International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(11): 423-425
www.biochemjournal.com
Received: 01-08-2024
Accepted: 03-09-2024

Rinju Lukose
Department of Renewable Energy Engineering, Dr. PDKV, Akola, Maharashtra, India

SR Kalbande
Department of Renewable Energy Engineering, Dr. PDKV, Akola, Maharashtra, India

Corresponding Author:
Rinju Lukose
Department of Renewable Energy Engineering, Dr. PDKV, Akola, Maharashtra, India

Biomass distillation for essential oil extraction: A techno-economic assessment

Rinju Lukose and SR Kalbande

DOI: https://doi.org/10.33545/26174693.2024.v8.i11f.2868

Abstract
Energy plays a critical role in supporting sustainable development, and today, conserving energy has gained heightened importance across industries. The overuse of fossil fuels, which has driven rapid industrialization and economic growth, is now recognized as a major contributor to environmental issues such as climate change, air pollution, and ecosystem degradation. These challenges have become some of the most pressing concerns worldwide, highlighting the urgent need to transition to cleaner, renewable energy sources. This study specifically examines the use of biomass energy for essential oil extraction, assessing its economic feasibility. Results indicate a benefit-cost ratio of 1.28 and a payback period of 23 months, confirming that a biomass distillation system is a cost-effective approach for essential oil extraction.

Keywords: Biomass, extraction, essential oil and economic analysis

Introduction
The global demand for essential oils has been steadily increasing, driven by their wide applications in the cosmetic, pharmaceutical, and food industries. Lemongrass oil, known for its distinctive aroma and medicinal properties, is among the most sought-after essential oils (Ganjewala and Gupta, 2013) [3]. Traditionally, lemongrass oil extraction has relied on energy-intensive methods, often using fossil fuels, which are both costly and environmentally unsustainable (Stratatakos and Koidis, 2016) [5]. In response to these challenges, renewable energy sources, particularly biomass, offer an eco-friendly and economically viable alternative for distillation processes.

Biomass energy, derived from organic matter such as agricultural residues, plant material, and other renewable resources, presents a sustainable option for the energy-intensive distillation required in essential oil extraction. This approach not only reduces dependency on fossil fuels but also offers potential cost savings, especially in rural or agricultural areas where biomass is readily available. Integrating biomass-based systems in essential oil production can promote sustainable practices while adding value to agricultural residues (Benyoussef and Bessah, 2014) [2].

This study explores the techno-economic viability of using a biomass distillation system for lemongrass oil extraction. By analyzing the technical requirements, economic factors, and overall efficiency of biomass energy in this context, the study aims to determine whether biomass distillation can serve as a feasible and sustainable method for lemongrass oil production. This assessment could provide valuable insights for farmers and essential oil producers, especially in regions with abundant biomass resources, to adopt renewable energy solutions that are both cost-effective and environmentally responsible.

2. Materials and Methods
2.1 Selection of Materials
Lemongrass leaves were collected from the field. The leaves were cleaned, chopped and dried.

2.2 Biomass Distillation System
Biomass distillation system was developed to extract essential oil from medicinal and aromatic plants.

The major components of the system were boiler, distillation still and condenser (Munir & Hensel, 2009) [4]. The steam from the boiler was directed into the distillation still, where the plant leaves were placed. As the steam passed through the leaves, it absorbed the volatile oils from the plant material. The steam, now carrying the essential oils, flowed into the condenser, where it was cooled. This cooling caused the steam to condense, separating the essential oils from the water, allowing the oil to be collected for use.

2.3 Economic analysis

Economic analysis of systems is of great importance across various domains because it offers insights into how the different components within a system interact and influence one another economically. By examining these relationships, economic analysis can reveal the financial dynamics, identify inefficiencies, and provide valuable information for decision-making. This type of analysis helps stakeholders understand the potential for optimization, resource allocation, and system improvement, ultimately ensuring that the system operates in an economically sustainable manner.

In the case of the biomass distillation system, an economic analysis was conducted using key financial indicators. These indicators allowed for a detailed assessment of the system's economic feasibility and long-term viability. The primary indicators used in this analysis, as suggested by Afzal *et al.* (2017) [1], included Net Present Worth (NPW), Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR), and Payback Period (PP). Each of these indicators provided a different perspective on the financial performance of the system and helped quantify its value in monetary terms.

Net Present Worth (NPW) was used to evaluate the current value of the system’s future cash flows, adjusting for the time value of money. Benefit-Cost Ratio (BCR) measured the system’s benefits relative to its costs, offering a clear understanding of its economic feasibility. Internal Rate of Return (IRR) provided insights into the system's profitability by determining the discount rate at which the net present value of cash flows equals zero. Finally, the Payback Period (PP) indicated the time required for the system to recover its initial investment. Together, these indicators provided a comprehensive analysis of the biomass distillation system’s economic performance, guiding decisions regarding its implementation and future development.

3. Results and Discussion

The economic feasibility of the biomass distillation system for extracting essential oils from medicinal plants was evaluated by taking into account various factors, such as the initial investment, average repair and maintenance expenses, and the costs associated with raw materials and oil production. These evaluations were based on average parameters obtained from experimental results, ensuring an accurate assessment of the system's financial performance. By considering both operational costs and anticipated returns, the analysis provided valuable insights into the profitability and long-term sustainability of the biomass distillation method. A summary of the economic parameters used to assess the essential oil extraction process is presented in Table 1, offering a comprehensive overview of the system's economic viability. Following points were considered to carry out the economic analysis of the biomass distillation system.

