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CHARACTERIZATION OF WASTE (PALM KERNEL SHELL AND MAIZE COB) FOR FUEL ENERGY GENERATION

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ABSTRACT: The short- and long-term properties of palm kernel shell (PKS) and maize cob, biomass waste, and crops with energy potential for use as fuel pellets in industrial and residential settings, are examined in this study. A thermogravimetric investigation was conducted to determine the distinctive thermal behavior of the biomass above plants in an air and inert environment at room temperature to 700°C for the heating rate of 10°C min-1. It was discovered that the weight loss trends in the two biomass samples were identical in trend. Three reaction zones—char degradation, dehydration, and breakdown—that generated volatility were seen when the samples were being tested in a nitrogen atmosphere. Dehydration, devolatilization, and char burning occurred in three reaction zones in an air environment. The proximate study revealed that PKS has 9.7% more volatile matter than maize cob whereas biomass has a 0.7% difference in carbon combustion value (15.1% for maize cob and 14.4% for PKS). The final study revealed that PKS had a greater heat value per kilogram than maize cob, which has heat of 16.4 MJ/kg and contains 47.6% carbon, 5.3% hydrogen, 44.3% oxygen, and 6.2% water. The findings of theoretical and experimental techniques showed that palm kernel shell has the highest calorific value, making it the best for biomass energy generation and fuel pellets for both residential and industrial use to power machinery and create income for investors.

KEYWORDS: Fuel, Energy, Crops, Thermal Behaviour, Inert and Air Environments.

1 INTRODUCTION

Global warming is caused by the steadily rising carbon dioxide (CO_2) emissions, which are mostly brought on by the burning of fossil fuels. As a result, finding alternative energy sources is essential for reducing CO_2 emissions and having a positive environmental impact. Some renewable energy sources, including wind and water power plants, needed biomass to be harvested using thermal methods. Since the same quantity of CO2 is drawn from the air over the plant’s development cycle, consistent energy sources help to reduce CO_2 emissions over time [1, 2].

Renewable energy is power that can be produced indefinitely. Cleanliness, price, stability, efficiency, and any potential environmental effects must all be taken into account when making a decision. Since fossil fuel stocks will inevitably deplete, businesses must move to renewable sources as soon as possible. Additionally, these fossil fuels pose a serious threat to ecological security and the delicate balance of the ecosystem [3, 4, 5].

Gases including carbon monoxide, nitrogen monoxide, nitrogen dioxide, and sulfur dioxide are produced when fossil fuels are burned. This dangerous substance impedes the growth of plants, causes smog, impairs human health, and directly contributes to air pollution [6]. Sulfur dioxide is primarily responsible for the production of acid rain, which severely damages marble crops and monuments. Due to coal mining, the land has become lifeless and unfruitful. Large areas of land cannot be used for agriculture due to this unfavorable side effect [7].

Biomass has the potential to meet the world's expanding need for renewable and sustainable alternatives since it is readily available, socially acceptable, and carbon-neutral. As a result, it is expected that humanity's transition away from fossil fuels and toward renewable energy technologies would improve environmental sustainability by reducing GHG emissions and diversifying the world's energy supply. To discover a replacement that is both environmentally benign and economically feasible, as well as a source of income for the people of Nigeria, it is urgently necessary to investigate biomass [8, 9].

The quest for energy sources with low greenhouse gas emissions and sustainable production has prompted interest in alternate biomass sources. However, storage, transportation, and lower energy density issues with using biomass fuels must be addressed. Energy density can be severely impacted by low-density levels, which raises the cost of storage and transit. Utilizing pellets as an alternative biomass source allows for densification, which lowers the amount of biomass while improving the quality of its energy. They are made mostly from agricultural plants and a variety of biomass resources. In every situation, it's critical to assess the fuel's attributes to ascertain whether it will work with the heating system and its handling capabilities [10, 11].

2 MATERIALS AND METHOD

2.1 MATERIAL SELECTION

The materials were sourced locally which are Palm Kernel Shell and Maize Cob.

