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Characterization And Evaluation Of Energy Potential Of Making Briquettes From Jatropha Hulls

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Abstract

Jatropha hulls, a by-product of jatropha oil production, are an abundant and undervalued resource. In this study, we explored the possibility of making biomass briquettes from jatropha husks using different compaction and peat clay binder techniques. The briquettes thus obtained were characterized to determine their physical and energetic properties. The results showed that the jatropha hull briquettes exhibited favorable combustion properties, with high calorific value and reduced emissions of air pollutants. This approach offers an innovative solution to valorize jatropha hulls while providing a renewable and clean fuel source.

Key words: Jatropha hulls, biomass briquette, waste recovery, energy potential, clean combustion.

Introduction

After harvest, agricultural residues remain, and it is important to manage them because uncontrolled incineration has negative effects on the environment, such as air pollution and loss of resources, and abandonment of these residues can lead to the spread of disease and parasites and the contamination of soils and aquifers, among other things [11]. However, these plant residues generated after harvest also constitute an accessible source of renewable energy [11]. The management of agricultural and agro-industrial by-products has become a major concern due to their impact on the environment and their underexploited energy potential. Jatropha hulls, residues from jatropha oil production, are one such by-product that is of growing interest as a potential source of biomass for energy production. In this study, we investigated the possibility of making biomass briquettes from jatropha husks and tested their energy potential for use as a renewable fuel.

Methods and materials

1 Jatropha curcas

1.1 Origin

Jatropha curcas L. is a shrub of the Euphorbiaceae family like rubber or cassava.The name jatropha comes from the Greek words “jatrós” which means doctor and “trophy” which means food. This etymology shows its medicinal properties [8].

According to [10], it originates from the North East of Brazil while according to [4], jatropha curcas is part of the flora of Mexico and probably northern Central America. According to [1], it appears to be native to Central America as well as Mexico where it is found naturally in coastal forests. From the Caribbean, jatropha was probably imported by Portuguese navigators from the Cape Verde Islands and Guinea Bissau to other African countries as well as Asia [8]. Today, this plant is widely cultivated in most dry tropical and subtropical regions [6].

1.2 Use

Every part of the jatropha plant is usable such as its leaves, hulls, latex and seeds as the following table indicate.

Table 1: Use of jatropha curcas [12]

Part of J.curcas L.to use		use
Fruits hulls		Fuel, green nature
Seeds	Seed oils	Soap production,fuel ,insecticide, medicinal use
	Seed cakes	Fertilizer, biogas production, fodder (from non toxic varieties
	Seed shell	fuels
Leaves		Medicinal uses
Latex		Anti-infammatory substances, contains wound healing protease,medicinal uses

1.3 Manufacturing process

The jatropha hulls have been air dried to reduce their moisture content. Different formulations of briquettes were prepared by mixing jatropha hulls with natural binders such as peat clay. The mixtures thus obtained were compacted using a briquette press in order to give shape to the briquette.

2 Characteristics of Jatropha Shell Briquettes

2.1 Physical and chemical properties of briquettes

- **Apparent Density**

Briquette bulk density measures the mass of the briquette per unit volume. It can influence the combustion and handling of briquettes. This parameter depends on the temperature, the pressure, and the duration of densification and the initial density of the biomass [9]. The formula is determined by the AFNOR/X 34B.N-287 standard by the equation:

$$\rho = \frac{m}{v} \quad (1)$$

Avec $v = \frac{\pi D^2 H}{4}$ (2)

ρ: density in kg/m^3,

v:volume of the briquette in m^3,

D : diameter of the briquette in m,

H : heigh of the briquette in m,

m : mass of the briquette in kg.

- **Volatile matter rate**

The determination follows the French standard NF M03-004 and the international standard ISO 562. The same sample that was used during the determination of the moisture content is heated to 550°C. It is calculated as follows:

$$T_{mv} = \frac{(m_2 - m_3)}{(m_2 - m_1)} \times 100 \quad (3)$$

T_{mv}: volatile matter content,

m_1: mass of the empty crucible fitted with its lid in g,

m_2:mass of the crucible with the anhydride sample in g,

m_3: mass of the crucible with its lid and the ash debris in g.

