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Exploration and Analysis of Fuel Briquettes Produced from Areca Leaves as a Promising Renewable Energy Alternative

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Abstract: In rural areas, areca leaves are typically chopped and either left to decompose at the base of areca trees or utilized as temporary shelter materials. This study investigates the potential of areca leaves as a sustainable fuel alternative by converting them into briquettes. The briquettes were produced using areca leaves of various particle sizes, with sawdust serving as an additive and wheat flour functioning as a binder. To evaluate the fuel properties, a proximate analysis was carried out to determine the moisture, ash content, volatile matter, and fixed carbon. This was done following the IS1350-1 standard, while the elemental composition—specifically sulphur, oxygen, nitrogen, and hydrogen—was assessed through ultimate analysis. Additionally, the gross calorific value (GCV) was determined in accordance with the IS1448-7 standard. The analysis revealed that briquettes made from areca leaf particles sized at 850µ exhibited the highest GCV of 14.57 MJ/kg, outperforming those made from particles of sizes 1700µ and above, 600µ, and 425µ. The results of both proximate and ultimate analyses were encouraging, indicating that the briquettes possess desirable physical and chemical characteristics, such as low moisture content (8.08%) and minimal ash residue (1.47%). Furthermore, the environmental impact of these briquettes is minimal due to their low sulphur (0.65%) and nitrogen (0.61%) levels. Consequently, producing briquettes from 850µ areca leaf particles, with sawdust as an additive, offers a high-quality, eco-friendly biomass fuel suitable for both domestic and industrial applications.

Keywords: *Biomass, Briquettes, Gross Calorific value, Proximate and Ultimate Analysis.*

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I. INTRODUCTION

In the current global landscape, energy is a fundamental driver of economic and social development, playing a crucial role in enhancing the quality of life and providing access to modern comforts [1]. To support these lifestyles, human consumption of energy—regardless of its source—has reached excessive levels [2]. In response to the escalating demand for energy, extensive research efforts over the past forty years have focused on identifying alternative energy sources that can supplement or reduce reliance on conventional fossil fuels while addressing associated environmental challenges [3].

India, often described as a nation of villages, comprises approximately 640,867 villages [4], with Karnataka alone accounting for 29,736 of them [5]. Due to the widespread availability and natural abundance of biomass, a significant portion of Indian households—especially in rural regions—rely on it for daily cooking needs [6]. Biomass is considered a renewable energy source that essentially stores solar energy in chemical form.

However, raw biomass presents several challenges in its natural state. It is difficult to store, transport, and handle due to its high moisture content, low bulk density, and inconsistent size and shape. These limitations can be mitigated through densification, commonly referred to as briquetting—a process in which loose biomass is compressed into solid fuel units known as briquettes. These briquettes exhibit improved density, higher energy content, and reduced moisture compared to raw biomass. The methodology for briquetting is not standardized and varies regionally, with processes that may or may not involve the use of binding agents [8].

The primary advantage of briquetting is the production of uniform, compact fuel units that are easier to handle, store, and transport. This simplification reduces operational costs related to logistics and material management. Briquetting has been widely studied, and a growing body of research continues to investigate various biomass sources [9]. Materials studied for briquetting include sawdust [10], paper-coconut blends [11], cotton stalks [12], spear grass [13], groundnut shells [14], corn cobs and rice husks [15], Jatropha

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seed husks [16], coconut shells, cocoa shells, and newspaper waste [17], among others.

Among biomass resources, arecanut waste has significant potential. Karnataka and Kerala together account for approximately 70% of India’s arecanut cultivation area and production. Other contributing states include Assam, West Bengal, Meghalaya, Tamil Nadu, Tripura, and Mizoram. Within Karnataka, the Chikmagalur district leads in both production (17.38%) and cultivated area (19.91%), followed by Shivamogga and Davanagere. Other major arecanut-growing districts in the state include Dakshina Kannada, Tumkur, Chitradurga, and Uttar Kannada [18].

