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# Thermochemical characterization of different mulberry species (*Morus* spp.) for bioenergy production

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**Abstract**
This study conducts a thorough thermochemical characterization of different mulberry species (*Morus* spp.) to assess their potential for bioenergy production. Key parameters including calorific value, wood density, ash content, and fuel value index (FVI) were analyzed across 28 mulberry clones. The results highlight significant variability among clones, with ME-0001, ME-0006, MI-0845, and ME-0220 showing promising energy properties characterized by low ash content and high wood density. The study underscores the importance of these parameters in evaluating mulberry biomass suitability for bioenergy applications. Future research directions include optimizing bioenergy production processes, genetic enhancement of mulberry clones, and conducting comprehensive environmental and techno-economic assessments to promote sustainable bioenergy solutions. This research contributes valuable insights to advancing mulberry biomass as a viable renewable energy source, supporting global energy security and environmental sustainability goals.

**Keywords:** Mulberry species, bioenergy production, calorific value, wood density, ash content

## Introduction

The increasing global demand for energy, coupled with the finite nature of traditional fossil fuels such as petroleum, coal, and natural gas, necessitates the urgent exploration of sustainable and renewable energy sources. Biomass, a renewable energy carrier, stands out as a particularly promising alternative due to its wide availability and potential to replace fossil fuels directly. Biomass not only ensures consistent power generation but also supports the production of various chemicals and transportation fuels, making it a versatile energy source (Safarian *et al*., 2021) [13].

Mulberry species (*Morus* spp.), traditionally known for their significance in sericulture, are now being recognized for their potential as a bioenergy resource. These species exhibit rapid growth, adaptability to various environmental conditions, and extensive availability, making them suitable candidates for bioenergy production. The thermochemical conversion of biomass, which includes processes such as drying, pyrolysis, combustion, and gasification, offers an efficient and lower-emission alternative to direct combustion (Kumar *et al*., 2015) [8]. Among these, gasification is particularly noteworthy for its ability to produce producer gas-a versatile blend of carbon monoxide, hydrogen, methane, and carbon dioxide-that can be utilized for heating, electricity generation, and as a fuel in various industrial applications (Goswami and Das, 2020) [6].

Despite the promising attributes of mulberry biomass, comprehensive studies on the thermochemical properties and gasification potential of different mulberry species are limited. Understanding these properties is crucial for evaluating the feasibility of mulberry as a bioenergy source. This study aims to fill this knowledge gap by performing an in-depth thermochemical characterization of 21$^{st}$ different mulberry clones. By analyzing key parameters such as moisture content, volatile matter, ash content, fixed carbon, elemental composition, and calorific value, this research will provide valuable insights into the suitability of mulberry species for bioenergy applications (Demirbas, 2001) [3]. The outcomes of this study are expected to contribute significantly to the development of sustainable bioenergy systems, offering an alternative energy source that can reduce dependence on fossil fuels, lower greenhouse gas emissions, and support global efforts towards a more sustainable energy future.

## Materials and Methods

### Sample preparation

Lignocellulosic woody materials of 28 different Morus tree species were obtained from Forest College and Research Institute in Mettupalayam, Tamil Nadu India located at a latitude between 11°19′37′′N and 11°19′39′′N and a longitude of 76°56′09′′E, at an altitude of 338m above sea level. For each species, a single three year-old tree, exhibiting a clean trunk and no damage, was chosen at random. These trees were cut down at the base, and were then chipped, air-dried, ground into powder and subsequently used for various tests and analyses.

### Moisture content of wood chip

100g of wood chips were weighed and dried in an oven at 105ºC for 8hrs. From the loss in weight, the moisture content was calculated using the following formula

$$\text{Moisture (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

### Basic density

The basic density of each wood sample was found out by using the displacement method (Haygreen and Bowyer, 1982) [14] and the density was calculated using the following formula.

$$\text{Basic Density} = \frac{E_2}{F + G}$$

Where, $E_2$- Green weight (after soaking in water for 48 hours); F – Oven dry weight; G – Deflection of the needle in cm due to water displacement

### Volatile matter

Volatile matter is termed as the weight loss due to heating of one gram of air dried biomass at 925 °C in muffle furnace for 7 minutes. Then the crucible is removed from muffle furnace and cooled in air. The volatile matter is calculated on dry basis as below.