- **Calorific value**

Calorific value is the energy released from combustion. It is specified in Higher calorific value (PCS) which is the energy released by combustion by recovering the latent heat of the water vapor and in Lower calorific value (LCI) which is the energy released by combustion without recovering the latent heat. The PCS was measured by the bomb calorimeter. The PCS is determined at ambient temperature and atmospheric pressure by adopting the process developed according to the French standard NF M03-005[13],[3].

$$PCS = \frac{K_1 \times E_{cal} \times (T_m - T_i) - K_1 \times E_{pt} \times (L_i - L_f)}{m_{échantillon}} \quad (4)$$

E_{cal}: calorimetric equivalent of the calorimeter and its accessories. Around 2460 cal/°C,

E_{pt}: calorific value of platinum. Its value is 2.3 cal/cm,

L_i: initial length of the platinum wire in cm,

L_f: final length of the platinum wire in cm,

T_i: initial temperature in °C,

T_m: maximum temperature in °C,

K_1: conversion factor of calories into Joules, of the order of 4.1855J/Cal,

$m_{échantillon}$:mass of the sample in g.

From this PCS we can determine the PCI according to the following formula:

$$PCI=PCS\times\left(\frac{E_{cond}\times K_2\times H_{ech}}{100}+\frac{E_{cond}\times T_H}{100}\right) \quad (5)$$

E_{cond}: heat of condensation equal to 2511J/g,

T_H: moisture content,

H_{ech}: hydrogen level of the sample in %,

K_2: proportionality factor which is equal to 8.937.

With :

$$H_{ech}=0{,}052\,T_{CF}+0{,}062T_{mv} \quad (6)$$

- **Fixed carbon rate**

This is the remaining carbon capacity after removal of volatile matter, ash and moisture. It is determined by the American Standard ASTM and given by the following formula:

$$T_{CF}= 100- T_{mv}- T_C \quad (7)$$

T_{CF} : fixed carbon rate in%,

T_C: ash content in %,

T_{mv}: volatile matter content in %.

2.2 Thermal efficiency

The water boiling test is used to determine the parameters that are linked to energy performance.

It announces the propensity of the hearth to determine the energy contained in the mass of fuel consumed. It is the ratio between the amount of energy transmitted to the water in the pot and the amount of energy produced by the briquette. It is expressed as a percentage according to [8]

$$\eta=\frac{m_e\times C_e(T_f-T_i)+m_{ev}\times L_v}{m_b\times PCI}\times 100 \quad (8)$$

With:

η: thermal efficiency in %,

m_e: mass of water in kg,

C_e: heat capacity of water in kJ/(kg.K),

m_{ev}: mass of water evaporated in kg,

L_v: latent heat of vaporization of water in kJ/kg,

m_b: mass of briquette consumed in kg,

T_f: final water temperature in K,

T_i: initial water temperature in K,

PCI: calorific value in kJ/kg.

2.3 Mechanical analysis of the briquette: Resistance to impact

According to [2], the impact resistance test consists of throwing the briquette to a height of 2m, dropping it on the ground, and repeating it until it breaks. The impact of resistance is the ratio between the numbers of falls that had to be made until the briquette broke to the number of pieces of the broken briquette [5].

$R_I = \frac{N}{n} \times 100$ (9)

R_I : impact resistance in %,

N: number of briquette falls,

n: number of pieces of briquette after throwing.

