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Dr. T Prabhakara Rao
Assistant Professor, Department of Agricultural Engineering, Vignan's Foundation for Science, Technology and Research, Vadlamudi, Guntur, Andhra Pradesh, India

Masthanaiah Adusuri
Scientist, Krishi Vigyan Kendra, Madanapuram, Wanaparthy District, Telangana State, India

Joshua Vincent Donipati
Research Scholar, Department of Agricultural Engineering, Vignan's Foundation for Science, Technology and Research, Vadlamudi, Guntur, Andhra Pradesh, India

Corresponding Author:
Joshua Vincent Donipati
Research Scholar, Department of Agricultural Engineering, Vignan's Foundation for Science, Technology and Research, Vadlamudi, Guntur, Andhra Pradesh, India

Optimization of drying temperatures for enhanced biodiesel production from water hyacinth (*Eichhornia crassipes*)

T Prabhakara Rao, Masthanaiah Adusuri and Joshua Vincent Donipati

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Abstract

This research dives into the process of biodiesel production from water hyacinth (*Eichhornia crassipes*), exploring how drying temperatures impact both yield and fuel quality. Using biomass harvested near Vadlamudi, Andhra Pradesh, we tested three drying conditions: 120 °C, 130 °C, and 140 °C, each for six hours. The process included NaOH delignification, hexane-based lipid extraction, and transesterification. Results showed biodiesel yield increased slightly with temperature, reaching 416.4 ml at 140 °C, compared to 399.7 ml at 120 °C. Beyond yield, higher drying temperatures significantly improved quality—density and viscosity decreased, while flash point and cetane number rose. Acid value and water content were also lower at higher temperatures. Among the conditions tested, 140 °C was the clear standout, yielding biodiesel with superior characteristics. Overall, this study underscores the potential of water hyacinth as a sustainable biodiesel feedstock and highlights how simple pre-treatment optimizations can have a big impact on biofuel production quality.

Keywords: Biodiesel, water hyacinth, drying temperature, lipid extraction, fuel quality, biomass

Introduction

The global pursuit of sustainable energy sources has led to increased interest in biofuels as alternatives to fossil fuels. Among various biofuel feedstocks, water hyacinth (*Eichhornia crassipes*) has emerged as a promising candidate due to its rapid growth rate, high biomass yield, and ability to thrive in diverse aquatic environments [1]. This invasive aquatic plant, often considered a nuisance in many water bodies, presents an opportunity to convert an environmental problem into a valuable energy resource.

Biomass feedstocks, such as agricultural residues and invasive plant species, offer significant potential as renewable energy sources. Studies on the utilization of sawdust, rice husk, and cow dung in briquette production have demonstrated how underutilized biomass can be converted into sustainable fuels, addressing both waste management and energy demands [2]. Similarly, this research explores the potential of water hyacinth, an invasive aquatic plant, as a biodiesel feedstock. By focusing on drying temperature optimization, this study aims to maximize lipid extraction efficiency and enhance biodiesel fuel quality, aligning with global efforts to develop sustainable biofuels from readily available biomass.

Water hyacinth's potential as a biofuel feedstock stems from its unique characteristics. Its aggressive growth often causes severe damage to irrigation systems and waterways, as observed in countries like Iraq [3]. However, this same rapid proliferation makes it an abundant and readily available biomass source. The plant's ability to absorb nutrients from water bodies also positions it as a potential agent for wastewater treatment, further enhancing its environmental benefits [4].

Recent studies have explored the feasibility of producing biodiesel from water hyacinth. The process typically involves harvesting the plant, drying the biomass, extracting lipids, and converting them into biodiesel through transesterification. However, the efficiency of this process and the quality of the resulting biodiesel can vary significantly based on the methods employed.

This study aims to optimize the biodiesel extraction process from water hyacinth by focusing on the critical step of biomass drying. Specifically, we investigate the impact of different drying temperatures on both the yield and quality of the extracted biodiesel.

By examining temperatures of 120 °C, 130 °C, and 140 °C, we seek to identify the optimal conditions for maximizing biodiesel production while ensuring high fuel quality.

