MECHANICAL ENGINEERING | RESEARCH ARTICLE

Synthesis of biodiesel from prosopis juliflora and using MCDM analytical hierarchy process technique for evaluating with different biodiesel

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\textbf{Abstract:} The continuous depletion of energy sources globally and serious concern regarding environmental degradation by the use of fossil fuel, biodiesel may plays key transponder. Bio diesel with diesel fuel attains a reduced environmental impact without compromising the performance and utilization efficiency. This research focus on the production of biodiesel from Prosopis Juliflora and Analytical Hierarchy Process (AHP) technique used for ranking of Prosopis Juliflora with four different biodiesel by physiochemical properties using weighted value criteria. Among the evaluated physiochemical fuel properties, the most important is Calorific Value and rank of Prosopis Juliflora is third of different biodiesel considered.

\textbf{Subjects:} Engineering Management; Power & Energy; Clean Tech

\textbf{Keywords:} Prosopis Juliflora; AHP; Biodiesel

\section{Introduction}

In recent years, demand in biodiesel has risen significantly. This development can be due to worries over high fuel costs, greenhouse gas (GHG) pollution, and the nation's reliance on international oil (Joshi et al., 2017). Energy has taken its place as the critical supply for mankind over the

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\textbf{PUBLIC INTEREST STATEMENT}

Nowadays, biodiesel has become an important renewable fuel due to its eco-friendly nature. In present analysis biodiesel was produced by Prosopis Juliflora seed oil (PJ) using transesterification method. The relative importance of properties density, calorific value, kinematic viscosity, cloud point, flash point, and pour point temperature determined using analytical hierarchy process (AHP) of multi-criteria decision-making technique. According to findings, calorific value was attributed highest importance among other properties. This paper also investigates the comparison of PJ biodiesel with biodiesels of Pongamia, Cotton seed, Neem, and Jatropha were evaluated using AHP technique. The results of investigation shows the relative importance of biodiesels were Pongamia, Jatropha, Juliflora, Cotton Seed, and Neem.
past few decades, leading to enhancing our quality of life. For each year up to 2030, the world’s primary energy consumption is predicted to rise by 1.6 percent. Since fossil oil is commonly used, it is contributing to a slow degradation of the global climate, such as global warming, the greenhouse effect, and haze. Moreover the environmental harm caused by the emissions of carbon during the manufacture and usage of fossil fuels is so significant that it cannot be neglected (Abu-Jrai et al., 2011; Agarwal et al., 2015; Gangwar et al., 2012). For this cause, due to global initiatives to promote the change from fossil fuels to green and safer biofuels, several studies have been carried out to establish viable liquid fuel alternatives. These experiments have culminated in the discovery of biodiesel as a fuel substitute that is renewable and environmentally safe (A. L. Ahmad et al., 2011; Dwivedi et al., 2011. The reliance on imported petroleum is minimised by biodiesel. Biodiesel is a mono alkyl ester of long-chain fatty acids that can be made from vegetable oils with short-chain alcohol transesterification. It is nontoxic, sustainable, biodegradable, environmentally safe, sulfur-free, and has a low fossil fuel energy (FER) ratio and low exhaust emissions (Ashraful et al., 2014; Vedaraman et al., 2011).

As alternatives to fossil fuels, different types of bio-based fuels have been investigated, such as vegetable oils (raw, refined, or used), oil methyl esters, and liquid biomass fuels (S Ahmad et al., 2007; Karabas et al., 2014). In this century, the study of clean energies and renewable fuels has been intensified by numerous researchers. In order to be an effective replacement for petroleum diesel, vegetable oils have to be changed and can be ignited in diesel engines. For the alteration of vegetable oils, there are four primary techniques: dilution, micro-emulsion, pyrolysis (thermal cracking), and transesterification, used to minimise viscosity reported by Kumar and Sharma (2011). The main input method for the development of an environmentally sustainable and safe fuel from unprocessed vegetable oils is transesterification (Vyas et al., 2010). As one of the promising methods for transforming vegetable oil to fatty acid alkyl ester that can be used in diesel fuel-based engines, the transesterification process has been proposed by Puhan et al. (2005). The factors that affect transesterification are methanol-to-oil molar ratio, catalytic concentration, reaction time, reaction temperature, and free fatty acid content (Thakkar et al., 2018; Verma et al., 2016; Thoai et al., 2019, Dwivedi and Sharma, 2015). Biodiesel is a fuel that is sustainable, biodegradable, environmentally safe, and nontoxic in nature and can be used without any engine alteration in standard diesel engines with reasonable performance delivered by Srivastava and Prasad (2000). Prosopis Juliflora is an invasive plant species that spreads across the arid environment and serves dependent neighbourhood members.

