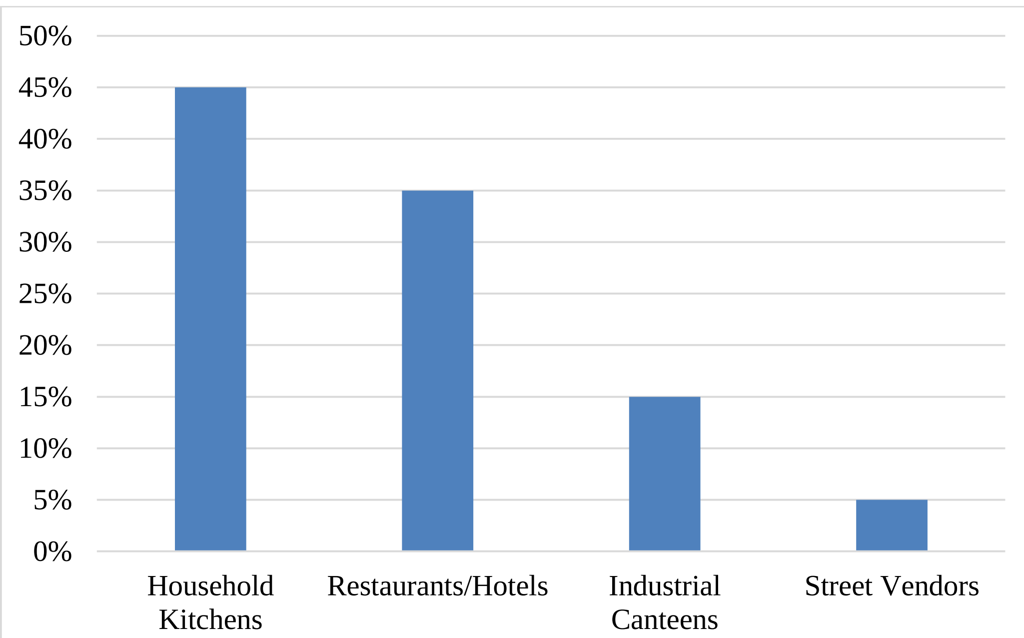

Figure 1: Graphical representation of Origin of Used Cooking Oil

Residential kitchens stand at 45% of the total sample, while restaurants and lodging facilities stand at 35%. Sellers on the streets and industrial canteens stand at 5% and 15%, respectively of the total. This has reflected the heavy potential for waste oil collection on residential and hospitality sectors and, therefore, focused strategies in both of these sectors can help upgrade feedstock supply for biodiesel."

The oil collection frequency for used cooking oil for the manufacture of biodiesel from respondents is depicted in Table 2. Frequency of collection of waste cooking oil provides some important insights in terms of analyzing the supply chain dynamics and the feasibility of the feedstock.

Table 2: Oil Gathering Period

Collection Frequency	Frequency (n)	Percentage (%)
Daily	30	30%
Weekly	50	50%
Monthly	20	20%
Total	**100**	**100%**