Currently, there is no universally defined procedure for producing biomass briquettes, allowing communities to utilize locally available agricultural residues to create briquettes tailored to regional needs. This decentralized approach eliminates the need to transport raw biomass from distant locations, supporting localized energy production [19]. Biomass briquettes serve both domestic applications—such as cooking, heating, and barbequing—and industrial needs, particularly in agro-based and food processing sectors, across rural and urban areas [20]. As products of renewable resources, biomass briquettes offer numerous advantages, including environmental benefits and reduced reliance on conventional fuels [21].

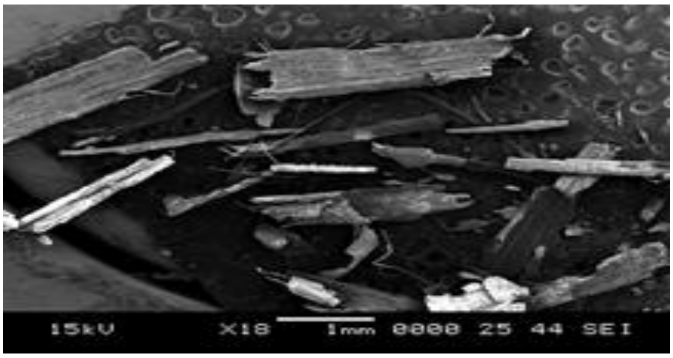
In view of the urgent need for sustainable energy alternatives derived from agricultural residues, this study proposes and evaluates a novel briquetting method that utilizes biomass waste to produce efficient and eco-friendly fuel briquettes.

II. MATERIAL AND METHODS

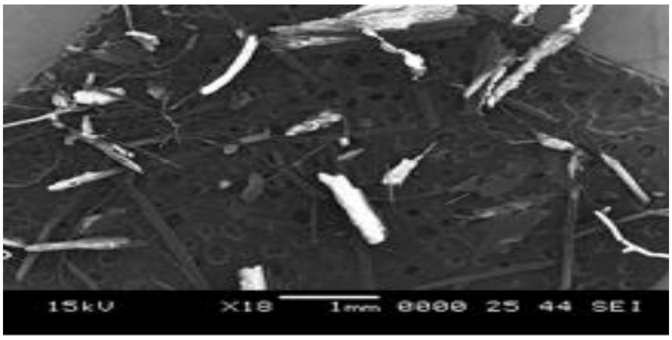
Areca plants are abundantly available in the state of Karnataka, making areca leaves a commonly found biomass resource, particularly in rural areas. In this study, areca leaves were selected for experimental briquetting and analyzed to evaluate the physical and mechanical properties of the resulting briquettes. A representative image of an areca leaf is presented in Figure 1.

To prepare the briquettes, areca leaves were collected from a local farm, manually chopped into small pieces using a knife, and subsequently dried under open sunlight to eliminate residual moisture content. Once adequately dried, the material was subjected to size reduction using a hammer mill. The milled areca leaf particles were then sieved in accordance with ASTM E11 standards [22], and particle sizes of 1700 µm and above, 850 µm, 600 µm, and 425 µm were selected for the briquetting process, as illustrated in Figure 2.

Fig 1 Areca Leaf

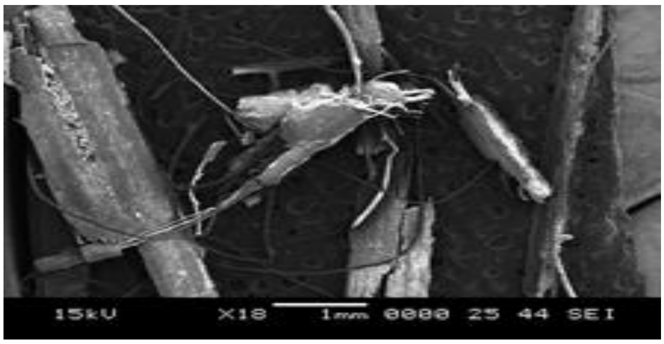


425µ



600µ

850µ



1700µ and above

Fig 2 SEM images of Areca Leaves of sizes 425µ, 600 µ, 850µ, and 1700µ and above

In the experimental phase, sawdust was incorporated as an additive to the areca leaf biomass, while wheat flour was employed as a natural binder. To determine an optimal formulation for briquetting, the areca leaf particles, sawdust, and wheat flour were mixed in a ratio of 2:1:1. The constituents were thoroughly blended to achieve a uniform mixture, which was then stored in a sealed container for 48 hours to allow the mixture to soften and facilitate compaction during briquetting.