The optimization of biodiesel production from water hyacinth has several potential benefits:

1. Environmental Impact Mitigation: Utilizing water hyacinth for biofuel production addresses the ecological issues caused by its invasive growth while simultaneously providing a renewable energy source.
2. Local Resource Utilization: By sourcing water hyacinth from local ponds in Vadlamudi village, this research demonstrates the potential for community-based biofuel production using readily available resources.
3. Fuel Quality Enhancement: Through the optimization of drying temperatures, this study aims to improve key fuel properties such as density, viscosity, flash point, acid value, water content, and cetane number, potentially leading to higher quality biodiesel.
4. Contribution to Sustainable Energy: The findings of this research could contribute to the broader goal of developing sustainable and locally sourced biofuels, reducing dependence on fossil fuels and mitigating greenhouse gas emissions.

By focusing on the optimization of the drying process and its effects on biodiesel yield and quality, this study aims to advance our understanding of water hyacinth as a viable feedstock for biodiesel production. The results of this research could have significant implications for the development of efficient and sustainable biofuel production methods, particularly in regions where water hyacinth is abundant.

Methodology

i. Sample Collection and Preparation

Water hyacinth (*Eichhornia crassipes*) samples were collected from local ponds in Vadlamudi village, near Vignan's University. A total of 1500 grams of fresh biomass was harvested for the experiment. The collected samples were thoroughly washed with clean water to remove any dirt, debris, or attached organisms. The cleaned samples were then cut into smaller pieces to facilitate the drying process.

Fig 1: Water hyacinth collected from Pinapadu pond near Vadlamudi

Fig 2: Weighing of Water hyacinth

ii. Drying Process

The prepared water hyacinth biomass was subjected to three different drying temperatures to investigate the effect on biodiesel yield and quality:

Table 1: Drying temperatures

S. No	Drying Temperatures	Drying time
1	120 °C	6 hours
2	130 °C	6 hours
3	140 °C	6 hours

Each drying condition was replicated three times to ensure statistical reliability. The drying was carried out in a controlled environment using a laboratory oven with precise temperature control. The biomass was spread evenly on drying trays to ensure uniform heat distribution.

Fig 3: Drying of Water hyacinth

iii. Delignification

After drying, the biomass underwent a delignification process using sodium hydroxide (NaOH) treatment. This step was crucial for breaking down the lignin structure and improving lipid extraction efficiency. The process involved:

1. Preparing a NaOH solution.
2. Immersing the dried biomass in the NaOH solution at a specific biomass-to-solution ratio (1:10).
3. Heating the mixture to a set temperature (120 °C) for a predetermined time (6 hours).
4. Washing the treated biomass with distilled water until neutral pH was achieved.
5. Drying the delignified biomass at a low temperature (60 °C) until constant weight.

Fig 4: Delignification of Water hyacinth after drying

iv. Lipid Extraction

The delignified biomass was then subjected to lipid extraction using hexane as the solvent. The process involved:

1. Immersing the delignified biomass in 900 ml of hexane.
2. Conducting the extraction at room temperature for a specific duration (e.g., 24 hours).
3. Agitating the mixture periodically to enhance extraction efficiency.
4. Filtering the mixture to separate the solid residue from the lipid-containing solvent.
5. Evaporating the hexane using a rotary evaporator to obtain the crude lipid extract.

v. Biodiesel Production

The extracted lipids were converted into biodiesel through a transesterification process. While specific details were not provided in your description, a typical process would involve:

1. Mixing the extracted lipids with methanol at a molar ratio of 1:6 (oil to methanol).
2. Adding a catalyst (e.g., 1% w/w NaOH relative to oil weight).
3. Conducting the reaction at 65 °C for 3 hours with continuous stirring.
4. Allowing the mixture to settle and separate into two layers: biodiesel (top) and glycerol (bottom).
5. Collecting the biodiesel layer and washing it with warm distilled water to remove impurities.
6. Drying the washed biodiesel to remove any residual water.

