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Produce Biodiesel using of Food Waste

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ABSTRACT –

Biodiesel is emerging as a sustainable fuel alternative due to the depletion of fossil fuels. Simultaneously, food waste poses environmental and health concerns, particularly when landfilled, as it generates harmful leachate. Converting food waste into biodiesel addresses both energy demand and waste management challenges. In this study, food waste from a hostel kitchen in India was dried to reduce moisture content, enhancing lipid extraction. Biodiesel was produced via transesterification using monohydric alcohol and a catalyst. Gas chromatography-mass spectrometry (GC-MS) identified key fatty acids like lauric, myristic, palmitic, stearic, and oleic acids, indicating biodiesel potential. The resulting fatty acid methyl esters (FAMEs) were quantified using GC-FID, and the fuel properties were compared with standard biodiesel specifications.

***Key Words*:** Food waste, Transesterification, Biodiesel, Petroleum derived diesel, clean energy.

1. INTRODUCTION

The growing reliance on petroleum fuels, driven by rapid urbanization and industrialization, has led to a global energy crisis, rising fuel prices, and serious environmental consequences such as global warming, ozone depletion, and water and soil pollution. Fossil fuels, being non-renewable, are unsustainable in the long term, prompting an urgent search for alternative, eco-friendly energy sources (M, 2011).

At the same time, increasing volumes of municipal solid waste (MSW), especially food waste, present significant management and environmental challenges. In India alone, MSW generation reached 700 tons per day in 2015, with food waste comprising the largest fraction (31.9%) (Srivastava R, 2014). Improper disposal—mostly through landfilling—results in harmful greenhouse gas emissions (CO_2, CH_4) and toxic leachates, contaminating soil and water resources (Karmee S.K., 2016; K, 2014).

Food waste, however, holds great potential for renewable energy production, particularly in the form of biodiesel and biogas. Biodiesel can be produced through methods such as pyrolysis, thermal cracking, and most commonly, transesterification, where oils or fats react with alcohol in the presence of a catalyst to produce alkyl esters and glycerol. The economic viability of this process depends largely on the feedstock cost. This study focuses on reusing kitchen waste to extract lipids for biodiesel production by identifying free fatty acids (FFAs), offering a dual benefit of waste management and alternative energy generation (S Barik).

In addition, kitchen waste is highly suitable for anaerobic digestion to produce biogas, a clean fuel rich in methane. Methane can serve as a renewable energy source for cooking and other applications, particularly in institutions producing large quantities of biodegradable waste. In Rajasthan, where over 300 educational institutions exist, significant food waste remains unutilized. This study aims to harness such waste in biogas digesters to meet campus energy needs. At Mewar University, biogas was successfully generated in a fixed-type plastic tank using food waste from hostels, canteens, and staff quarters (Rajashekhara K, NCMPC - 2019).

2. MATERIALS AND METHODS

2.1 Sources and generation of food waste

Food waste collected from the RD Engineering College hostel includes vegetable scraps, fruit waste, and other leftover food items. The treatment of such waste can generate hazardous by-products, often due to the use of chemicals during processing. Food manufacturing must comply with stringent regulations set by local and national food safety authorities. The range of food products—spanning from everyday staples to specialty and ethnic items—is produced under controlled conditions with safety as a top priority.

2.2 Sample collection site

Food waste is collected from RD Engineering College, Ghaziabad, India. This sampling location site is chosen because of huge amount of food waste generation. Food waste after collection is brought to the laboratory for further analysis.