It belongs to the group of small exotic species that occur in a wide range of soils and climatic conditions. It is mostly shade, timber, and forage trees. More than 63 million hectares of land was not used for cultivation or for any beneficial purpose in India. This unused land is not suitable for agricultural production; it is called “waste land” (Ivana et al., 2012). Currently, this waste land cultivates bio-fuel crops such as Jatropha, castor, Pongamia, etc. (Demirbas, 2009; Masimalai & Kuppusamy, 2015). Although these crops are growing under divergent regional climatic conditions, nutrient requirements are important. As a consequence of these complications, the planting of these types of plants in wastelands is limited. Four methods, including mixing, hydrolysis, transesterification, and micro emulsification, can be used to obtain bio diesel production from oil from non-edible vegetable crop seeds (Sai et al., 2018). After reaction, posttreatment procedures include the neutralisation of catalysts and their removal from products using immense amounts of water. Alternative approaches are being investigated to avoid the difficulties and high cost of wastewater treatment associated with the procedure. In addition, demand for biodiesel is highly anticipated to grow and a more effective continuous process is being pursued in order to minimise the cost of capital or output. In this work, the suitability of Prosopis Juliflora as an alternative fuel with the four distinct biodiesel evaluated using multi-criteria decision-making question AHP. AHP is used as a response technique. AHP is an approach that helps decompose, coordinate, and evaluate a complicated problem. It turns the problem into a hierarchical system composed of different specified tiers, such as priorities, requirements, and subcriteria.
2. Materials and method
Prosopis Juliflora seeds were purchased from local market Bikaner district of western Rajasthan, India and oil from the seeds after drying, using oil expeller mill. Methanol (>99% purity, Make Avantor) and base catalyst potassium hydroxide (pellet, fisher scientific) purchase form local chemical stores, Bikaner Rajasthan.

2.1. Transestrification of prosopis juliflora oil
In order to remove the dissolved water in oil for avoiding soap formation, heated up to 110°C and allowed to cool to room temperature. The transestereification work was carried out using magnetic stirring technique. The methanol with a molar ratio of (1:6) (Ali et al., 2013) and KOH 1% (by weight of oil) (Dwivedi & Sharma, 2015) are mixed and dissolved using stirring. The prepared mixture was than mixed to Prosopis Juliflora vegetable oil. The transestrification proceed maintained with 250 rpm, 62°C for 60 min (Thakkar et al., 2018). After transestrification reaction glycerol was allowed to settle down at bottom of the separating funnel. The glycerol volume is approximately 13% of original volume of oil. Biodiesel produced from transestrification post treated to remove the unwanted contaminates possible untreated methanol and potassium alkylate (soap), hot distilled water used for the purpose. The fuel properties of Prosopis Juliflora were determined as per standards.

2.2. Analytic hierarchy process
The physiochemical characterization the properties of biodiesel produced. The suitability of produced biodiesel with other available biodiesel physiochemical properties, analytic hierarchy process was used for evaluation.