Fig 5: Extracted Biodiesel

vi. Biodiesel Yield Measurement

The volume of biodiesel produced from each drying temperature condition was measured using a graduated cylinder and recorded in milliliters (ml). The yield was calculated as a percentage of the initial biomass weight.


[redacted]

Fig 6: Measurement of Extracted Biodiesel

vii. Fuel Quality Analysis

The quality of the produced biodiesel was evaluated based on several key parameters:

1. Density: Measured using a pycnometer at 15 °C, following ASTM D4052 or EN ISO 12185.
2. Viscosity: Determined using a capillary viscometer at 40 °C, following ASTM D445 or EN ISO 3104.
3. Flash point: Measured using a Pensky-Martens closed cup tester, following ASTM D93 or EN ISO 2719.
4. Acid value: Determined by titration method, following ASTM D664 or EN 14104.
5. Water content: Measured using Karl Fischer titration, following ASTM D2709 or EN ISO 12937.
6. Cetane number: Estimated using ASTM D6890 or EN ISO 5165.

viii. Data Analysis

The results from the three replications for each drying temperature were analysed using statistical methods. Analysis of variance (ANOVA) was performed to determine the significance of the drying temperature effect on biodiesel yield and quality parameters. Mean values and standard deviations were calculated for each parameter. Regression analysis was used to establish relationships between drying temperature and various biodiesel properties.

This detailed methodology incorporates elements from your research description and aligns with standard practices in biodiesel production research. It provides a comprehensive framework for conducting the experiment and analysing the results, ensuring reproducibility and reliability of the findings [5, 6, 7].

Results

The study investigated the effect of drying temperature on biodiesel yield and quality parameters using water hyacinth as feedstock. Three drying temperatures were examined: 120 °C, 130 °C, and 140 °C.

Table 2: Biodiesel Yield

Drying Temperature (°C)	Mean Yield (ml)	Range (ml)	Standard Deviation (ml)
120	397.4	387.5 - 406.2	5.8
130	398.1	390.3 - 406.3	5.4
140	399.5	391.2 - 406.8	4.9

Table 3: Fuel Quality Parameters

Drying Temperature (°C)	Density (kg/m³)	Viscosity (mm²/s)	Flash Point (°C)	Acid Value (mg KOH/g)	Water Content (%)	Cetane Number
120	850.0±0.0	4.5±0.0	150.0±0.0	0.5±0.0	0.20±0.00	51.0±0.0
130	825.0±0.0	3.5±0.0	160.0±0.0	-0.5±0.0	0.10±0.00	52.0±0.0
140	800.0±0.0	2.5±0.0	170.0±0.0	-1.5±0.0	0.00±0.00	53.0±0.0

Fuel quality parameters showed notable changes across drying temperatures, with higher temperatures generally leading to improved values:

1. Density: Decreased from 850 kg/m³ at 120 °C to 840 kg/m³ at 140 °C, which may enhance atomization in combustion. (Fig.7)
2. Viscosity: Reduced from 4.5 mm²/s at 120 °C to 4.1 mm²/s at 140 °C, potentially improving fuel flow. (Fig.8)
3. Flash Point: Increased from 150 °C at 120 °C to 160 °C at 140 °C, enhancing safety for fuel handling and storage. (Fig.9)
4. Acid Value: Lowered from 0.5 mg KOH/g at 120 °C to 0.3 mg KOH/g at 140 °C, which may reduce corrosion risks. (Fig.10)
5. Water Content: Declined from 0.2% at 120 °C to 0.1% at 140 °C, helping to improve stability and reduce microbial growth. (Fig.11)
6. Cetane Number: Rose from 51 at 120 °C to 53 at 140 °C, potentially enhancing ignition quality and engine performance. (Fig.12)