Fig. 1: Test made by impact resistance

Results

- **Volatile matter rate**

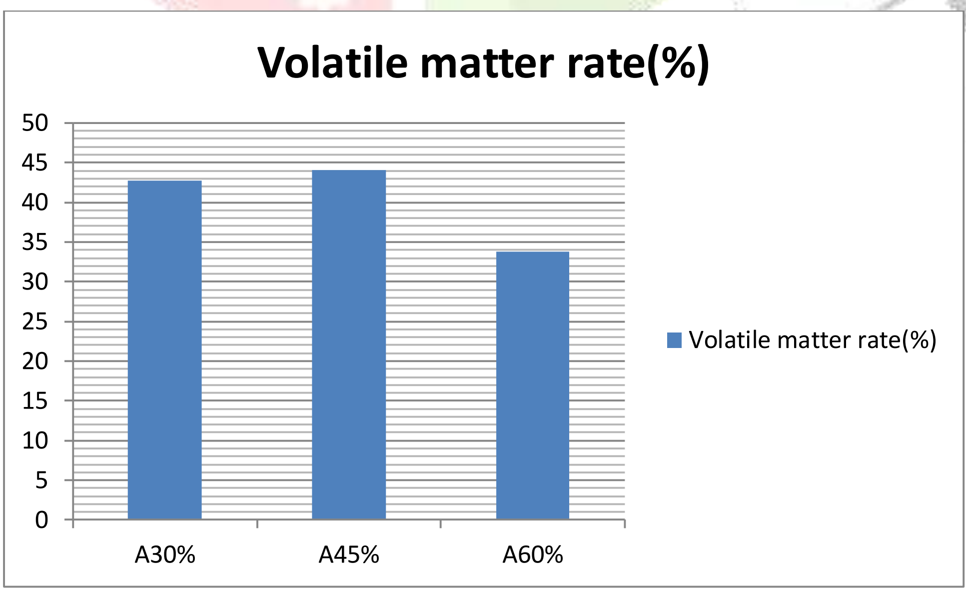

Fig. 2: Volatile matter rate depending on the rate of starch used

By binding jatropha hull particles together, peat clay can encapsulate volatile compounds and prevent them from escaping during combustion. This results in cleaner, more stable combustion, with fewer smoke emissions and air pollutants. This minimizes fluctuations in the rate of volatile materials emitted. By adjusting the briquette formulation, it is possible to control the level of volatile matter to meet the specific requirements of a given application.

- **Fixed carbon rate**

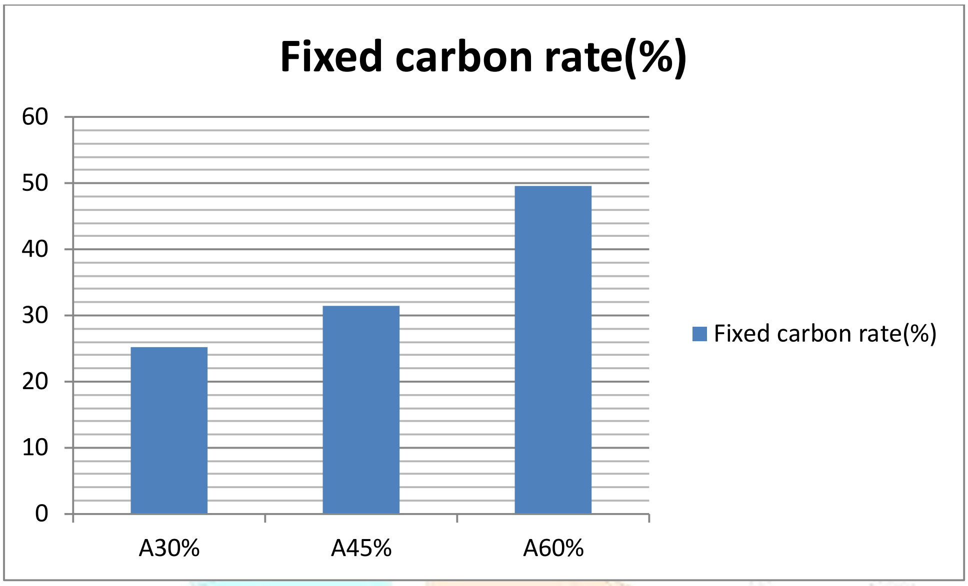

Fig. 3: Fixed carbon rate depending on the rate of starch used

Proper formulation with adequate peat clay ratio promotes more uniform and consistent combustion, thereby maintaining a higher fixed carbon ratio during combustion.

- **PCI**

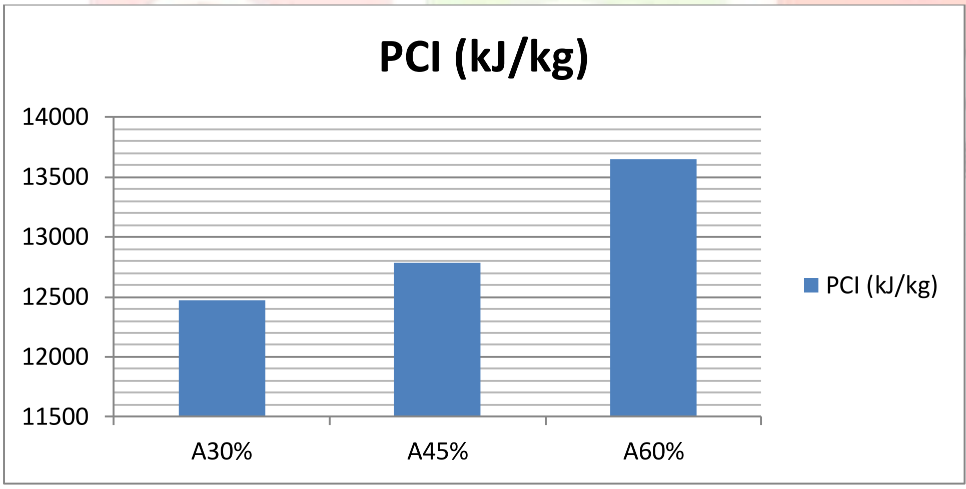

Fig. 4: PCI depending on the rate of starch used

Better cohesion reduces the amount of ash produced during combustion, which increases the net PCI of the briquettes.