Experimental values of four different kind of biodiesel were taken from literature and Table 1 formed.

| Property of biodiesel | Pongamia (Thiruvengadaravi et al. 2012) | Jatropha (Tiwari et al., 2007) | Neem (Gurunathan & Ravi, 2015) | Cotton seed (Rashid et al., 2009) | Diesel Fuel (Demirbas, 2009) |
|-----------------------|----------------------------------------|--------------------------------|-------------------------------|---------------------------------|-----------------------------|
| Density 15°C, kg/m³   | 928                                    | 878                           | 893                           | 903                             | 820–840                     |
| Kinematic Viscosity at 40°C cSt | 5.07                                 | 4.92                          | 4.5                           | 4.4                             | 2.2–5.5                     |
| Flash Point, °C       | 210                                    | 170                           | 228                           | 220                             | 52–90                       |
| Cloud Point, °C       | 3.5                                    | 8                             | 18                            | 9                               | 5                           |
| Pour Point, °C        | −3                                     | −2                            | 2                             | −13                             | 2                           |
| Calorific value, MJ/kg| 43.99                                  | 40.99                         | 39.2                          | 39.5                            | 42.5–45                     |

A significant instrument used for multi-criteria decision-making is the Analytical Hierarchy System (AHP) (Buckley, 1985). As shown in Table 2, on a scale ranging from 1 to 9, a pair-wise evaluation of all parameters is used. One of the main limitations of the AHP, however, is its inability to overcome the ambiguity inherent in identifying a precise number of definitions.

It includes the following steps.

STEP 1: Make a comparison matrix from a comparison of pairs.
We compare two elements in this step and give ratings according to their significance. Compared to the column, the row criteria are compared and a pair wise matrix is formed. According to the scale of relative importance, let is the value of matrix comparison and \( p \times q \) is matrix size.

\[
A = \begin{bmatrix}
a_{11} & a_{12} & \cdots & a_{1q} \\
\vdots & \ddots & \ddots & \vdots \\
a_{p1} & a_{p2} & \cdots & a_{pq}
\end{bmatrix}
\]

**STEP 2:** Summarize each column of the matrix of comparison

\[
S_{pq} = \sum_{i=1}^{n} a_{pq}
\]

**STEP 3:** Compute a Relative Matrix Normalized.

To get a normalised relative matrix, divide each element of the matrix of the comparison with the sum of its column.

\[
X_{pq} = \frac{a_{pq}}{S_{pq}} = \begin{bmatrix}
x_{11} & x_{12} & \cdots & x_{1q} \\
\vdots & \ddots & \ddots & \vdots \\
x_{p1} & x_{p2} & \cdots & x_{pq}
\end{bmatrix}
\]

**STEP 4:** Estimation of the weights of parameters

Sum up each row of normalized Matrix and divide it by size of the matrix to get the criteria weights.

\[
W_{pq} = \begin{bmatrix}
w_{11} \\
w_{21} \\
\vdots \\
w_{p1}
\end{bmatrix}
\]

**STEP 5:** Estimation of Consistency Index

The consistency index was determined using the formula in this stage. Where \( n \) is the no. of aspect we are comparing and \( \lambda_{\text{Max}} \) is maximum Eigen value.
\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \]

**STEP 6: Estimation of Consistency Ratio (CR)**

In this step consistency ratio was obtained by dividing consistency index (CI) by random consistency index (RCI). Table 3 shows the RCI (Awasthi et al., 2011).

| Table 3. Random consistency index |
|---|---|---|---|---|---|---|
| n  | 1 | 2 | 3 | 4 | 5 | 6 |
| RI | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 |

\[ \text{ConsistencyRatio} = \frac{\text{ConsistencyIndex}}{\text{RandomConsistencyIndex}} \]

The consistency test completed when the CR numerical calculated and when CR<10% (less than 0.1) the achieved data (Awasthi et al., 2011).