2.2 METHODOLOGY

The samples were weighed and burnt. There were variations in the specimen's weight as its temperature was raised monitored, and recorded until there was no change. The samples' volatile and moisture contents were assessed by thermogravimetric analysis (TGA) and the variety of characteristics includes moisture loss, decarboxylation, pyrolysis, solvent and plasticizer loss, oxidation, and degradation for biomass or other substances. The proximate analysis technique was used to characterize biomass as moisture content, ash content, volatile matter, and fixed carbon percentages. The fixed carbon percentage is dependent on the results of the other three parameters [12]. The Moisture Content (MC), Ash content (AC), Volatile matter (VM) and Fixed carbon percentage (FC) were calculated using Equation 1, 2, 3, and 4 {12], [13].

$$\text{Moisture content (MC) (\%)} = \frac{w_o - w}{w_o} \quad (1)$$

Where; W_0 is the initial weight of the sample and crucible together,

and W is the resulting weight of the dry sample.

$$\text{Ash content (\%)} = \frac{w_a}{w_o} \quad (2)$$

Where W_a is ash weight.

$$\text{Volatile Matter (\%)} = \frac{w_v}{w_o} \quad (3)$$

Where Wv is the ash weight sample.

$$\text{FC \%} = 100 - (\text{\% Ash} + \text{VM} + \text{MC}) \quad (4)$$

2.3 GAS EMISSION AND PARTICULATE MATTER (PM) ANALYSIS

An infrared analyzer was used to continually assess molar percentages of oxides of carbon in thermogravimetric (TG) output. At every 10 seconds, the experimental uncertainty for gas measurement was recorded along with the gas composition using a Flame Ionized Detector (FID) [1].

2.4 THERMO-GRAVIMETRIC KINETIC APPROACH

The method employed using the mentioned equations 5 to 7 [14] was used to calculate reaction kinetics parameters. The vitalization reaction's overall kinetics are provided by

$$\frac{dx}{dt} = -kx^{n} \tag{5}$$

where x is sample mass, k is reaction constant, and n is in order of the reaction.

$$K = Ae^{(-E/RT)} \tag{6}$$

$$L_{n\partial}\left[\frac{-1}{w_o - w_f}\right]\left[\frac{dw}{dt}\right] = L_n(A) - \left[\frac{E}{RT}\right] + nL_n\left[\frac{w - w_f}{w_o - w_f}\right] \tag{7}$$

Where wo is initial mass, w_t is final mass, w is mass at any time, $\frac{dy}{dt}$ is the ratio of change in mass to change in time; A is the preexponential factor, and R is the universal gas constant [12].

Geospatial software was used to theoretically assess the potential of certain biomass agricultural leftovers. All agricultural leftovers are allotted for burning or gasification for energy and heating requirements, according to preliminary and final evaluations. The material melting point was impacted by a high quantity of ash in the alkaline and alkaline earth. In an environment of inert nitrogen and air, a 10°C/min heating rate was used to perform a thermogravimetric examination on two biomass samples, palm kernel shell, and maize cob. Below 140°C, the moisture was removed. The early degradation of biomass was seen between 200°C and 340°C in an inert environment, and between 200°C and 300°C in an atmosphere. Over 400°C, the second degradation of biomass in an inert atmosphere happened constantly, and the remnants of maize cobs and palm kernel shells were noted. Devolatilization took place between 180 and 325 °C, while char combustion took place between 320 and 450 °C [15, 16].

To pinpoint the areas of decomposition and assess kinetic characteristics (activation energy, frequency factor, and reaction order), thermal breakdown of palm oil fronds and palm kernel shells was performed in a TGA. According to the decomposition profiles, cellulose and hemicellulose for both types of palm oil waste degraded at temperatures between 320 and 350 °C and 280 to 300 °C, respectively. According to the literature, no lignin breakdown was seen. When compared to a corn cob, PKS was shown to decompose more quickly. First-order reaction kinetics and the breakdown patterns of palm oil wastes were well-matched [14].

3 RESULTS AND DISCUSSION

The differential thermal analysis (DTA) signal and weight loss were collected throughout the analysis process. Physical, chemical, and thermal characteristics of biomass fuels were categorized. Important chemical characteristics of biomass were also assessed in the final analysis. A biomass fuel sample's proximate analysis measures the moisture, volatile matter, ash, and fixed carbon content while the ultimate analysis determines the biomass's carbon, hydrogen, and oxygen composition. Tables 1 and 2 contain the findings.