Weight loss due to volatile matter = Total losses of weight - losses due to moisture

### Fixed carbon (%)

The content of fixed carbon is determined by subtracting the sum of ash (%), volatile matter (%) and moisture content (%) from total of 100 percent composition.

FC (%) = 100 - (% Ash + % Volatile matter + % Moistur content)

### Higher heating value (MJ Kg$^{-1}$)

The heating value of *Morus* spp. was calculated by using Demirbas (1997) [15] methods.

$$\text{HHV} = 0.196\text{FC} + 14.119$$

Where,
FC- Fixed carbon

### Calorific value

Calorific value was estimated using the oxygen bomb calorimeter. One gram of powdered wood sample derived from *Morus* spp was made into pellet and placed in a crucible inside the bomb calorimeter and subjected to rapid combustion at 25 atmospheric pressure by connecting a nichrome fuse between the terminals of the pellet through a small cotton thread. Prior to ignition, the bomb was filled with oxygen and placed in the calorimeter vessel, to which 1.5 L of distilled water was added. Initial temperature of water ($T_i$) in the vessel and the maximum temperature attained after burning pellets were recorded ($T_f$) calorific value were calculated by Indian Standard (IS-1350-1966).

$$\text{CV} = (\text{Ti} - \text{Tf}) \text{ X Water equivalent value}$$

Where,
CV= Calorific value; $T_i$ = Initial temperature of water; $T_f$ = Final temperature of water; Water equivalent value = 2250

### Fuel value index

The fuel value index was calculated for the mulberry species by using the following formula suggested by Bhatt *et al.* (2010) [1].

$$\text{FVI} = \frac{(\text{Calorific value X Density})}{\text{Ash content (\%)}}$$

## Results and Discussion

### Proximate analysis of mulberry clones

The screening of ideal fuel wood species based on its fuel value index which is a combination of three factors *viz.*, calorific value, density and ash content. An ideal fuel wood species should have high calorific value, high wood density and low ash content (Marques *et al.*, 2020; Kumar *et al.*, 2011 and Deka *et al.*, 2007) [10, 9, 2]. Hence, the mulberry clones were characterized for various energy properties and the results are discussed here under

Density and ash content are important parameters directly affect the calorific value. High wood ash content had a negative effect on heat of combustion because a considerable part of volume cannot be converted into energy hence it less desirable as fuel. High density coupled with low moisture content adds to its desirability and it always preferred as fuel because of its high energy content per unit volume and slow burning rate and it produces better quality ember (Kataki and Konwer, 2001) [7]. In the present investigation, ash content varied from 0.60 % (ME-0001) to 2.70 % (MI-0768). Four mulberry clones *viz.*, ME-0001, ME-0006, MI-0845 and ME-0220 recorded less ash content than other clones. The basic density and moisture content varied from 341.50 Kgm$^{-3}$ (MI-0308) to 735.95 Kgm$^{-3}$(MI-0807) and 13.30 % (MI-0395) to 25.37 % (MI-0017) respectively. The current study was in concurrence with the findings of Kataki and Konwer (2001) [7] in some indigenous species wood which recorded the wood density ranged from 0.507 gcm$^{-3}$ to 0.741gcm$^{-3}$; low ash content (0.91 % to 1.93 %) and low moisture content (42.81 % to 57.16 %).