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A custom briquetting machine, based on piston press technology, was developed using locally sourced materials and tools. The machine featured a mould with internal dimensions of 12 × 8 × 10 cm. The softened mixture was loaded into the mould and compressed using a hydraulic jack exerting a pressure of 1.28 MPa. The pressure was maintained for 30 seconds to ensure proper compaction, after which the briquettes were carefully ejected from the mould [23]. To reduce moisture content and improve structural stability, the formed briquettes were sun-dried in ambient conditions for a duration of 19 days [24].

III. RESULT AND DISCUSSION

Proximate analysis was conducted to evaluate the fundamental constituents of the areca leaf briquettes, specifically measuring the content of moisture, ash, volatile matter, and fixed carbon. This analysis was performed in accordance with the IS 1350-1 standard [25]. In addition, ultimate analysis was carried out to determine the elemental composition of the briquettes, including the percentages of oxygen, sulfur, nitrogen, and hydrogen, following the guidelines specified in IS 1350-1 [25].

To assess the energy potential of the areca leaf briquettes, the gross calorific value (GCV) was determined based on the IS 1448-7 standard [26]. The results of both the proximate and ultimate analyses, along with the GCV values for briquettes produced from particle sizes of 1700 µm and above, 850 µm, 600 µm, and 425 µm, are presented in the following table.

Table 1 Investigation of outcome for Areca Leaf Briquettes Prepared using Sizes 1700µ and over, 850µ, 600µ, and 425µ with Sawdust and Wheat Flour as Additive and Binder Correspondingly

Sl. No.	Parameters	Additive used: Sawdust			
		Areca Leaves of 1700µ and above	Areca Leaves of 850µ	Areca Leaves of 600µ	Areca Leaves of 425µ
1	GCV, MJ/kg	11.22	14.57	11.93	10.78
Proximate analysis					
1	Moisture content, %	6.18	8.08	7.98	7.93
2	Ash content, %	8.30	1.47	1.98	1.87
3	Volatile matter, %	81.58	75.12	75.33	75.40
4	Fixed carbon, %	3.94	14.42	14.71	14.80
Ultimate analysis					
1	Hydrogen, %	6.97	6.23	6.80	6.82
2	Nitrogen, %	0.47	0.61	0.59	0.59
3	Sulphur, %	0.61	0.65	0.59	0.58
4	Oxygen, %	19.42	19.87	19.15	19.15

A total of four briquette samples were prepared using sawdust as an additive and wheat flour as a binding agent. These samples were subsequently analyzed to assess their fuel properties. Figures 4 through 7 illustrate the comparative characteristics of the four briquettes. The experimental results from the proximate analysis, ultimate analysis, and gross calorific value (GCV) assessments were graphically represented to highlight the variations among the different particle size-based briquettes.