Table 1. Proximate and Elemental analyses of Maize Cobs and Palm Kernel Shell

Characteristics	Maize Cob	Palm Kernel Shell
Moisture (%-air dry)	7.2	7.8
Volatile matter (%- air basic)	70.8	80.5
Ash (%-air basic)	1.6	4.3
Fixed carbon (%-air basic)	15.1	14.4

In air dry conditions shown in Table, the moisture of corn cob 7.2 % was found higher than 7.8% of palm kernel shells. The palm kernel shell has a high ash content of 4.3 % while the maize cob value is 1.6 %. The volatile matter of the Palm kernel shell was 70.8 % whereas that of the Palm kernel was 80.5 %. Fix carbon was approximately 15.1 % but higher than PKS. The proximate analysis revealed that both have almost the same combustion value (15.1% maize cob and 14.4 % PKS) in terms of carbon while PKS 9.7 % contains more volatile matter than maize cob. Figure 3 shows the characterization of the biomass constituents.

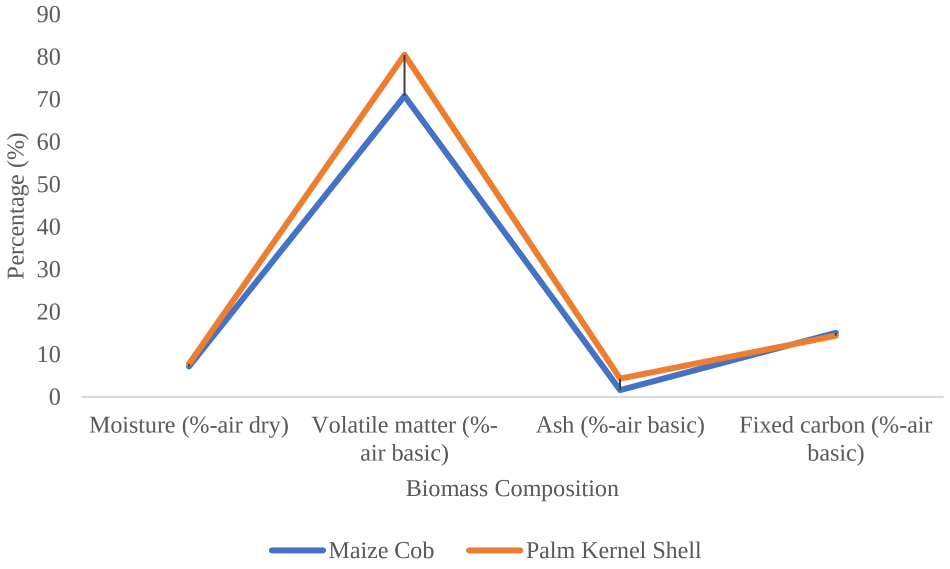

Fig. 1. Comparison of MC and PKS Calorific heat content

Figure 3 indicates the proximate analysis supremacy of carbon contents and volatile matter PKS 9.7 % over maize cob. The non-isothermal weight loss curves for the two biomass samples at 10°Cmin-1 under nitrogen atmosphere thereby showed thermal behavior similarity to each other. Three distinct weight loss stages were identified that concretized the research objective.

The results of the ultimate analysis of carbon, hydrogen, oxygen, and low heat value are listed in Table 2.

Table 2. Ultimate and Elemental analyses of Maize Cobs and Palm Kernel Shell

Characteristics	**Maize Cob**	**Palm Kernel Shell**
Carbon (%-dry Basic)	47.6	48.8
Hydrogen (%-dry basic)	5.3	6.2
Oxygen (%-dry basic)	42.8	44.3
Low Heat Value	16.4	18.5

The ultimate analysis showed that clean hydrogen gas in PKS (6.2 %) is higher than 5.3 % of maize cob. In terms of carbon contents that support combustion, PKS has 48.8 % whereas maize cob has 47.6 %. PKS with 44.3 % is more combustible than 42.8 % of maize cob. The heat value of PKS with 18.5 MJ/kg showed superior over maize cob of 16.4 MJ/kg

The thermal degradation of PKS and maize cob biomass in an inert atmosphere is tabulated as contained in Table 3.

Table 3. Thermal Degradation of Biomass in Inert Environment

Characteristics	**Maize Cob**	**Palm kernel shell**
Carbon (%-dry Basic	47.6	48.8
Hydrogen(%-dry)	5.3	6.2
Oxygen (%-dry basic)	42.8	44.3
Low Heat Value	16.4	18.5

Hydrogen piqued the interest in simple local power-generating methods. A good substitute for fossil fuels has been suggested. Table 3 shows both data in an inert environment revealed carbon content of biomass lower than 50 % in both cases whereas PKS would burn higher than maize cob with 48%/47.6% carbon, 6.2%/5.3% hydrogen, 44.3%/42.8% Oxygen, and 18.5%/16.4% heat value respectively.