Characterization of wood physical properties of mulberry clones

| Clones | Basic Density (Kg/m$^3$) | Volatile matter (%) | Fixed carbon (%) | Calorific value (KJ g$^{-1}$) | Fuel value index | HHV (MJ. Kg$^{-1}$) |
|---|---|---|---|---|---|---|
| ME-0025 | 709.92** | 70.92 | 25.93** | 9.82 | 275.23 | 19.20 |
| MI-0211 | 613.69 | 76.15 | 21.74 | 12.79* | 548.24** | 18.38 |
| ME-0001 | 586.88 | 69.94 | 28.58** | 13.06** | 1275.62** | 19.72* |
| ME-0109 | 606.89 | 72.21 | 25.34** | 12.46 | 452.21 | 19.08 |
| MI-0013 | 646.80** | 73.82 | 22.42 | 14.13** | 441.12 | 18.51 |
| MI-0349 | 578.55 | 75.98 | 21.78 | 12.18 | 448.47 | 18.39 |
| MI-0395 | 567.98 | 78.35** | 18.96 | 13.77** | 371.69 | 17.84 |
| MI-0536 | 611.12 | 77.47* | 18.91 | 9.62 | 289.59 | 17.83 |
| MI-0615 | 610.03 | 71.49 | 24.33 | 12.82** | 321.90 | 18.89 |
| MI-0718 | 617.93 | 66.15 | 30.11** | 12.70** | 391.89 | 20.02** |
| MI-0768 | 630.19 | 69.47 | 27.12** | 12.72** | 296.77 | 19.43 |
| MI-0034 | 590.74 | 76.74* | 20.33 | 6.99 | 179.42 | 18.10 |
| MI-0663 | 549.16 | 75.83 | 19.97 | 11.90 | 251.33 | 18.03 |
| MI-0685 | 640.07* | 70.58 | 26.83** | 11.07 | 378.90 | 19.38 |
| MI-0017 | 590.94 | 79.06** | 18.47 | 12.96** | 402.58 | 17.74 |
| ME-0006 | 604.05 | 72.97 | 24.18 | 13.05** | 972.99** | 18.86 |
| MI-0807 | 735.92** | 75.40 | 22.25 | 13.26** | 583.68** | 18.48 |
| MI-0845 | 676.76** | 74.86 | 21.70 | 12.42 | 987.38** | 18.37 |
| ME-0220 | 595.24 | 66.22 | 27.51** | 12.41 | 769.78** | 19.51 |
| ME-0095 | 497.43 | 66.28 | 25.90** | 11.58 | 265.28 | 19.19 |
| MI-0308 | 341.50 | 67.38 | 26.42** | 12.82** | 285.68 | 19.30 |
| Mean | 600.09 | 72.73 | 23.75 | 12.12 | 485.23 | 18.77 |
| SEd | 16.05 | 2.00 | 0.48 | 0.22 | 10.46 | 0.44 |
| CD(0.05) | 31.95 | 3.99 | 0.95 | 0.44 | 20.81 | 0.88 |
| CD (0.01) | 42.39 | 5.29 | 1.26 | 0.58 | 27.62 | 1.16 |

** Significant at 1% level* Significant at 5% level

Fuel value of wood is greatly depends on its calorific value and is generally believed to be one of the important parameters to compare one fuel wood with another. In the present study, the calorific value varied between 6.99 KJ g$^{-1}$ (MI-0034) and 14.13KJ g$^{-1}$ (MI-0013). Calorific value is one of the critical factors for energy utilization of mulberry clones and the analysis indicated existence of wider variation among the clones due to the different biochemical contents such as cellulose, hemicellulose, lignin, extractives and ash forming minerals (Kataki and Konwer, 2001) [7].

