

Green and Sustainable Entrepreneurship: Argemone Mexicana Seed as Source of Biodiesel Production and Marketing

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Abstract: The worldwide energy landscape is changing due to green concerns of environment and the depleting reserves of fossil fuel. It is now inclined towards renewable and sustainable resources. Biodiesel has evolved as one of the promising renewable energy alternatives due to biodegradable and its eco-friendly nature. On the other hand, the reliance on feedstock which is safe to be eaten, for its production has raised concerns. A debate of food versus energy has started which prompted the exploration of underutilized and non-edible sources. Argemone Mexicana, locally known as Satyanashi or Kataiya, stands out as a promising feedstock. Its non-competitive nature with food crops and high oil content make it viable. This research reveals the prospective in Argemone Mexicana seeds, examining the whole process from seed oil removal to biodiesel production and its characterization. The oil content of above said seeds, ranging as of 25–35%, was extracted using solvent extraction and mechanical pressing methods. The seeds oil underwent transesterification process, where a reaction takes place between triglycerides of the oil and methanol in presence of a catalyst, producing biodiesel and a by-product as glycerol. For maximizing biodiesel yield and quality, the process parameters, like molar ratio of methanol and oil, catalyst concentration, time of reaction and reaction temperature etc, have to be optimized. The derived biodiesel was evaluated for their physicochemical properties, like density, viscosity, Kinematic viscosity etc. These properties were compared to EN 14214 standard, in addition to conventional diesel. The obtained results established that Argemone Mexicana biodiesel meets the necessary specifications, assuring its suitability for utilizing in diesel engines with insignificant modifications. Moreover, the by-product glycerol may be refined for applications in industries, enhancing the economic viability of production process.

Keywords: Argemone Mexicana, Biodiesel, Green Marketing, Transesterification, Non-edible oil, Underutilized seed.

1. Introduction:

The rising global demand of energy, tied with environmental issues and the diminishing resources of fossil fuels, has mandated a change toward renewable energy sources. Along with these, biodiesel has evolved as a promising entrant due to its biodegradable, renewable and eco-friendly properties. Biodiesel, mainly composed of fatty acid methyl esters (FAME), may be extracted from different biological feedstock, like edible oils, non-edible oils, fats and waste materials. Though, the widespread use of edible oils as biodiesel feedstock raises considerable concerns on food versus fuel conflicts, which initiated exploring another option as non-edible feedstock.

Argemone Mexicana, non-edible feedstock, have garnered attention due to their ability to grow in arid and wasteland regions, high oil content and abundance, without challenging with food crops. It is a wild plant that thrives in deserted and neglected lands, building it an efficiently, environmentally sustainable and economically viable choice for biodiesel production. Argemone Mexicana seeds contain 25–35% oil, affluent in triglycerides appropriate for transesterification, the major chemical process to produce biodiesel.

The production of biodiesel from non-edible feedstock, Argemone Mexicana offers various economic and environmental benefits. Unlike fossil fuels, the biodiesel is carbon-neutral, meaning carbon dioxide released during combustion is balanced by carbon absorption during the growth of the plant of feedstock. Furthermore, biodiesel contains zero sulfur, dropping the risk of acid rain, and its higher biodegradability reduces long-term environmental damage. Such features along with global efforts to lessen climate change and endorse sustainable energy practices.

India, as a speedily developing nation, undergoes dual challenges of energy protection and environmental sustainability. This country's reliance on fossil fuels heavily causes greenhouse gas emissions and enhances dependence on imports, badly impacting the economy. In this perspective, the farming of Argemone Mexicana as well as its use like a biodiesel feedstock represents a significant prospect to address these challenges. Argemone Mexicana's ability to develop in underutilized or degraded lands may transform wastelands into useful areas, simultaneously contributing in development of rural area and energy sustainability. Through leveraging the unexploited potential of Argemone Mexicana, following research aligns with global revelation of sustainable development. The outcomes can serve as groundwork for policymakers, researchers and entrepreneurs to implement significant biodiesel projects that concentrate on the dual objectives of environmental conservation and energy security.

The marketing potential and commercial opportunities related with Argemone Mexicana biodiesel can also be explored. The cost-effectiveness of utilizing a non-edible feedstock, joined with increasing worldwide demand for renewable fuels, reflects a lucrative business model. This study highlights the role of individual in promoting biodiesel making, particularly in rural areas. Employments can be generated by establishing decentralized production units which contribute to local financially viable development while aligning through the global ideas of sustainable development.

This paper aims to investigate the potential as a feedstock for biodiesel production in Argemone Mexicana. The study discusses the extraction process of oil, biodiesel production via transesterification, along with its properties characterization. It also highlights the economic and environmental benefits of biodiesel and explores opportunities for entrepreneurship in the production and marketing. A particular emphasis is sited on optimizing production processes and to ensure compliance with the standards of international biodiesel such as EN 14214.