2.3 Food waste analysis

About 4kg of food waste is accumulated and taken to the laboratory. Moisture content is removed and standard temperature was determined. Different drying methods were carried out i.e., oven drying (55 ˚C, 75 ˚C, 105 ˚C), freeze drying (-4 ˚C) and sun drying (25-30 ˚C) to decide the gold standard temperature. The important venture to be faced for biodiesel manufacturing became green lipid extraction because it incorporates water along meals debris. After drying the sample has been grinded to powdered form. The powered pattern has been used for lipid extraction (Olkiewicz M, 2014)

2.4 Lipid extraction and analysis

Lipid extraction was performed using a Soxhlet apparatus with methanol as the solvent. The efficiency of extraction depends on the octanol-water partition coefficient (K_ow), which represents the ratio of a compound's concentration in octanol (hydrophobic phase) to that in water (hydrophilic phase). After extraction, the mixture was filtered using Whatman 42 filter paper (125 mm) to separate solids from the liquid. Methanol was recovered via rotary evaporation at 70 °C and reused in subsequent extractions. The extracted lipid was stored in a desiccator overnight and weighed to determine the yield. Further analysis was conducted using gas chromatography–mass spectrometry (GC-MS) to identify free fatty acids, indicating the biodiesel potential of the food waste. The remaining residue post-extraction can be explored for pharmaceutical applications, such as in medications, capsules, and plant nutrients.

3. RESULTS AND DISCUSSION

3.1 lipid analysis and Moisture content

Moisture removal is a critical step in enhancing lipid extraction and biodiesel production, as excess water can block solvent penetration by surrounding food particles. The drying method and temperature significantly influence moisture content and lipid yield. In general, higher drying temperatures result in lower moisture levels and increased lipid recovery (Olkiewicz M, 2014).

Among tested methods, sun drying achieved 4.4% moisture in 240 hours at 25–30 °C, yielding 15.8% lipid, though it is time-consuming and weather-dependent. Freeze drying resulted in 7.2% moisture in 48 hours. Oven drying was most effective, with 105 °C yielding only 0.1% moisture and a lipid yield of 36.9%, compared to 2.3% at 55 °C and 1.5% at 75 °C. However, excessively high temperatures may damage fatty acid chains essential for biodiesel.

To assess the impact of food composition, samples were collected weekly over seven days. Waste from vegetarian meals (e.g., rice, pulses, vegetables, paneer) and non-vegetarian meals (e.g., chicken, mutton, fish) were compared. Fat content per 100 g was 14 g in chicken, 21 g in mutton, 12 g in fish, and 20.8 g in paneer. Lipid yield was higher in mixed (veg + non-veg) waste due to greater fat content, aligning with the principle that higher oil content leads to higher lipid and biodiesel yield.

Table -1: Effect of lipid yield due to food waste composition

S. No.	Days	Food waste composition	Lipid yield (%)
1	Monday	Vegetarian	32.5
2	Tuesday	Vegetarian and non-vegetarian (Non Vegetarian Mess)	37.5
3	Wednesday	Vegetarian	36.8
4	Thursday	Vegetarian	30.2
5	Friday	Vegetarian and non-vegetarian (Non Vegetarian Mess)	36.4
6	Saturday	Vegetarian	37.3
7	Sunday	Vegetarian and non-vegetarian (Non Vegetarian Mess)	37.2

3.2 Lipid Analysis

Lipid extraction was carried out using a Soxhlet apparatus with methanol as the solvent. Lipids are classified into neutral and polar types; neutral lipids are water-insoluble but dissolve well in organic solvents like methanol, chloroform, and hexane. Solvent extraction enables the separation of target compounds—such as triglycerides—by heating the mixture near the solvent's boiling point, allowing solvent evaporation while retaining the lipids (MW, 2009).

Methanol plays a key role in extracting triglycerides, phospholipids, and cholesterol. The extracted lipids were analyzed using gas chromatography–mass spectrometry (GC-MS) to identify free fatty acids. Table 2 presents the fatty acids detected in the analysis, confirming the potential of food waste as a viable feedstock for biodiesel production (Ferraza T.P.L., 2004).