1. The capacity of the distillation system was 20 kg.
2. The initial cost of distillation system was Rs. 100000 and the cost of boiler was Rs. 1, 00,000.
3. Two batches were considered per day.
4. The operating days of biomass distillation system was considered as 200 days.
5. Labour cost was considered to be 250 Rs/day
6. Repair and maintenance cost of the system was assumed to be 10 percent of total capital cost per year.

3.1 Net present worth (NPW)

The net present worth of the biomass distillation system was determined by taking into account the initial investment, the interest rate applied, and the annual profit generated by the system. The net present worth was calculated for next 10 years. Consequently, the net present worth for processing lemongrass (operating for 200 days per year) was calculated to be Rs. 456,379/-, as detailed in Table 1.

Table 1: Economics of biomass distillation system using lemongrass

Sr. No.	Parameters	Values	Unit
1.	Capacity of machine	20	kg
2.	Capital cost of machine	2,25,000	Rs.
3.	No of days of operation in a year	200	days
4.	No of batches per day	2	batch/day
5.	Life of system	10	Yr
6.	Repair and maintenance cost (10% of capital cost)	22500	Rs.
7.	Total cost of material per year	40000	Rs.
8.	Cost of Electricity unit consumed per year	540	Rs/yr
9.	Cost of Production include repair and maintenance cost	221040	Rs
10.	Market value of the product	336000	Rs
11.	Net Profit per year (B-A)	114960	Rs/yr
12.	Payback Period (Capital cost/Net profit)	1 Year 11 Months	-
13.	Payback Period	23	months

3.2 Benefit-cost ratio (BCR)

The benefit-cost ratio of the developed biomass distillation system was calculated by dividing the present worth of the benefits by the present worth of the costs. For lemongrass, the present worth of the benefit stream was Rs. 2,064,574/-, while the present worth of the cost stream was Rs. 1,608,195/-. This resulted in a benefit-cost ratio of 1.28 for lemongrass, based on 200 operational days per year.

3.3 Payback period (PP)

The payback period of the developed biomass distillation system was calculated by progressively adding the net cash flow generated by the system until the total cumulative net cash flow matched the initial investment. This method helps determine how long it will take for the system to recover its initial costs through the profits it generates over time. By examining the cash inflows over a specified period, the payback period reflects the time it takes for the system to become financially self-sustaining. As indicated in Table 2, for lemongrass production, the developed system achieves a payback period of 23 months, assuming the system operates for 200 days per year.

3.4 Internal rate of return (IRR)

The internal rate of return (IRR) for the biomass distillation system was calculated and found to be 45% for lemongrass over a 10-year period. This high IRR indicates a strong commercial return on the investment.

Table 2: Economic indicators of biomass distillation system

Sr. No.	Economic indicator	Values
1.	Net present worth (NPW)	Rs. 456379
2.	Benefit cost ratio (BCR)	1.28
3.	Payback period (PP)	23 months
4.	Internal rate of return (IRR)	45 percent

4. Conclusion

Essential oils are highly concentrated and aromatic extracts derived from plants, known for their various applications across industries such as aromatherapy, fragrance, food, and pharmaceuticals. These oils are valued for their therapeutic and sensory properties, making their extraction an important process in many commercial sectors. Traditional methods of extraction often require significant energy input, leading to the exploration of more sustainable alternatives, such as renewable energy technologies. The adoption of renewable energy technology for essential oil extraction, particularly through biomass distillation, represents an innovative and eco-friendly approach. This method not only reduces the environmental impact but also aligns with global trends towards sustainability and energy efficiency.

The techno-economic feasibility of the biomass distillation system for extracting essential oils was thoroughly analyzed, considering both technical and financial parameters. The analysis revealed a benefit-cost ratio of 1.80, indicating that for every unit of cost invested in the system, 1.80 units of benefit are returned. This is a strong indicator of the system's economic viability and its potential for generating positive financial returns. Additionally, the system's payback period was calculated to be 23 months, meaning that the initial investment would be fully recovered in less than two years of operation. Given these favourable financial indicators, it can be concluded that the biomass distillation system is not only technically effective but also economically feasible, making it a viable option for large-scale adoption in the essential oil extraction industry.

5. References

1. Afzal A, Munir A, Ghafoor A, Alvarado JL. Development of hybrid solar distillation system for essential oil extraction. Renewable Energy. 2017;113:22-29. doi: 10.1016/j.renene.2017.05.027.
2. Benyoussef EH, Bessah R. Potential of renewable energies integration in an essential oils extraction process. Applied Mechanics and Materials. 2014;492:561-567.
3. Ganjewala D, Gupta AK. Lemongrass (Cymbopogon flexuosus Steud.) Wats essential oil: overview and biological activities. Recent Progress in Medicinal Plants. 2013;37:235-271.
4. Munir A, Hensel O. Biomass energy utilization in solar distillation system for essential oils extraction from herbs. In: International Conference for Biophysical and Socio-economic Frame Conditions for the Sustainable Management of Natural Resources (Tropentag 2009); 2009 Oct 6-8. p. 6-8.
5. Stratakos AC, Koidis A. Methods for extracting essential oils. In: Essential Oils in Food Preservation, Flavor and Safety. Academic Press; 2016. p. 31-38.