2. Materials and Methods

2.1 Argemone Mexicana Seed as a Feedstock

Argemone Mexicana, which is commonly known as the Mexican poppy, locally called as Satyanashi or Kataiya, is a tough and drought-resistant plant that thrives in arid and neglected lands. Its capability to be raised in regions unsuitable for traditional agriculture makes it an ultimate choice for biodiesel production. This plant produces seeds with rich oil content. The vegetable oil contains mainly triglycerides which can be easily converted to biodiesel through the transesterification process. Argemone Mexicana, unlike edible feedstock such as palm oil or soybean, is non-edible and does not clash with food crops, addressing one of the serious concerns of food versus fuel conflicts.

The flexibility of Argemone Mexicana to grow within wastelands and degraded soils adds toward its appeal as a sustainable feedstock. Producing this plant does not need fertile land, high agricultural inputs or extensive irrigation, making it a cost-effective alternative for biodiesel production. Its extensive availability in tropical and subtropical regions, extra supports its potential as a consistent source of raw material for biodiesel.



Argemone Mexicana Seeds

Additionally, the usage of non-edible oils like Argemone Mexicana supports to environmental sustainability by promoting the use of underutilized resources. This aligns through the goals of reducing greenhouse gas emissions as well as minimizing dependency on fossil-fuels. By tapping into this renewable and abundant feedstock, biodiesel production can happen to more sustainable, rural development and supporting energy security.

2.2 Production Techniques for Biodiesel

Seed Oil Extraction

The withdrawal of oil from *Argemone Mexicana* seeds is a decisive step in the biodiesel production course, as the quality and yield of the extracted oil considerably influence the overall efficiency. There are two commonly used methods for oil extraction: solvent extraction and mechanical pressing. The choice of oil extraction technique depends on factors such as mass production scale, cost of production, and its application, with both approach offering different advantages for biodiesel production from *Argemone Mexicana* seeds.

Solvent extraction is one of the efficient methods, capable of extracting a high percentage of oil. A chemical solvent, for example n-hexane, is used to dissolve the oil from the squeezed seeds. The n-hexane-oil mixture is then alienated. Then n-hexane is recovered through distillation or evaporation. Mechanical pressing is a simple and cost-effective technique, mainly suitable for small-scale production. The seeds are crushed in this method to extract the oil. It is inexpensive and requires minimal infrastructure. Solvent extraction is followed in this study. The observations are as follows:

Oil extraction Result Table:

Set of Experiment				Result
S. No.	Heating Time (hr)	Solvent-Solid Ratio (ml:gm)	Temperature (°C)	Oil yield (%age)
1	4	6:1	55	25.2
2	6	8:1	60	30.6
3	8	10:1	65	34.8
4	8	10:1	60	32.6
5	6	8:1	55	30.0
6	4	6:1	65	29.2

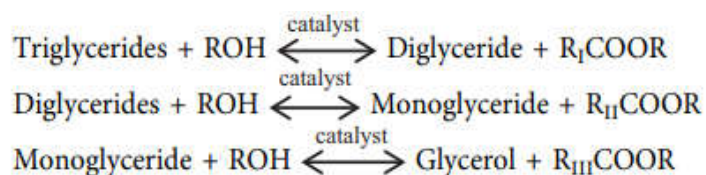
Biodiesel Conversion Processes

The change of *Argemone Mexicana* seed oil into biodiesel is achieved through the transesterification process. This chemical process involves the conversion of triglycerides of the seed oil into the fatty acid methyl esters (biodiesel) and the glycerol, by means of an alcohol (commonly methanol) and a catalyst. Transesterification is one of the most efficient and widely used methods for biodiesel production. The mechanism of transesterification includes three reversible steps:

1. The diglycerides and fatty acid methyl esters are formed in first stage of reaction between the triglycerides of oil and methanol.
2. The monoglycerides and additional fatty acid methyl esters are formed in second stage of reaction between diglycerides and methanol.
3. Finally, glycerols and additional fatty acid methyl esters are formed in third stage of reaction between monoglycerides and methanol.

In this way biodiesel or fatty acid methyl esters and glycerols as bi-product are formed.