The higher volatile matter content promotes a reduction in the ignition temperature of the biomass and greater reactivity of the combustion. The fixed carbon percentage represents the remaining mass after the release of volatile matters except moisture and ash content. The total extractives contributed significantly to the increase of the fixed carbon content in the wood (Marques *et al.*, 2020) [10]. In current investigation, the fixed carbon ranged from 18.47 % (MI-0017) to 30.11% (MI-0718) and nine mulberry clones recorded significantly higher fixed carbon due to the displacement of volatile matters which ranged between 79.06 % (MI-0017) and 66.15 % (MI-0718). The present findings are in agreement with that of Desta and Ambaye (2020) who reported the ash (0.99 to 4.44 %) and fixed carbon content (5.96 to 22.39 %) of fire wood and Pirraglia *et al.*, (2012) [12] reported that ash content (4.02 % and 1.83 %), fixed carbon (22.15 % and 36.61 %) and volatile matter (73.84 % and 61.60 %) recorded for *E. macarthurii* and *E. benthamii* respectively.

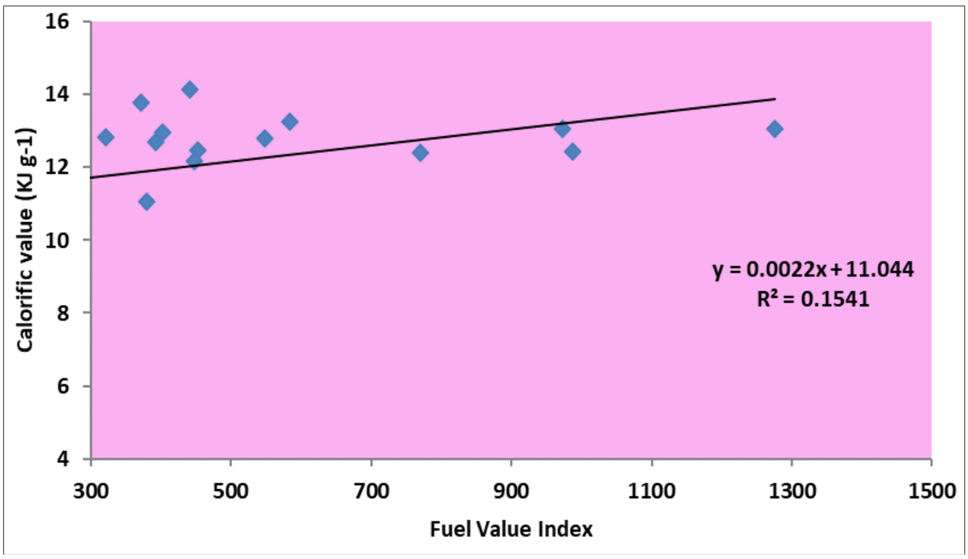


**Fig 1:** Relationship between fuel value index and basic density among the mulberry clones

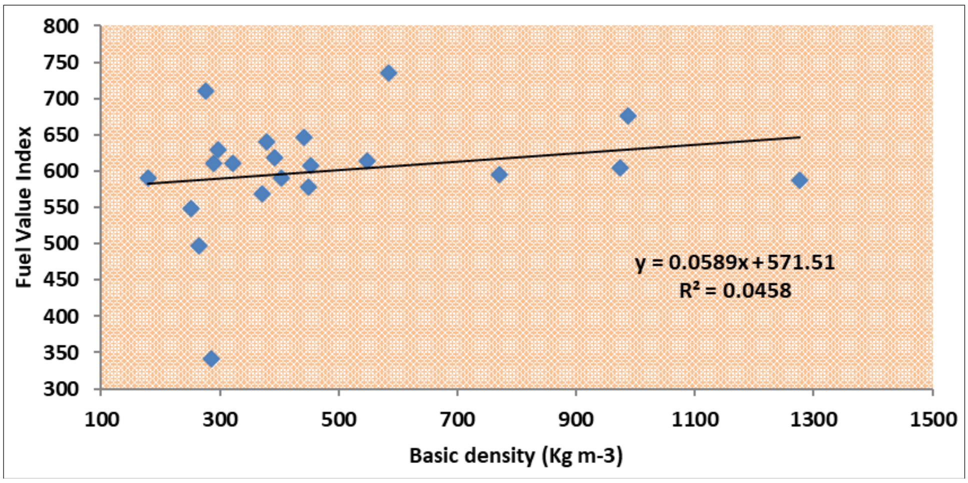


**Fig 2:** Relationship between fuel value index and calorific value among mulberry clones

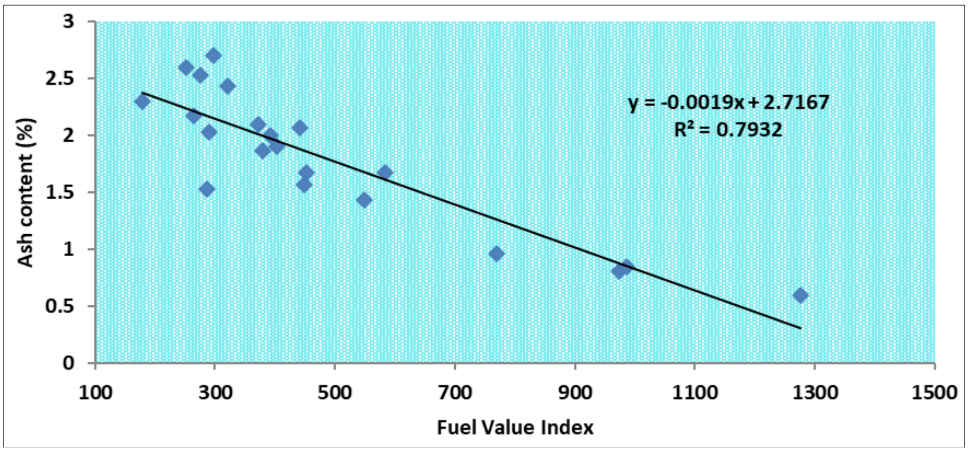


**Fig 3:** Relationship between fuel value index and ash content among the mulberry clones

The fuel value index is a combination of calorific value, density, and ash content of species and it will be most appropriate in determining the suitability of a wood as fuel through estimates of combustibility and ability of hot flame produced by wood species. FVI is the quality measurement factor most frequently used in ranking the preferred fuel wood species (Deka *et al.