A higher density of briquettes, due to a greater amount of peat clay, affects their ability to release heat during combustion and therefore decreases the PCI of the briquettes. Higher moisture content caused by the addition of peat clay reduces the PCI of the briquettes because part of the energy released during combustion is used to vaporize the water present in the briquettes.

- **Density**

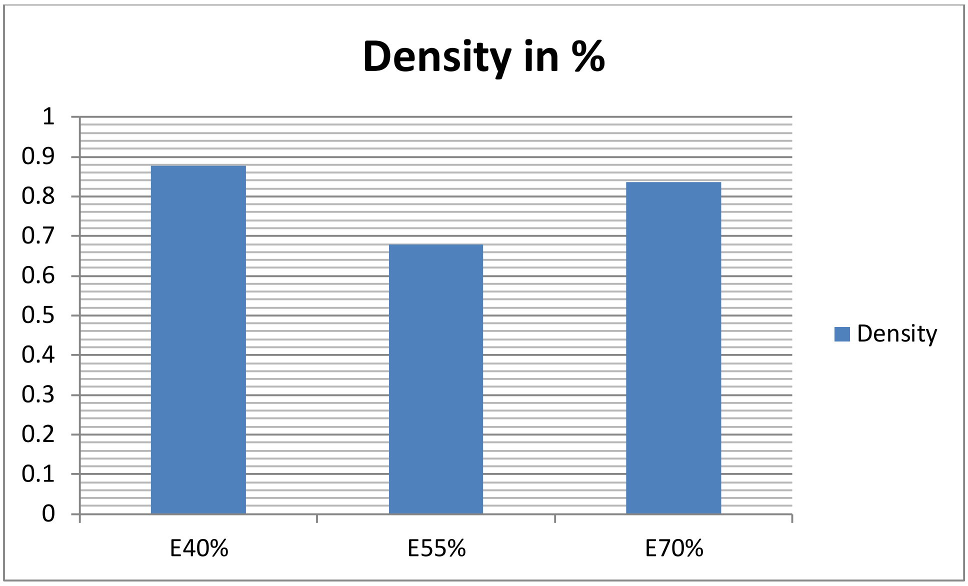

Fig. 5: Density versus percentage of water

An adequate amount of water in the raw material mixture improves uniform distribution of particles and better cohesion between them during briquette formation. This leads to denser briquettes because more material is compressed into a given volume.

While excess water makes the mixture of raw materials too liquid, with compromises the formation of briquettes. If the mixture is too wet, it is difficult to compress it effectively, resulting in less dense and more fragile briquettes.

Properly controlled water levels help maintains briquette density during drying by avoiding excessive shrinkage or distortions due to density gradients.

