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Exploring the Economic Feasibility of Biodiesel Production from Waste Vegetable Oil

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***Abstract* – A case study analyzed the production cost of converting Waste Vegetable Oil (WVO) into biodiesel using a small-scale unit. The net cost was Rs. 66.54 per liter, with feedstock accounting for 60% of the total cost. Co-products like seed cake and glycerin reduced costs by 21% and 2%, respectively, demonstrating the potential of biofuels as a renewable and environmentally friendly energy source.**

***Keywords* – Pongamia pinnata, biodiesel, seed cake, free fatty acids, seed oil, transesterification and glycerin.**

I. Introduction

Fossil fuels are the dominant energy source, used in transportation and industries worldwide. India ranks fourth globally in fossil fuel consumption. However, their limited availability and non-renewable nature contribute to environmental pollution. Biofuels, including ethanol, biogas, and biodiesel, are emerging as a renewable and eco-friendly alternative. Biodiesel, derived from vegetable oil and animal fats, can be used as a feedstock for biodiesel production. Factors like availability, cost, oil content, and biodiesel properties influence the cost. Biodiesel performance is comparable to conventional diesel fuel, and it can reduce particulate matter, hydrocarbons, and carbon emissions [1-2].

India, a country that imports 80% of its crude oil and spends a third of its GDP on fossil fuel procurement [1], has initiated a Biofuel Policy in 2009 to reduce imports and achieve energy self-reliance. The country has found that extracting biodiesel from non-edible oil seeds, such as Pongamia pinnata, is more economically viable than from edible oil seeds. The Karnataka State Biofuel Development Board (KSBDB) has initiated several projects, including the Biofuel Information and Demonstration Centre (BIDC).

II. Production Process

Transesterification is a chemical process that converts triglycerides into diglycerides, monoglycerides, alkyl esters, and glycerol using alcohol (methanol or ethanol) and a catalyst (NaOH or KOH). It enhances the conversion efficiency and purity of esters, with glycerol produced as a by-product. Methanol is commonly used due to its lower cost. Transesterification reactions can be carried out using an alkali or acid method, depending on the free fatty acid (FFA) content in the oil. The acid method is more expensive and time-consuming, while the alkali-based method is suitable for FFA levels between 1.5% and 4%. Cleaned seeds are crushed using an expeller, and the extracted oil is filtered through a micro-filtration unit. The pure oil is analyzed for its free fatty acid content, which determines the appropriate transesterification process. The oil is heated to 65°C, and a methoxide solution is prepared based on FFA content. The reaction proceeds for 90 minutes, converting triglycerides into biodiesel and glycerin. The mixture is then separated in Reactor-II, and the resulting biodiesel is washed with warm water to remove excess soap and methanol, then heated to 110°C to eliminate any remaining methanol and soap. The resulting pure biodiesel undergoes quality tests to ensure its standards.

III. Materials and Methods

The cost of producing biodiesel from Pongamia pinnata was assessed during 2013-14 at the Biofuel Information and Demonstration Center in Karnataka, India. The project, sponsored by the Karnataka State Biofuel Development Board and the University of Agricultural Sciences, involved crushing 6,000 kilograms of Pongamia seeds, based on the average monthly output.

3.1 Production Unit

The Karnataka State Biofuel Development Board (KSBDB) provided a 50 LBP production unit for biodiesel production from Pongamia pinnata seeds, priced at Rs. 10,00,000 in 2012-13. The unit, manufactured by Malnad

Biodiesel Extraction Industries, was equipped with various instruments such as a decorticator, oil expeller, settling tank, micro-filtration unit, transesterification unit, and other necessary equipment for biodiesel production. The unit was priced at Rs. 10,00,000.

3.2 Chemicals and Reagents

The production of biodiesel from Pongamia pinnata involves the transesterification process, which involves the exchange of the organic group R' of an ester with the organic group R' of an alcohol, typically catalyzed by an acid (H2SO4) or a base (NaOH or KOH). The alkali method was used due to the low free fatty acid (FFA) content of Pongamia oil.

The lists of the chemicals and reagents required for biodiesel production from 6000 kilograms of pongamia seeds. Isopropyl alcohol, totaling 2500 milliliters at a rate of 770 rupees per unit, amounts to 1924 rupees. Phenolphthalein Indicator, in 50 milliliter quantities priced at 150 rupees per unit, contributes 75 rupees to the total. Methanol, required in 375 liters and priced at 55 rupees per unit, accounts for 20,625 rupees. Sodium Hydroxide, at 10 kilograms and a rate of 225.6 rupees per unit, sums up to 2,256 rupees. The total cost of all the chemicals and reagents amounts to 24,880 rupees.