Transesterification Reactions



Transesterification Result Table:

Set of Experiment				Result
S. No.	Heating Time (minute)	Molar Ratio (Alcohol:Oil)	Catalyst Concentration (%age of oil)	Biodiesel yield (%age)
1	60	4:1	0.4	92
2	60	6:1	0.4	94
3	60	6:1	0.6	91
4	75	4:1	0.6	80
5	75	4:1	0.8	85
6	75	6:1	0.8	93

Reaction Parameters

A number of reaction parameters influence the yield efficiency and quality of biodiesel formed:

- Alcohol-to-Oil Molar Ratio
- Catalyst Type and Concentration
- Reaction Temperature
- Reaction Time
- Stirring Speed



Biodiesel Produced in different set of Experiments

2.3 Properties of Argemone Mexicana Biodiesel

The biodiesel developed from Argemone Mexicana seed oil carries out the properties that make it an appropriate alternative to conventional diesel fuel. One of the decisive properties of Argemone Mexicana biodiesel is density, which normally ranges between 0.86 and 0.90 g/cm³. This is within the acceptable range for biodiesel. Density ensures proper atomization during fuel injection. The other decisive property is viscosity, an indispensable parameter for engine performance, is somewhat higher than petroleum diesel although remains within the normal biodiesel range of 3.5–5.0 mm²/s. Viscosity ensures even fuel flow without clogging the engine

elements. The flash point was observed 135 °C, higher than petro-diesel, reflecting better safety during handling and storage. This evaluated properties are compared with international biodiesel standards like EN 14214, ensuring sustainability with diesel engines.

2.4 By-Products and Their Management

The transesterification process intended for biodiesel production starting from Argemone Mexicana oil produces glycerol as the main by-product, along with minimal quantities of residual biomass and soap. Professional management of these by-products is crucial to enhance the overall economic and sustainability of the process.

Glycerol, accounting for around 10% of the entire output, has considerable industrial value. Raw glycerol can be developed through processes such as distillation, filtration, and neutralization, to produce high-purity glycerol. Treated glycerol is used in various industries, including chemical manufacturing, cosmetics, pharmaceuticals, and food. For example, in skincare products, it serves as a humectant and a key ingredient in producing nitroglycerin for explosives. Furthermore, crude glycerol, as a feedstock, can be utilized for producing biogas or bioethanol, further contributing to generate renewable energy. Remaining biomass, such as seed cake which is left after oil extraction, is an additional valuable by-product. This biomass, rich in organic content, may be used as an organic fertilizer and soil conditioner, predominantly in degraded lands. On the other hand, it can be processed for animal feed if toxic components are removed.

Efficient management of these by-products minimizes waste and also enhances the economic viability of biodiesel production, further making the process more sustainable and profitable.

3. Results and Discussions

The oil content was determined in the range of 25–35% for Argemone Mexicana seeds, consistent with earlier reports for non-edible feedstock. Solvent extraction method demonstrated a relatively higher recovery yield than mechanical pressing process, thereby suggesting its superiority for large-scale applications where utmost oil recovery is essential.

Following transesterification process, the conversion efficiency was extensively influenced by various parameters such as methanol-to-oil molar ratio, catalyst concentration, reaction temperature etc. An optimal yield was obtained under conditions of 6:1 molar ratio, 0.4% catalyst concentration, 60 min heating time, which produced biodiesel of high purity with minimal residual triglycerides. The by-product glycerol separated efficiently, supporting the economic feasibility of the process through prospective industrial utilization.

The physicochemical properties of the produced biodiesel were compared with EN 14214 values and conventional diesel. Parameters such as density, kinematic viscosity etc was within satisfactory limits. Notably, the viscosity values fell close to the required range, ensuring smooth injection in diesel engines without alteration. The flash point was higher than petro-diesel,

reflecting enhanced safety during handling and storage. Sulfur content was negligible, reinforcing the eco-friendly profile of the fuel.

From an entrepreneurial and sustainability perception, the dual advantages of feedstock availability and market potential highlight significant prospects. The non-edible character of the seeds removes ethical barriers, whereas green marketing strategies can influence its low carbon footprint to appeal to environmentally cognizant consumers and policy frameworks promoting biofuels. Furthermore, the valorization of glycerol as a secondary product additional strengthens economic feasibility, making the whole value chain more sustainable.

4. Conclusion

This study demonstrates the viability of non-edible, everywhere available as weeds and underutilized *Argemone Mexicana* seeds as a sustainable feedstock for biodiesel production. The plant's adaptability, non-edible nature and high oil content make it a promising candidate for large-scale productions and applications. Biodiesel from *Argemone Mexicana* accepts international standards and offers environmental and economic benefits. Entrepreneurs can take advantage of this long term opportunity to contribute to sustainable development whereas addressing the energy challenges too.

Overall, the results authenticate that biodiesel derived from *Argemone Mexicana* is not only technically feasible but also aligns with the principles of green and sustainable entrepreneurship. Its incorporation into local energy systems might reduce reliance on fossil fuels while encouragement rural employment and value addition through small-scale enterprises.

Future research should focus on enhancing yield efficiency, developing cost-effective production technologies and exploring genetic improvement of the plant.

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