- **Thermal efficiency**

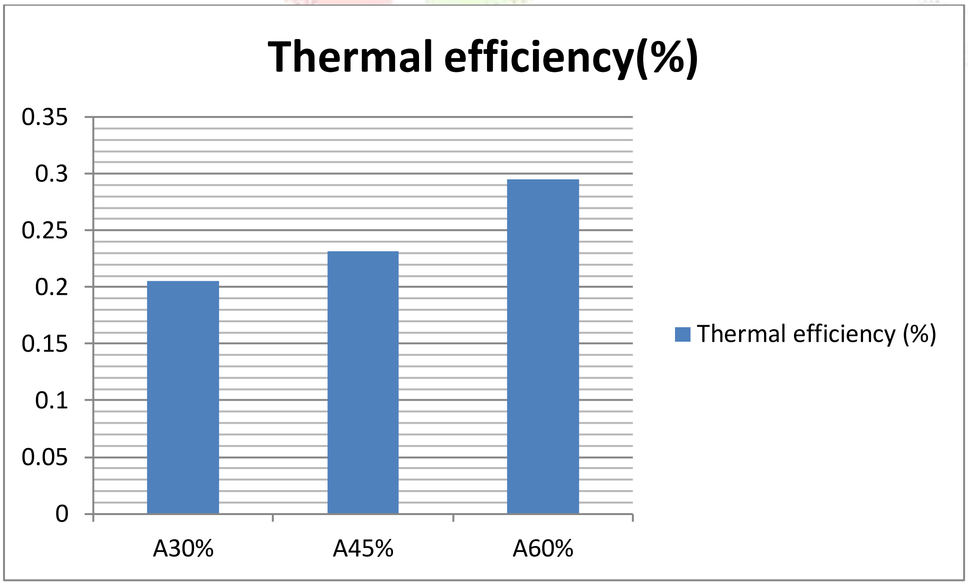

Fig. 6: Thermal efficiency depending on the level of starch used

Too much peat clay in the briquette formulation can make the surface of the briquettes less porous, which can make ignition more difficult and slow the burn rate. This can reduce thermal efficiency because slower combustion can lead to inefficient use of the thermal energy produced.

A different chemical composition or higher moisture content can affect the way the briquettes burn and release heat when burning. A balanced formulation is necessary to maintain optimal combustion properties and therefore maximum thermal efficiency.

- **Impact resistance**

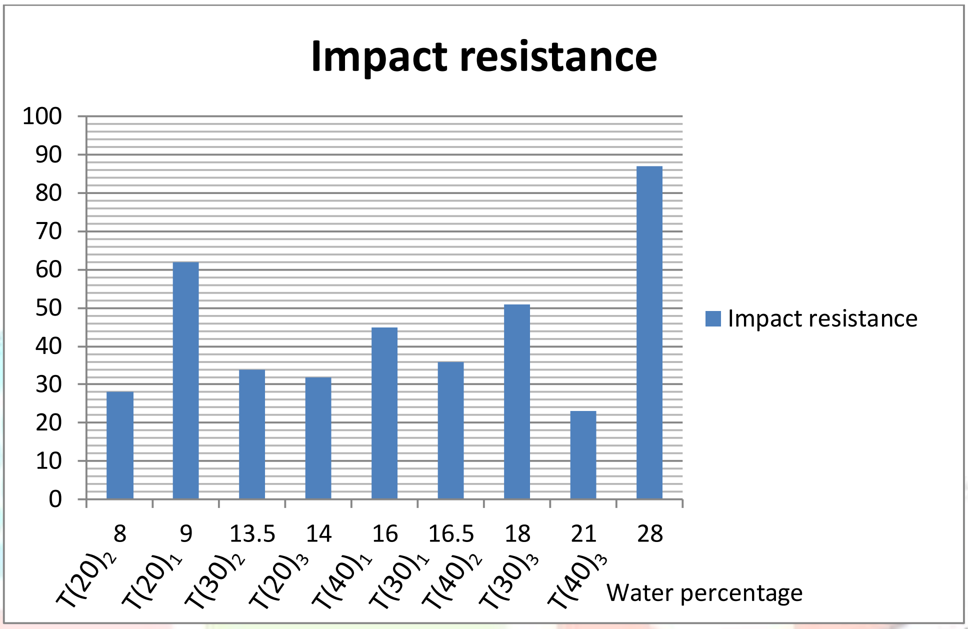

Fig. 7: Resistance rate to impact of volatile matter as a function of water percentage

Denser briquettes generally have a stronger internal structure and are less likely to break from impact. Optimum moisture content can help keep briquettes together while preventing them from becoming too fragile or brittle.

Still, it is important to find a balance between impact resistance and ease of use of briquettes. Excessive peat clay content can make the briquettes too stiff or difficult to break, which can make them difficult to use in certain contexts, for example when used as fuel in domestic cooking appliances.

Discussions

Our results suggest that jatropha hull briquettes could provide a perpetual source of renewable fuel. However, considerations such as availability of raw materials, production costs and logistics requirements must be taken into account to assess the affordability of this approach.

Conclusion

Manufacturing briquettes from jatropha husks offers promising potential as an alternative renewable energy source. The results of this study showed that jatropha hulls have a favorable chemical composition, with adequate volatile matter content and an interesting calorific value. In addition, the process of manufacturing briquettes from these shells proved to be technically feasible, with compaction pressure and temperature parameters that could be optimized to obtain quality briquettes.

Evaluation of the energy potential of jatropha hull briquettes revealed a competitive calorific value compared to other traditional fuel sources. Combustion test results also showed satisfactory thermal stability and relatively low air pollutant emissions, highlighting the favorable environmental potential of these briquettes. With continued research and appropriate support, jatropha hull briquettes could play an important role in the transition to a more sustainable and decarbonized energy future.

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