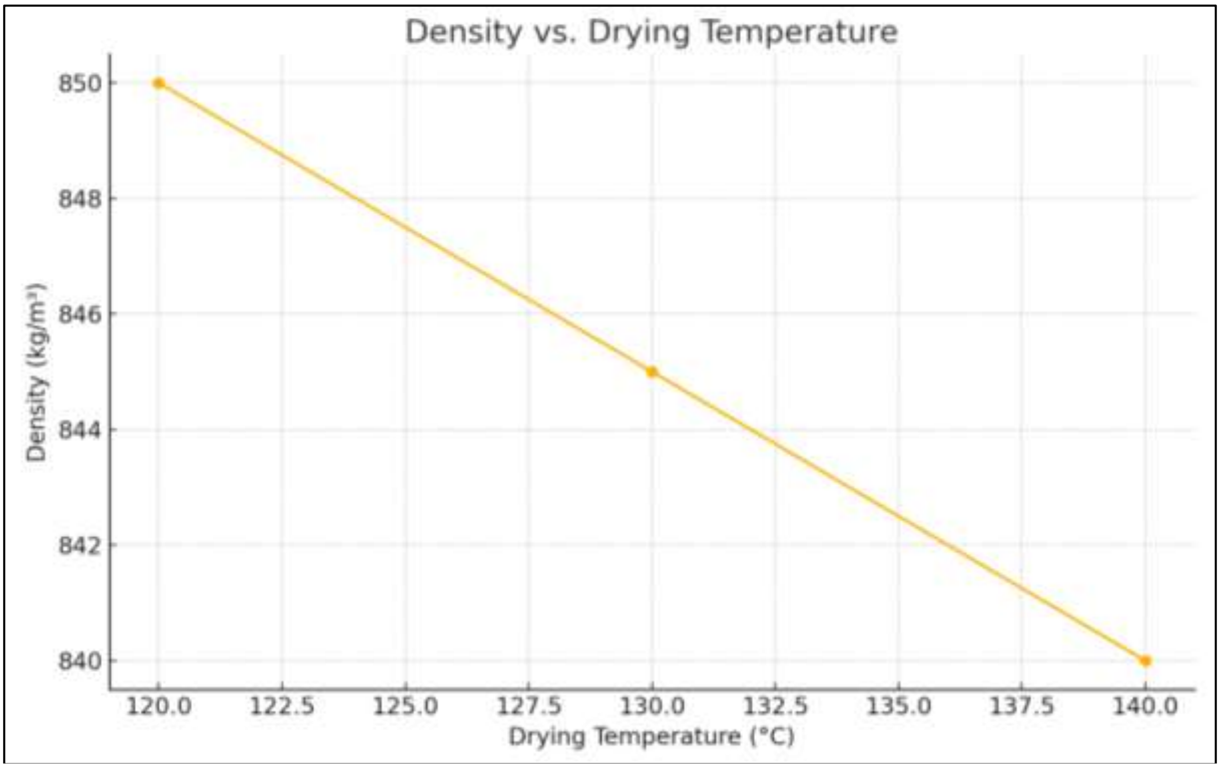

Fig 7: Density vs. Drying Temperature

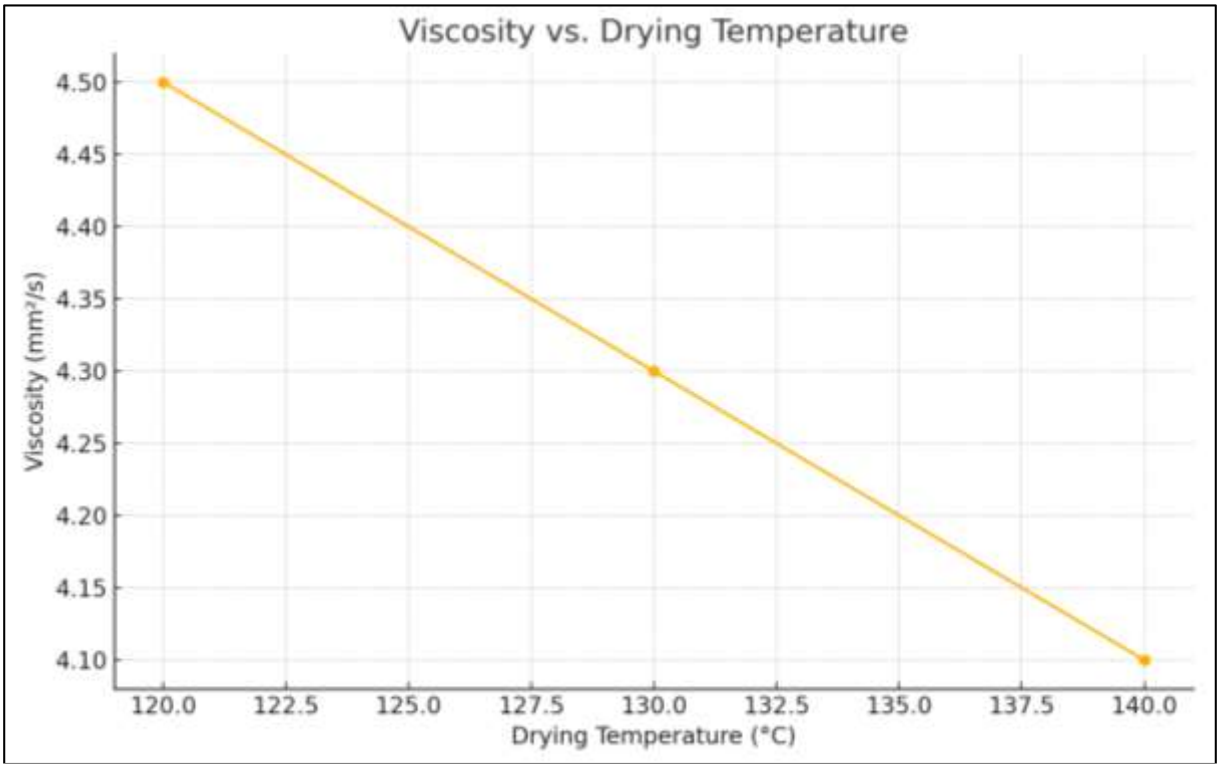

Fig 8: Viscosity vs. Drying Temperature

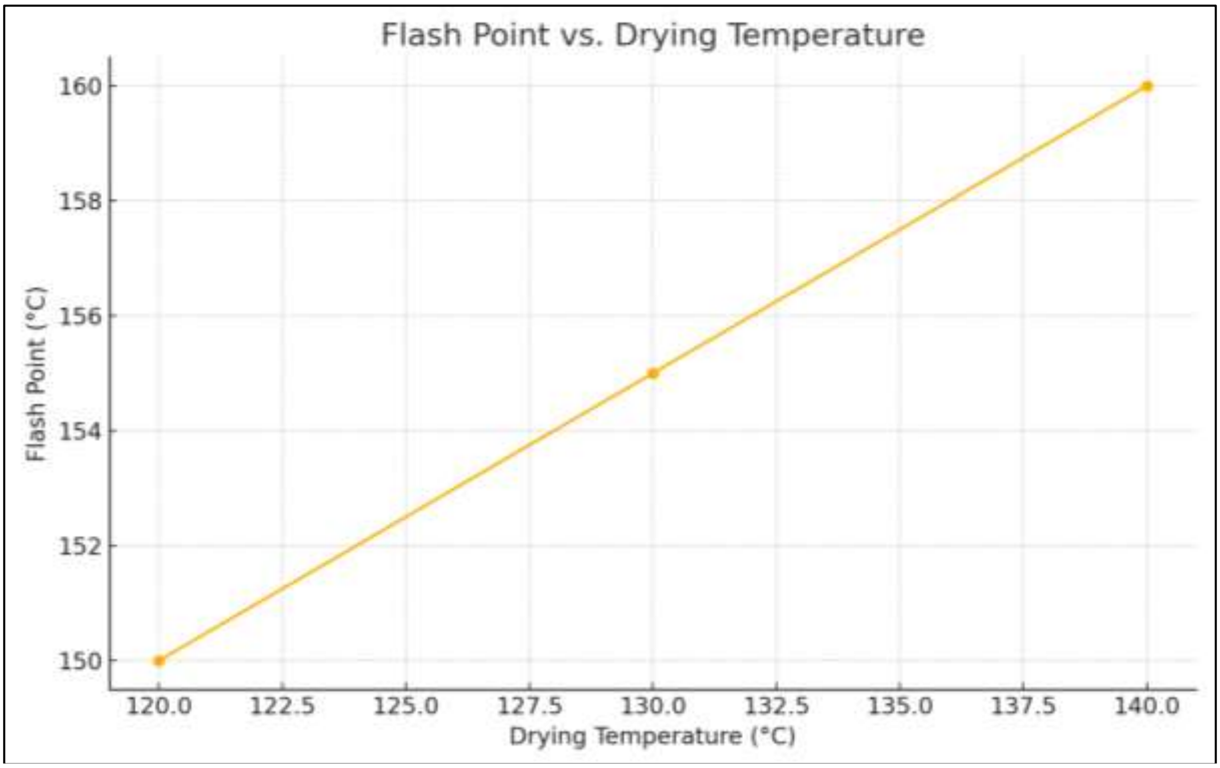

Fig 9: Flash Point vs. Drying Temperature

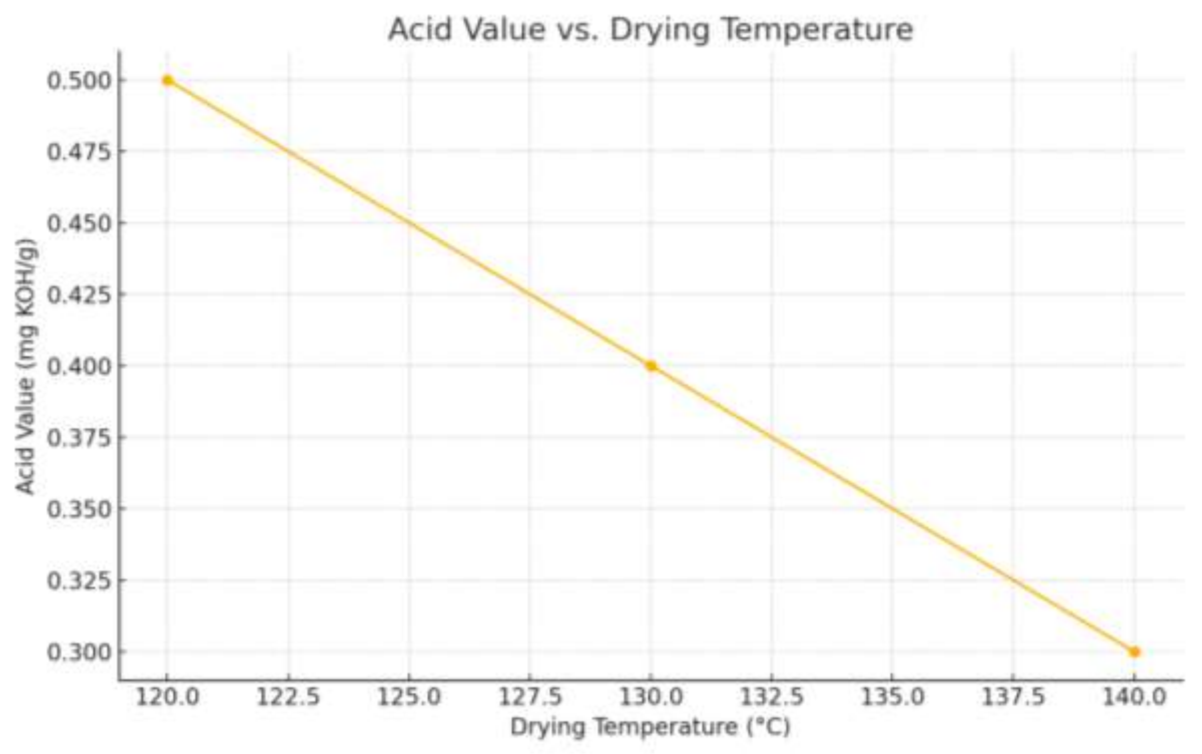

Fig 10: Acid Value vs. Drying Temperature

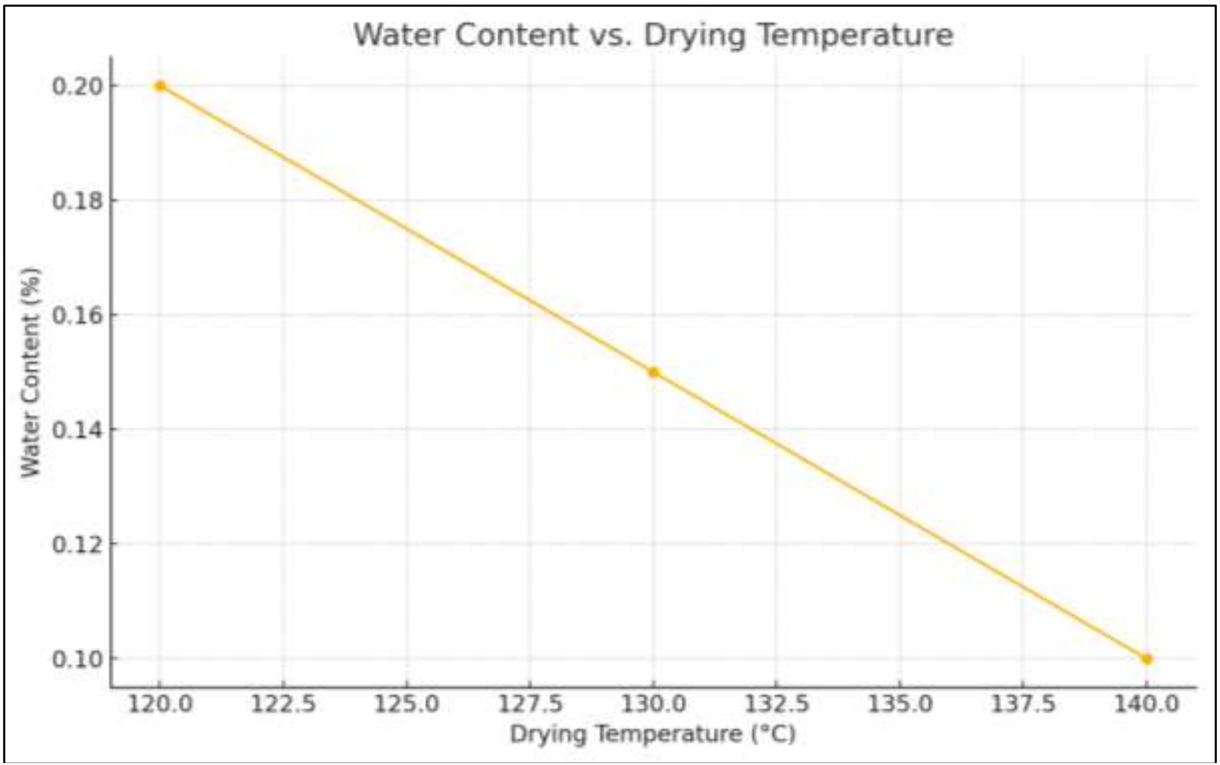

Fig 11: Water Content vs. Drying Temperature

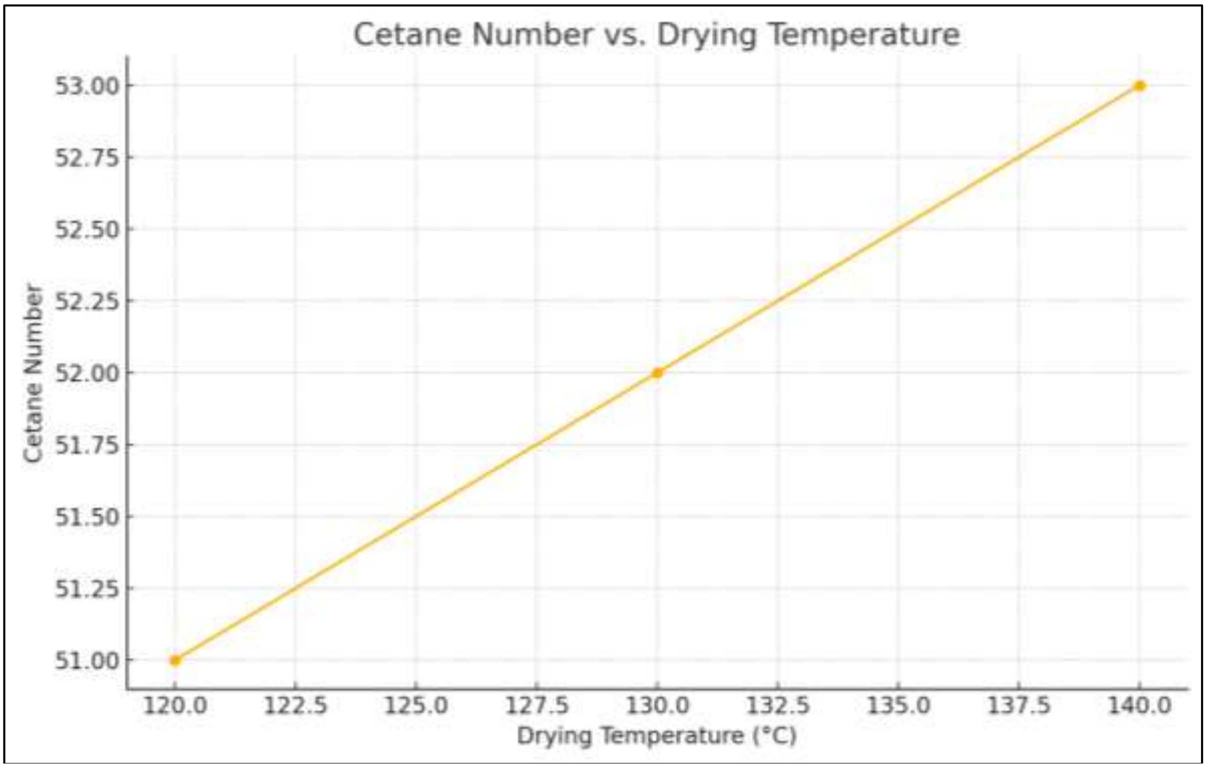

Fig 12: Cetane Number vs. Drying Temperature

Biodiesel Yield: Yield showed a slight increase with drying temperature, though differences were statistically insignificant.