*, 2007) [2]. Hence, it is important to know the exact relationship between fuel value index with calorific value, density and ash content of evaluated mulberry clones with effect on energy properties. In the present study the fuel value index positively correlated with wood density and calorific value (Figure 1 & 2) whereas FVI with ash content is negatively correlated with each other (Figure 3). In the present study, the FVI range varied from MI-0034 (179.42) to 1275.62 (ME-0001). Evbuomwan and Okorij (2018) [5] reported similar trend for FVI in *Peltophorum pterocarpum, Terminalia catappa, Psidium guajava, Azadirachta indica, Gmelina arborea* and *Mangifera indica* and they reported the FVI ranged from 32.41 (*Terminalia catappa*) to 190.64 (*Gmelina arborea*), Bhatt *et al.*, (2010) [1] reported FVI of some fire wood trees and it ranged from 306.9 (*Bischofia javanica*) to 1178.6 (*Castanopsis indica*) and Nabi *et al.*, (2017) [11] when evaluating FVI of species, the highest FVI observed in *Prunus dulcis* (1067.42). In the present study all the mulberry clone recorded higher fuel value index barring ME-0025, MI-0536, MI-0768, MI-0663, ME-0095 and MI-0308. Hence, the current investigation extended a greater scope of using mulberry for energy generation.

## Conclusion

The thermochemical characterization of various mulberry species (*Morus* spp.) for bioenergy production has revealed significant variability in key parameters such as calorific value, density, ash content, and fuel value index (FVI). Mulberry clones ME-0001, ME-0006, MI-0845, and ME-0220 demonstrated particularly favorable energy properties with lower ash content and higher density, contributing to their suitability as efficient bioenergy feedstocks. The positive correlation observed between FVI, wood density, and calorific value underscores their importance in assessing the fuel quality of mulberry biomass. Future research should focus on optimizing bioenergy production processes, genetic improvement of mulberry clones, and conducting comprehensive environmental and techno-economic assessments to facilitate sustainable utilization of mulberry biomass for bioenergy applications. These efforts are essential in promoting mulberry as a promising renewable energy source and supporting global efforts towards energy security and environmental sustainability.