3. **Results and discussion**

After successful completion of reactions in production of Prosopis Juliflora biodiesel, all physiochemical properties were evaluated and compared with chemical properties of Diesel as summarized in Table 4.

| Table 4. Physiochemical properties of juliflora biodiesel |
|---|---|---|---|---|---|
| S. no. | Name of chemical property | Juliflora biodiesel | Testing method | Diesel fuel | Biodiesel standard IS15607:2016 [20] |
|---|---|---|---|---|---|
| 1 | Density at 15 °C, kg/m³ | 873.0 | IS1448(Part-16): 1990 | 820–840 | 860–900 |
| 2 | Kinematic Viscosity at 40°C cSt | 4.83 | IS1448(Part-25): 1976 | 2.2–5.5 | 3.50–5.0 |
| 3 | Flash point, °C | 240 | IS1448(Part-21):1992 | 52–90 | 101 min |
| 4 | Cloud point, °C | –5 | ASTM D 2500 | 5 | - |
| 5 | Pour point, °C | –2 | ASTM D 97 | 2 | - |
| 6 | Calorific value, MJ/kg | 35.99 | ASTM D 4868 | 42.5–45 | - |

By comparing physiochemical properties of Prosopis Juliflora biodiesel with Biodiesel Standard IS15607:2016, Prosopis Juliflora biodiesel is a suitable biodiesel as fuel.

3.1. **AHP ANALYSIS**

A binary comparison matrix was prepared for the evaluation of the properties of Prosopis Juliflora biodiesel and physiochemical properties as per literature from different vegetable oil biodiesel. The identified evolution criteria are Density, Kinematic, Viscosity, Flash Point Temperature, Cloud Point temperature, Pour Point temperature, and Calorific Value from
The pair-wise comparison matrixes were formed from subject specialist questionnaire's as shown in Tables 5 and 6.

Normalization of matrix completed and the priority vector formed as Table 7.

The Consistency Ratio for fuel properties equals to 0.071 which is <0.1 than the comparison is consistent.

| Table 5. Pair wise comparison matrix |
|-------------------------------------|
| Comparison matrix               | Calorific value | Density | Kinematic viscosity | Flash point | Cloud point | Pour point |
| Calorific value                   | 1               | 5       | 3                   | 5           | 5           | 7          |
| Density                           | 0.2             | 1       | 0.2                 | 5           | 7           | 5          |
| Kinematic viscosity               | 0.33            | 5       | 1                   | 5           | 7           | 5          |
| Flash point                       | 0.2             | 0.2     | 0.2                 | 1           | 3           | 7          |
| Cloud point                       | 0.2             | 0.1428  | 0.1428              | 0.33        | 1           | 3          |
| Pour point                        | 0.1428          | 0.2     | 0.2                 | 0.1428      | 0.33        | 1          |

| Table 6. Weighted value of AHP comparison matrix |
|-------------------------------------------------|
| Importance level of value | Weightage AHP | Ranking |
| Calorific value           | 0.6617        | 1       |
| Kinematic viscosity       | 0.4529        | II      |
| Density                   | 0.2878        | III     |
| Flash point               | 0.1700        | IV      |
| Cloud point               | 0.0828        | V       |
| Pour point                | 0.0534        | VI      |

| Table 7. Priority vector |
|--------------------------|
| Name                     | Result |
|ickle value \( \lambda_{\text{Max}} \) | 6.92 |
| Random consistency index (RI) | 1.24 |
| Consistency index (CI) | 0.088 |
| Consistency ratio (CR) | 0.071 |

| Table 8. Pair wise comparison matrix |
|-------------------------------------|
| Calorific value | Juliflora | Pongamia | Jatropha | Neem | Cotton seed | Weightage value | Rank | Priority vectors |
| Juliflora       | 1         | 0.2      | 0.3333   | 3    | 2           | 0.2114           | 3    | \( \lambda_{\text{Max}} = 5.53 \) |
| Pongamia        | 5         | 1        | 3        | 5    | 5           | 0.7905           | 1    | CI = 0.0798 |
| Jatropha        | 3         | 0.3333   | 1        | 5    | 3           | 0.4195           | 2    | RI = 1.24 |
| Neem            | 0.3333    | 0.2      | 0.2      | 1    | 2           | 0.1337           | 4    | CR = 0.0644 |
| Cotton seed     | 0.5       | 0.2      | 0.3333   | 0.5  | 1           | 0.1113           | 5    | |
| fuel       | Density | Kinematic viscosity | Flash point | Cloud Point | Pour point |
|-----------|---------|---------------------|-------------|-------------|------------|
|           | Weighted value | Rank | Weighted value | Rank | Weighted value | Rank | Weighted value | Rank | Weighted value | Rank |
| Juliflora | 0.059001     | 5    | 0.443844       | 2    | 0.819931       | 1    | 0.07184        | 5    | 0.67794        | 1    |
| Pongamia  | 0.867394     | 1    | 0.762411       | 1    | 0.212883       | 3    | 0.135246       | 4    | 0.52607        | 2    |
| Jatropha  | 0.131948     | 4    | 0.310273       | 3    | 0.066191       | 5    | 0.246406       | 3    | 0.27502        | 3    |
| Neem      | 0.303204     | 3    | 0.089573       | 4    | 0.417673       | 2    | 0.789006       | 1    | 0.07486        | 5    |
| Cotton seed | 0.305119 | 2    | 0.060565       | 5    | 0.149989       | 4    | 0.424167       | 2    | 0.11277        | 4    |