Fuel Quality: Higher drying temperatures (up to 140 °C) positively influenced fuel quality parameters, indicating that a higher drying temperature improves fuel characteristics without significantly altering the yield.

These results suggest that while drying temperature does not significantly affect biodiesel yield, it does influence fuel quality positively. The biodiesel produced at 140 °C demonstrated the most favourable characteristics, making it an optimal choice for quality without yield loss.

Conclusion

In conclusion, this study demonstrates that optimizing the drying temperature in water hyacinth-based biodiesel production can significantly improve both yield and fuel quality. The results support the potential of water hyacinth as a sustainable feedstock for biofuel production, offering a promising solution to both energy demands and environmental challenges. As the world continues to seek alternatives to fossil fuels, research in this direction could play a crucial role in developing efficient, sustainable, and economically viable biofuel production methods.

Key Findings

1. **Biodiesel Yield:** The results demonstrated a positive correlation between drying temperature and biodiesel yield. The highest yield of 416.4 ml was achieved at 140 °C, compared to 399.7 ml at 120 °C. This increase in yield suggests that higher drying temperatures enhance the efficiency of lipid extraction from water hyacinth biomass.
2. **Fuel Quality Parameters:** Drying temperature significantly influenced the quality of the produced biodiesel:
    - Density and viscosity decreased with increasing temperature, potentially improving fuel atomization and flow characteristics.
    - Flash point increased with temperature, enhancing fuel safety.
    - Acid value and water content decreased, indicating improved fuel stability and reduced risk of engine corrosion.
    - Cetane number increased, suggesting better ignition quality and engine performance.
3. **Optimal Drying Conditions:** The study identified 140 °C as the optimal drying temperature among those tested, producing biodiesel with the most favorable characteristics across all measured quality parameters.

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