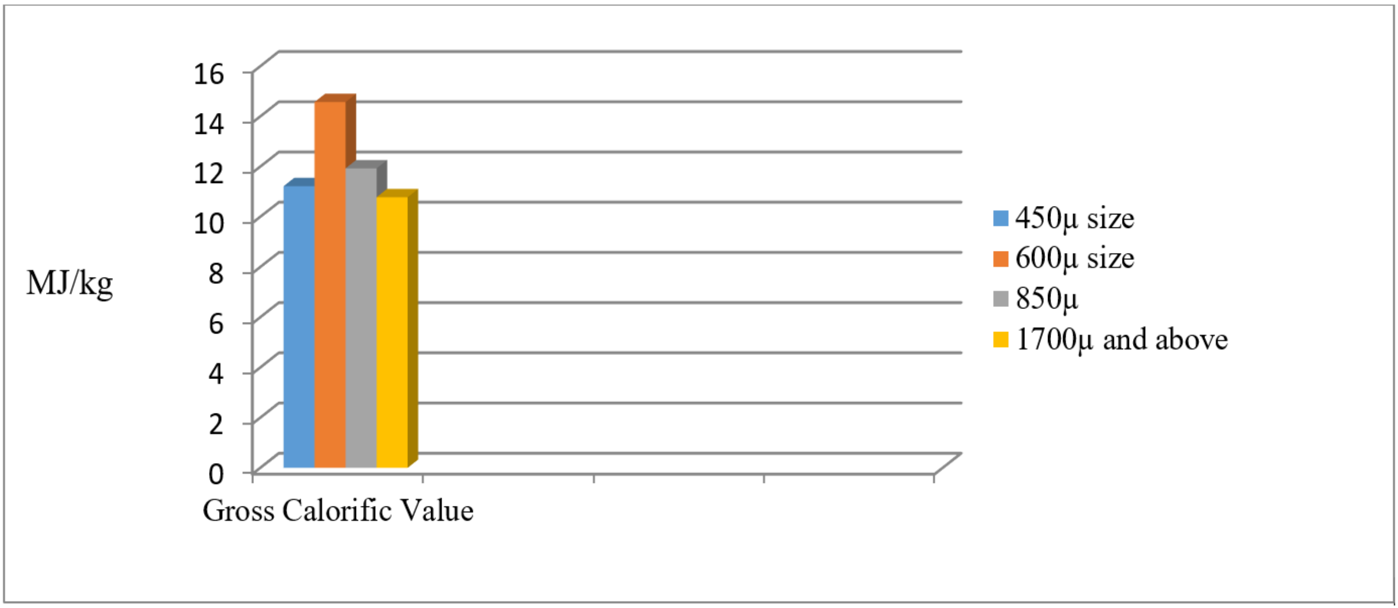

Fig 3 Gross Calorific value of Areca leaf Briquettes of Different sizes along with Sawdust and Wheat Flour as Additive and Binder Correspondingly

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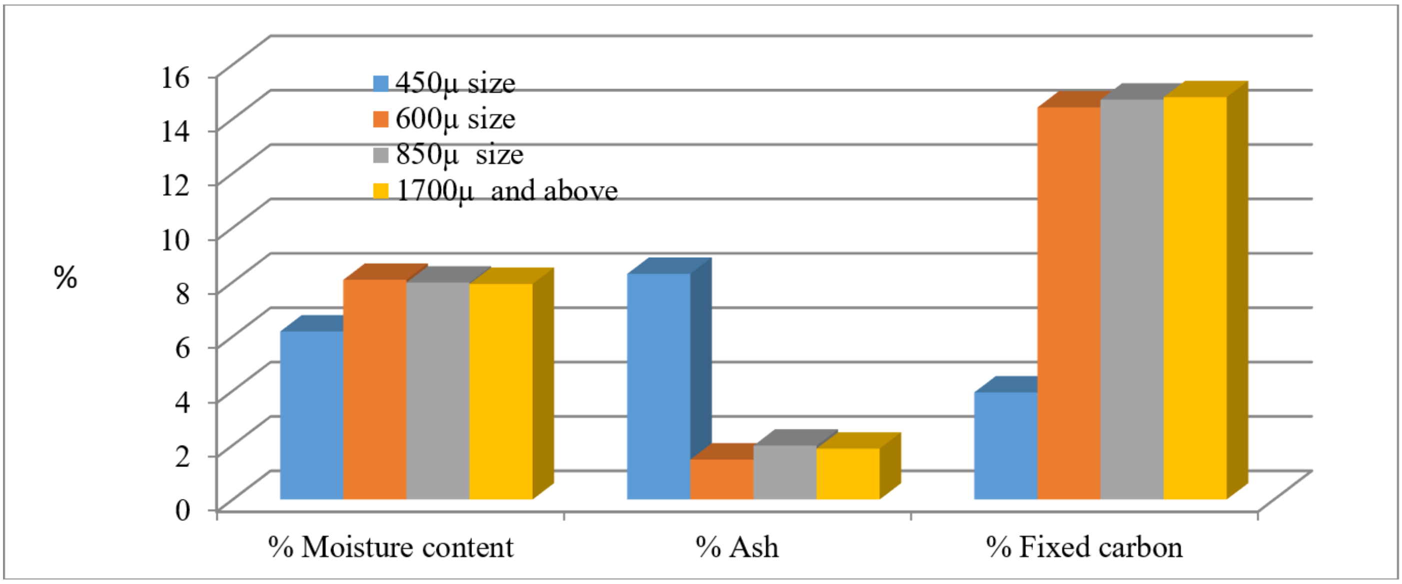