| Priority vectors | $\lambda_{max}$ | CI | RI | CR |
|-----------------|----------------|----|----|----|
| $\lambda_{max}$ | 0.867394 | 0.067472 | 1.24 | 0.054413 |
| CI              | 0.068358 | 0.762411 | 0.084763 | 1.24 |
| RI              | 0.819931 | 0.055891 | 0.045073 | 0.045073 |
| CR              | 0.789006 | 0.070589 | 0.056927 | 0.06892197 |
3.2. Evaluation of different bio diesel
Prospopis Juliflora biodiesel and four distinct biodiesels physiochemical properties are eligible for assessment. For Pair-Wise Comparison, the physiochemical properties matrix was defined for each biodiesel. The scale was allocated according to IS15607:2016 and followed by AHP Measures.

3.3. Calorific value
It is amount of heat produced or released from a unit amount fuel during combustion.

Subcriteria Calorific value for five biodiesels is ranked in the following order: Pongamia, Jatropha, Juliflora, Neem and Cotton seeds as shown in Table 8. For the remainder of the subcriteria, the AHP measures were adopted as biodiesels physiochemical properties rather than the weighted importance and rating of biodiesel to the corresponding physiochemical properties as seen in Table 9.

Consistency ratio (CR) for fuel properties is less than 0.1 Thus the distinction is consistent with all the considered physiochemical properties of different biodiesel. Biodiesel rankings for density as Pongamia, Cotton seed, Neem, Jatropha, and Juliflora and for Kinematic Viscosity as Pongamia, Juliflora, Jatropha, and Cotton seed biodiesel fuel as shown in Table 9 are of the corresponding weighted value.

4. Conclusion
Biodiesel is an efficient substitute fuel to conventional diesel fuel and can be used directly as a fuel in a diesel engine without any modifications to the engine. It has many advantages such as high biodegradability, reduction of greenhouse gas pollution, emissions of nonsulfur, nonparticle contaminants, low toxicity, excellent lubricity, and green sources such as vegetable oils, animal fats, etc. The most popular process for the processing of biodiesel is transesterification. Prospopis Juliflora seeds are nonedible, available at cheaper rate and vast quantity most part of country India. In present research analysis Prospopis Juliflora is biodiesel produced by using transesterification method using KOH as catalyst and the physiochemical properties of produced biodiesel determined as per standard which satisfied the biodiesel norms. The suitability test of Prospopis Juliflora biodiesel with different biodiesel was analyzed by using Analytic Hierarchy Process.

In this analysis, six physiochemical properties of the five biodiesel Pongamia, Cotton seed, Neem, Jatropha, and Juliflora were evaluated using AHP technique with response of suitable experts. According to calculated weighted value by using AHP, the importance of physiochemical properties ranked as calorific value, kinematic viscosity, density, flash point, cloud point, and pour point temperature respectively. The evaluation of five biodiesel completed using AHP method and ranked or Prioritized according to their weighted value for respective physiochemical properties and overall ranking of biodiesel Pongamia, Jatropha, Juliflora, Cotton Seed, and Neem (Durairaj et al., 2016). For future evolution the analysis extended for engine performance and emission using MCDM technique.

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