3.3 Products obtained in the Biodiesel production process

The clean seeds were crushed using a mechanical expeller, resulting in seed cake as a by-product and oil as the primary product. This oil was then subjected to transesterification, a process that converts the oil into biodiesel and glycerin. The resulting products from the biodiesel production process using 6000 kilograms of pongamia seeds are detailed below: Pongamia oil: 1500 liters, Seed cake: 4200 kilograms, Biodiesel: 1410 liters, and Glycerin: 240 liters.

3.4 Total cost of Production including operating cost:

The total cost of biodiesel production is influenced by several factors including feedstock cost, fixed costs, and variable costs. For this study, Pongamia pinnata seeds were selected as the feedstock, purchased at a rate of Rs. 15 per kilogram from the local market. Fixed costs encompassed various expenses such as building rent, machine depreciation (calculated over a 15-year depreciable life with an annual escalation rate of 1%), labor costs, office expenditures, and electricity charges. However, working capital and VAT on biodiesel were not included in the analysis. Additionally, the cost of chemicals, reagents used in transesterification, and testing of Free Fatty Acid (FFA) and final biodiesel quality were accounted for in the calculation.

This study provides a detailed breakdown of the production costs for biodiesel derived from 6000 kilograms of pongamia seeds. The total cost of production includes expenses such as the procurement of pongamia seeds, transportation charges, cost of chemicals and reagents, electricity consumption, labor costs, office supervision, building rent, and depreciation value. These expenses amount to a total of Rs. 1,48,742.

Income generated from the byproducts of the biodiesel production process, namely seed cake and glycerin, is also accounted for in the analysis. The sale of 4200 kilograms of seed cake at Rs. 15 per kilogram yields a total income of Rs. 63,000, while 240 liters of glycerin sold at Rs. 25 per liter generates an additional Rs. 6,000. Consequently, the total income from the byproducts amounts to Rs. 69,000.

Considering the income from the byproducts, the net production cost of biodiesel for 1410 liters is calculated. Subtracting the total income from the byproducts (Rs. 69,000) from the total cost of biodiesel production (Rs. 1,48,742) yields a net production cost of Rs. 79,742. This figure provides an insight into the financial aspect of biodiesel production, factoring in both expenses and income from byproducts.

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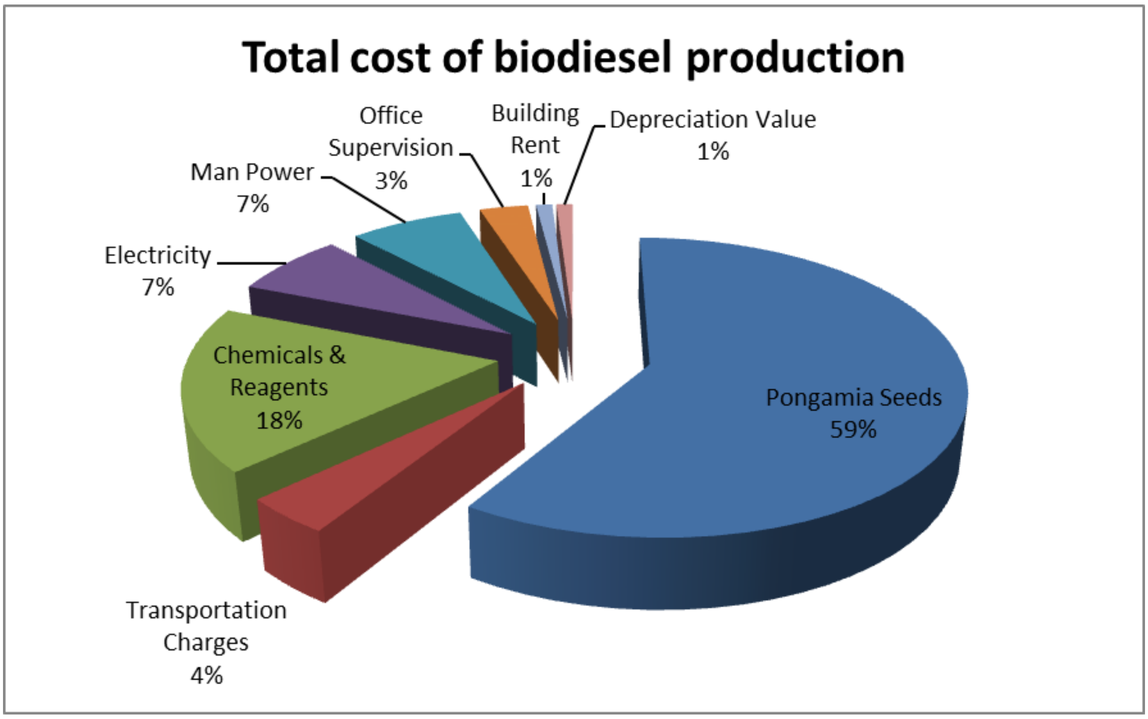