Fig 4 Percentage of Moisture content, ash and fixed carbon of Areca leaf briquettes of different sizes along with Sawdust and Wheat Flour as Additive and Binder correspondingly

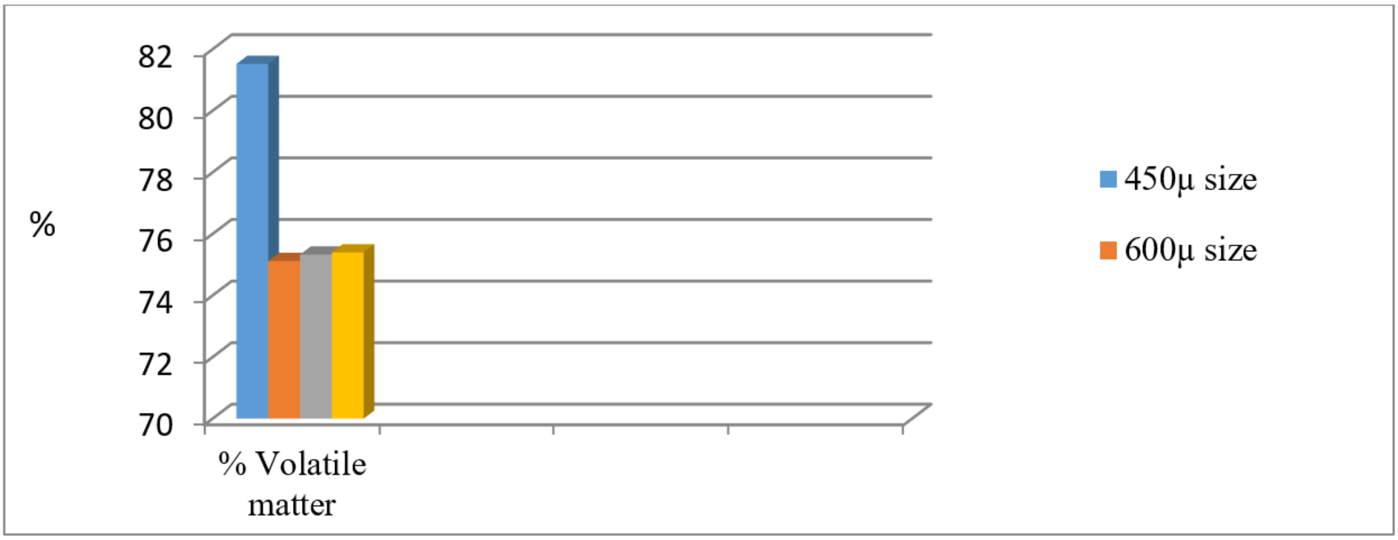

Fig 5 Percentage of Volatile matter of different sizes along with Sawdust and Wheat Flour as Additive and Binder correspondingly