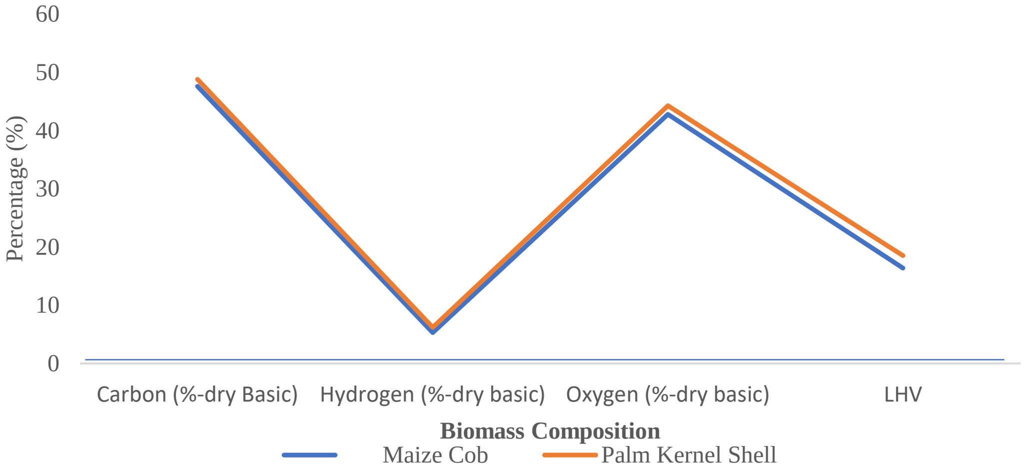

Fig. 2. Graph of Biomass Composition and Heat Content

The dual biomass was observed in an inert atmosphere and the results presented in Figure 4 that, the water loss content in corn cob is less than of PKS. The carbon content of biomass is lower than 50 % in both cases whereas PKS would burn higher than maize cob with 48%/47.6% carbon, 6.2%/5.3% hydrogen, 44.3%/42.8% Oxygen, and 18.5%/16.4% heat value respectively. This implies that the thermal capacity of PKS for combustion as fuel is high.

Table 4. Thermal Degradation of Biomass in Air Environment

Samples	Water Loss (%)	Temperature (ºC)	Weight loss (%)	Temperature (ºC)	Weight (%)	Residue (%)
Corn Cob	8.6	200 - 300	72	340 -500	7.5	4.0
PKS	9.0	200 - 300	76	340 - 500	9.4	2.1

Table 4 shows the dual biomass in the air environment that, water loss content in corn cob with 8.6 % is less compared with 9.0 % of PKS. The residue weight loss in thermal degradation of 4% corn cob is much higher in residue weight to 2.1% PKS. This implies that the thermal capacity of PKS for combustion as fuel is high.

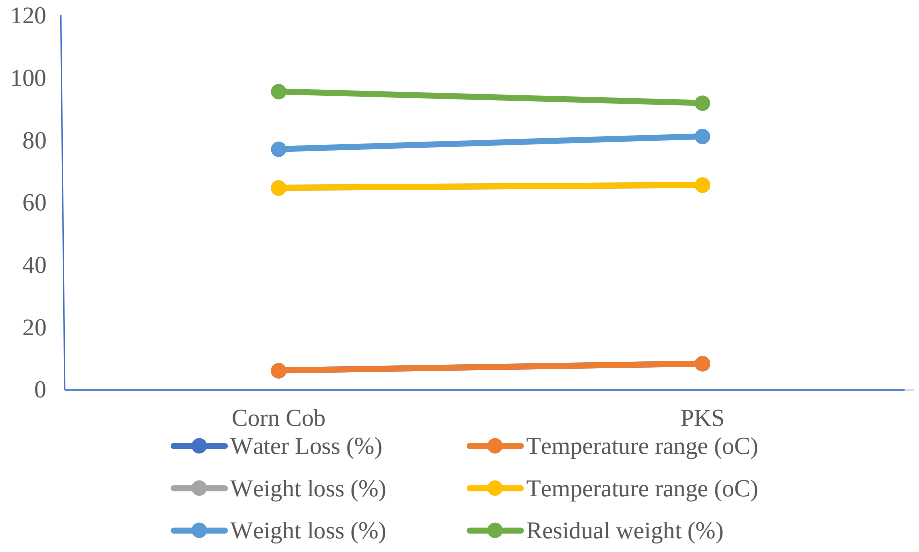

Fig. 3. Graph of Biomass Weight Loss and Temperature in Nitrogen Environment

The total weight loss was found high in PKS to be 57.3% and 58.6% as indicated in Figure 5. At a temperature range of 200 – 300^oC, OKS has a weight loss of 8.4%, 6.2% of maize cob whereas at 350 – 800^oC, PKS lost 15.6% and maize cob 12.4%. It implies that weight loss in a nitrogen environment favour corn cob than PKS.