## Future scope of the study

The comprehensive thermochemical characterization of different mulberry species (Morus spp.) for bioenergy production has laid a solid foundation for future research and application. Moving forward, studies can focus on optimizing bioenergy production processes from mulberry biomass through refining gasification techniques and exploring integrated bioenergy systems. Genetic studies could further enhance this by identifying superior mulberry clones with enhanced energy properties. Environmental assessments, techno-economic analyses, and policy developments are crucial to assessing the feasibility and sustainability of scaling up mulberry biomass utilization for bioenergy. Additionally, exploring integrated biomass utilization and engaging stakeholders can facilitate the development of holistic and sustainable bioenergy solutions. These efforts collectively aim to advance mulberry biomass as a viable and environmentally beneficial source for bioenergy production.

**Author contribution**

This work was carried out in collaboration among all authors. Author Manickavasagam Mithilasri did conceptualization, performed methodology, wrote, and prepared the original draft. Author K.T. Parthiban supervised and reviewed the study. Authors M. Sabarish and R. Kalpana did formal analysis. Author Shankar S.M helped in software development. All authors read and approved the final manuscript.

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**Conflict of interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

**References**

1. Bhatt BP, Sarangi SK, De LC. Fuelwood characteristics of some firewood trees and shrubs of Eastern Himalaya, India. Energy Sources Part A Recovery Util Environ Eff. 2010;32(5):469-474.
2. Deka D, Saikia P, Konwer D. Ranking of fuelwood species by fuel value index. Energy Sources Part A Recovery Util Environ Eff. 2007;29(16):1499-1506.
3. Demirbas A. Biomass resource facilities and biomass conversion processing for fuels and chemicals. Energy Convers Manag. 2001;42(11):1357-1378.
4. Desta HM, Ambaye CS. Determination of energy properties of fuelwood from five selected tree species in tropical highlands of southeast Ethiopia. J Energy. 2020.
5. Evbuomwan BO, Okorji CJ. Determination of the fuel wood properties of selected Nigerian wood trees. Glob Sci J. 2018;6(7):1019-33.
6. Goswami S, Das A. Gasification of biomass and its applications. Biomass Convers Biorefinery. 2020;10(3):1-14.
7. Kataki R, Konwer D. Fuelwood characteristics of some indigenous woody species of north-east India. Biomass Bioenergy. 2001;20(1):17-23.
8. Kumar A. Thermochemical conversion of biomass. Renew Energy. 2015;74:904-913.
9. Kumar JIN, Patel K, Kumar RN, Bhoi RK. An evaluation of fuelwood properties of some Aravally mountain tree and shrub species of Western India. Biomass Bioenergy. 2011;35(1):411-414.
10. Marques RD, da Cunha TQG, Chagas MP, Venturoli F, Belini GB, Yamaji FM, *et al*. Wood quality of five species of the Cerrado for energy purposes. Sci For. 2020;48(125):3225.
11. Nabi S, Qaisar KN, Rather SA, Khan PA, Nabi B. Fuelwood characteristics of some important tree species in prevalent agroforestry systems of District Budgam, Kashmir Valley. Int J Curr Microbiol App Sci. 2017;6(11):3801-3806.
12. Pirraglia A, Gonzales R, Saloni D, Wright J, Denig J. Fuel properties and suitability of *Eucalyptus benthamii* and *Eucalyptus macarthurii* for torrefied wood and pellets. BioResources. 2012;7(1):217-235.
13. Safarian S. Biomass as a renewable energy source. Renew Energy. 2021;164:507-520.
14. Haygreen JG, Bowyer JL. Forest products and wood science: An introduction; c1982.
15. Ayas A, Demirbas A. Turkish secondary students' conceptions of the introductory concepts. Journal of Chemical Education. 1997 May;74(5):518.