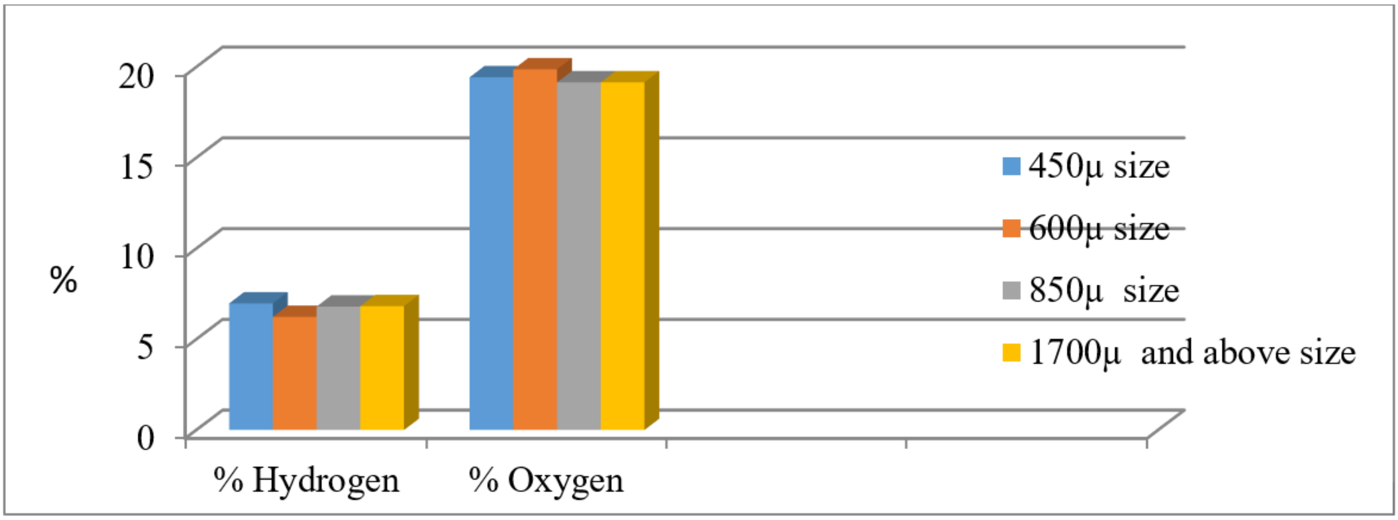

Fig 6 Percentage of Hydrogen and Oxygen of different sizes along with Sawdust and Wheat Flour as Additive and Binder correspondingly

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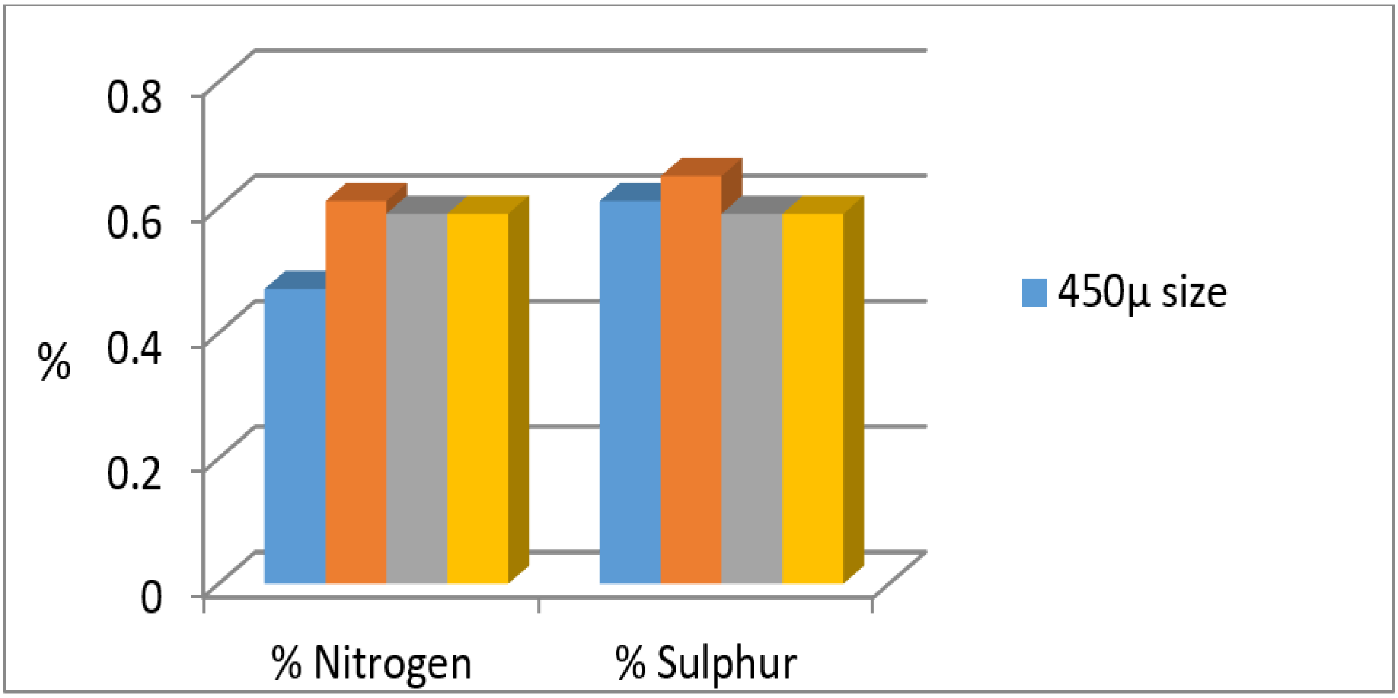