Fig 1: Total cost of biodiesel production for 6000 kgs of pongamia seeds

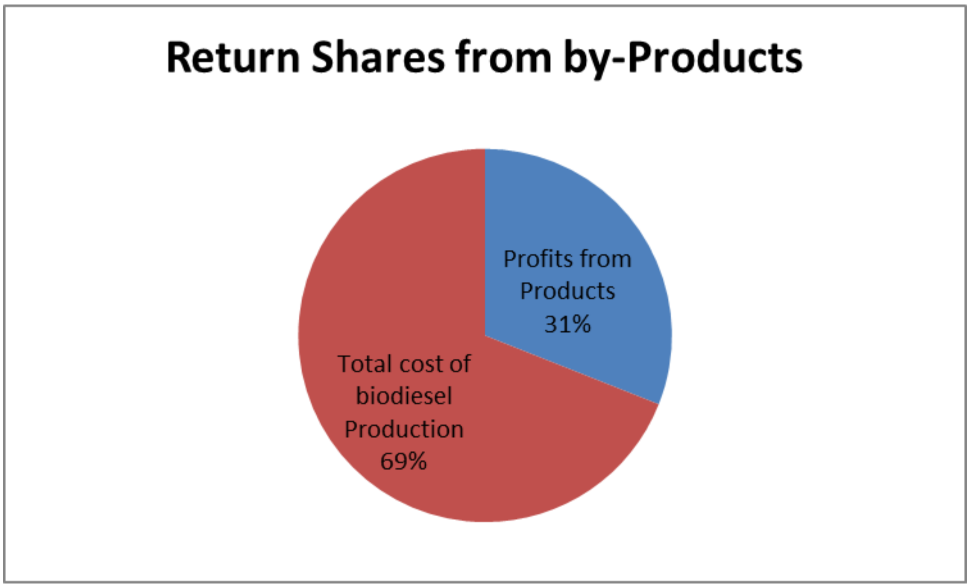

Fig 2: Return shares from by-products for 6000 kgs of pongamia seeds

IV. Results and Discussion

The study analyzed Waste Vegetable Oil, which had a 25% oil content, and its conversion into biodiesel through transesterification. The primary cost factor was feedstock, accounting for 60% of the total production cost. Chemical expenses for the oil-to-biodiesel conversion constituted 17% of the total cost. Operating costs also played a significant role. The major cost drivers were feedstock cost, plant size, and glycerin value [3], it was found that the major cost drivers were the cost of feedstock, plant size, and the value of glycerin.

This study uses a 50 LBP plant size for small-scale biodiesel production, as plant size significantly impacts total production cost. Economic analyses comparing different biodiesel plants using the alkali method for soybean oil found higher-capacity units more economically viable, indicating the suitability of this plant size [4].

The study found that chemical solvents in transesterification are the second most significant cost factor, accounting for 17% of total production costs. The cost is primarily determined by the type of catalyst used, with the alkali method being more cost-effective and efficient [5]. The study uses the alkali method due to FFA levels below 4.5% in the oil. Seed cake and glycerin, obtained from Pongamia pinnata biodiesel production, are used in agriculture and soap industries. These co-products significantly reduce production costs by 21% and 2%, respectively, compared to previous studies indicating a 6-6.5% reduction in production costs [6-7]

V. Conclusion

The main cost drivers for biodiesel production are feedstock (60%), chemicals used in transesterification (17%), and operating costs (10%). Seed cake and glycerin significantly reduced production costs by 21% and 2%, respectively. Considering socio-economic benefits like afforestation, carbon sequestration, pollution reduction, and employment generation could further minimize production costs.

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