Table-2: Free fatty acids identified in lipid analysis

S.N.	RETENTION TIME	ORGANIC COMPOUNDS
1	4.070	Caproic acid (C6:0)
2	9.191	Lauric acid (C12:0)
3	11.181	Mystric acid (C14:0)
4	12.595	Palmitic acid (C16:0)
5	13.741	Stearic acid (C17:0)
6	13.853	Oleic acid (C18:0)

3.3 Transesterification

Transesterification was conducted using methanol as the solvent and sulfuric acid as the catalyst. The reaction was carried out at a methanol-to-lipid molar ratio of 11:1, with 2.4 wt.% catalyst, at 60 °C for 2–3 hours. Performing the reaction near methanol's boiling point enhances its miscibility with lipids, improving solubility and accelerating the reaction rate, especially in mass transfer–controlled processes (D, 1997). However, to avoid methanol evaporation, literature recommends conducting the reaction just below its boiling point (S, 2004).

At elevated temperatures, methanol exhibits better interaction with non-polar lipid phases, facilitating faster and more efficient conversion. Under these optimized conditions, a biodiesel yield of 31.9% was achieved. The resulting biodiesel was washed with distilled water to remove impurities and obtain a purified final product.

3.4 Biodiesel Properties

To acquired biodiesel became further analyzed to decide its physical and chemical properties after which in comparison with diverse requirements as summarized in **Table-3**.

S.N.	PROPERTIES	ASTM D6751	EN14214	IS 15607 (2005)	OBTAINED VALUE
1	Density at 15°C (kg/m3)	875-900	860-900	860-900	876
2	Kinematic viscosity (mm2 /s)	1.9-6.0	3.5-5.0	2.5-6.0	2.5
3	Acid value (mg of KOH/g),	Max 0.5	0.5	0.5	0.60
4	Pour point (°C)	-3 to 12	-	-	7.5
5	Calorific value (MJ/kg)	-	35	-	30
6	Metals (Na+K) (mg/kg)	5	5	-	2
7	Metals (Ca+Mg) (mg/kg)	5	5	-	1.78
8	Ash content, percent by mass, Max	0.02	0.02	0.02	0.0081

The biodiesel produced from food waste exhibited a **density of 876 kg/m³**, aligning with ASTM, EN, and IS standards. Its **kinematic viscosity** was measured at **2.5 mm²/s**, well within the ASTM D6751 specified range of 1.9–6.0 mm²/s (Test Method D445), indicating good flow properties and atomization for engine use. The **acid value** was **0.60 mg KOH/g**, slightly exceeding the 0.5 mg KOH/g limit set by ASTM D6751 and EN 14214, likely due to incomplete conversion of triglycerides to fatty acid esters.

The **pour point** was found to be **8 °C**, within ASTM D6751's range (−3 to 12 °C), indicating moderate cold-weather performance. The **gross calorific value** of the biodiesel was **30 MJ/kg**, which is lower than the standard 35 MJ/kg (EN 14214) and diesel's 45.5 MJ/kg, implying higher fuel consumption.

Alkali metals (Na + K) were found at **2 mg/kg**, and alkaline earth metals (Ca + Mg) at **1.78 mg/kg**, both within the EN 14538 limit of 5 mg/kg. The **ash content** was **0.0081**, well below the acceptable limit of 0.02, suggesting low inorganic impurities.

4. CONCLUSION

To address the fossil fuel crisis, environmental pollution, and rising energy demands, replacing non-renewable resources with renewable alternatives is essential. Among these, converting waste materials into biodiesel presents a sustainable solution. Low-cost feedstocks such as sewage sludge, industrial waste, and used cooking oil have been explored for biodiesel production to reduce waste and disposal challenges. In this study, **kitchen food waste** was utilized for biodiesel generation. The waste was dried, and **lipids were extracted using methanol**, yielding **36.9%**. Fatty acid composition was identified using **GC-MS**, while **GC-FID** was employed to analyze fatty acid methyl esters in the biodiesel. The fuel's **physicochemical properties met standard requirements**. Moreover, the remaining residue holds potential for reuse in **pharmaceuticals** and as **soil or plant nutrients**, supporting a circular and sustainable approach to waste management and clean fuel production.

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