Fig 7 Percentage of Nitrogen and Sulphur of different sizes along with Sawdust and Wheat Flour as Additive and Binder correspondingly

Among the areca leaf briquettes fabricated using different particle sizes—1700 µm and above, 850 µm, 600 µm, and 425 µm—with sawdust as an additive and wheat flour as a binder, the briquette made from 850 µm particles demonstrated the highest gross calorific value (GCV) at 14.57 MJ/kg. This energy content aligns well with other common biomass fuels and is sufficient to meet energy demands for cooking and other domestic applications. The GCV obtained compares favourably with those of other biomass briquettes, such as almond shell (19.49 MJ/kg), corncob (20.89 MJ/kg), cowpea (14.37 MJ/kg), and soybean (12.95 MJ/kg), confirming its potential as an effective biofuel.

Moisture content is a critical factor influencing the efficiency and combustion quality of briquettes [25]. Generally, lower moisture content correlates with a higher calorific value and improved storability. The moisture content for the 850 µm areca leaf briquette was recorded at 8.08%, which is within the acceptable range for efficient combustion and long-term storage, as recommended by [26].

Volatile matter is another significant indicator of fuel quality, as a higher percentage suggests ease of ignition and prolonged flame duration. High volatility typically indicates better combustion behaviour and responsiveness to thermal input. The areca leaf briquette exhibited a volatile matter content of 75.12%, which falls within the optimal range of 70–86% for quality biomass briquettes, as supported by [27]. This characteristic enhances flame stability and suggests that the briquette can ignite easily and sustain combustion effectively.

Fixed carbon, representing the portion of carbon remaining after the volatile matter has been driven off, serves as the principal heat-generating component during char combustion. The fixed carbon content for the 850 µm areca leaf briquette was found to be 14.42%, which is indicative of a strong heating capability and contributes significantly to the overall thermal value of the briquette.

Ash content is another key parameter, as it affects both the efficiency of combustion and the ease of post-combustion clean-up. High ash levels can hinder heat transfer to the fuel surface and reduce oxygen diffusion, thereby lowering combustion efficiency. Moreover, ash contributes no calorific value and may lead to increased particulate emissions. The selected areca leaf briquette contained only 1.47% ash, which is favorable, suggesting minimal combustion residue and reduced environmental impact.

In summary, the 850 µm areca leaf briquette with sawdust and wheat flour as additives demonstrates promising fuel properties, combining satisfactory energy output with favorable combustion and handling characteristics [28].

IV. CONCLUSION

The results indicate that areca leaf briquettes produced using 850 µm particle size and sawdust as an additive exhibit a gross calorific value of 14.57 MJ/kg, which is sufficient to meet typical energy demands. The physicochemical properties of these briquettes demonstrate favorable characteristics, including low moisture content (8.08%) and low ash content (1.47%), both of which contribute to efficient combustion and ease of handling. Furthermore, the briquettes are environmentally sustainable, as reflected in their low sulfur (0.65%) and nitrogen (0.61%) content, minimizing the emission of harmful gases. Therefore, areca leaf briquettes of 850 µm particle size, prepared with sawdust and wheat flour, present a viable and eco-friendly biomass fuel option for both domestic and industrial applications.

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