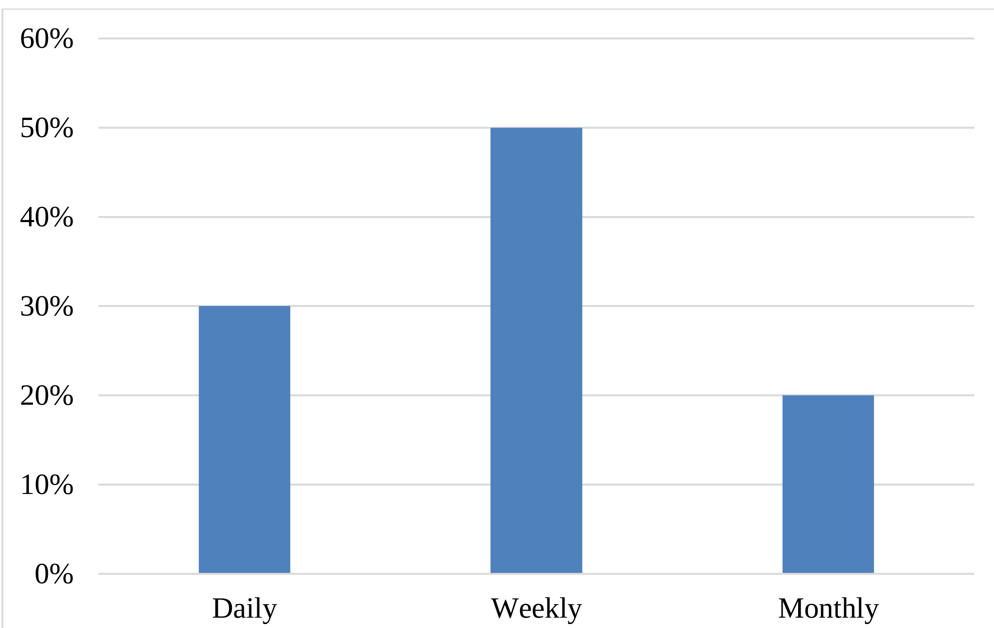

Figure 2: Graphical representation of Oil Gathering Period

The majority of respondents (50%) gather used cooking oil once a week, according to Table 2, indicating a steady and controllable source for the manufacturing of biodiesel. Furthermore, 30% of respondents said they gather oil every day, suggesting a large, reliable supply that most likely comes from businesses like canteens and restaurants. 20%, on the other hand, collect oil on a monthly basis, which represents lower amounts, frequently from homes. The possibility of using used cooking oil as a sustainable feedstock for the generation of biodiesel is supported by these data, which collectively point to a well-distributed collection frequency.

The respondents' thoughts on the viability of turning used cooking oil into biodiesel are shown in the following table (Table 3). Their perceptions are divided into three categories: not feasible, fairly viable, and highly feasible. The frequency and percentage distribution of these viewpoints among the 100 study participants are shown in the table.

Table 3: Respondents' Perceptions of the Feasibility of Biodiesel

Opinion	**Frequency (n)**	**Percentage (%)**
Highly Feasible	60	60%
Moderately Feasible	30	30%
Not Feasible	10	10%
Total	**100**	**100%**

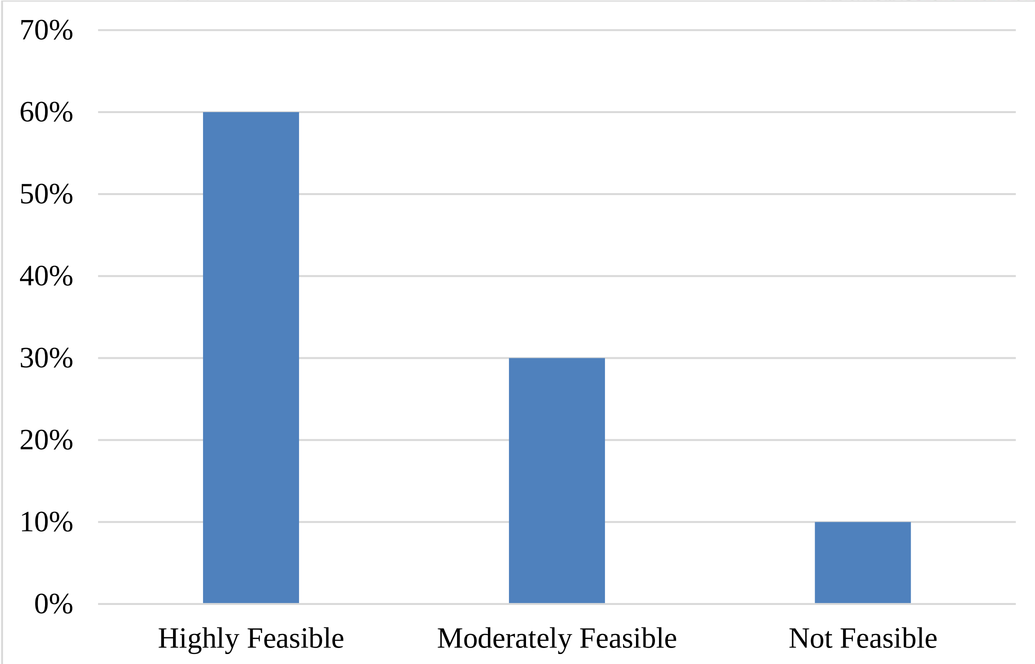

Figure 3: Graphical representation of Respondents' Perceptions of the Feasibility of Biodiesel

The majority of respondents (60%) believe that producing biodiesel from used cooking oil is very possible, according to the data in Table 3, indicating a high level of trust in the technology's potential. A further 30% think it is somewhat doable, expressing some hope but with reservations, and 10% think it is not practicable, expressing uncertainties or worries about the process's viability. This distribution shows a definite tendency towards the feasibility of using used cooking oil to produce biodiesel, with an overall optimistic prognosis.

5. CONCLUSION

This study highlights the potential of using waste cooking oil as a sustainable feedstock for biodiesel production through the transesterification process. Conducted in Jhansi, India, the study revealed that waste cooking oil is abundantly available from both residential kitchens and commercial establishments like restaurants and hotels, with a consistent collection frequency, primarily once a week. The survey results indicate strong support for the feasibility of converting used oil into biodiesel, with 60% of respondents recognizing its potential as a viable alternative fuel. These findings underscore the importance of efficient collection systems for used cooking oil, emphasizing its role as an affordable and accessible resource for biodiesel production, which can contribute to waste reduction, resource conservation, and the promotion of renewable energy.

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