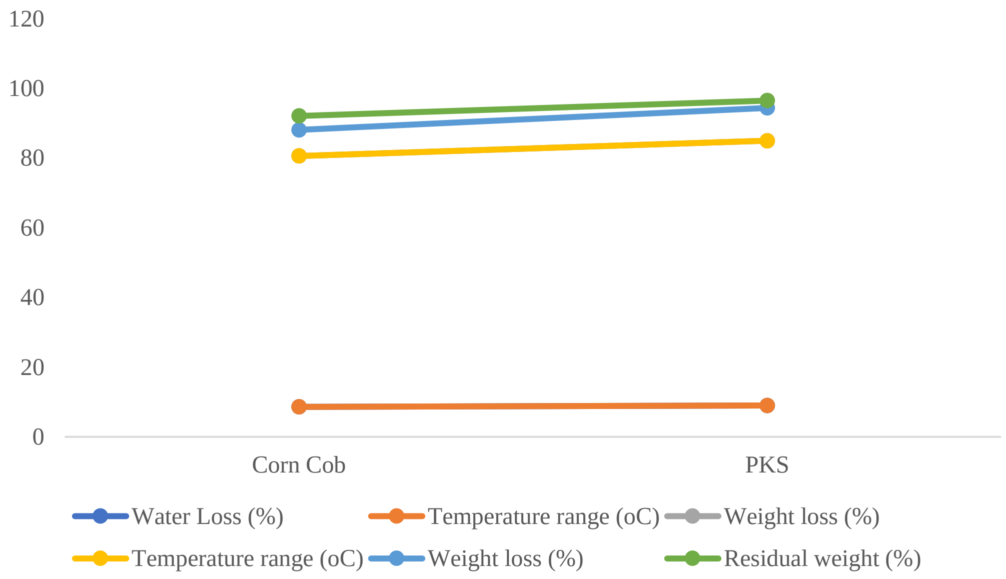

Fig. 4. Weight in Air Environment

Figure 6 revealed variations in weight losses in PKS (9 - 9.4%) and maize cobs (7.5 - 8.6%) at different temperatures. The total amount of weight loss in PKS is more than that of maize cob. This indicates a high degree of flammability of PKS over maize cob.

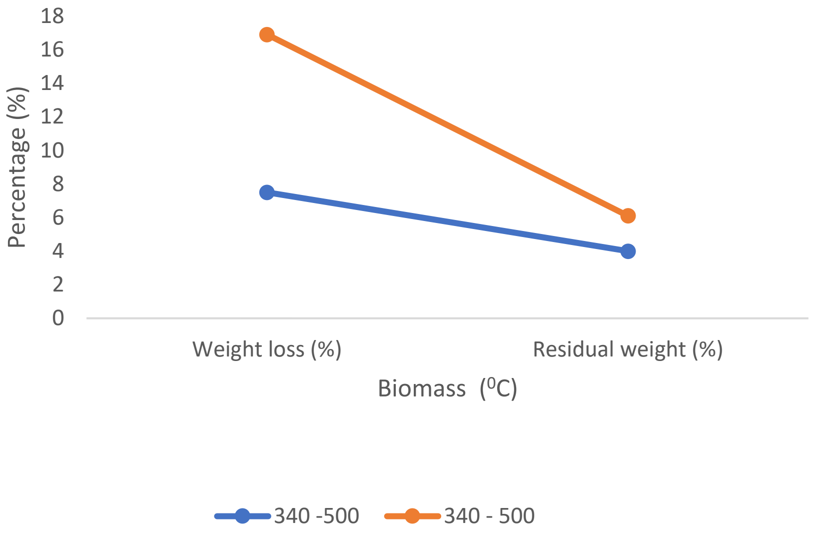

Fig. 5. Biomass Weight Loss and Residual Weight in Air Environment

Figure 7 shows a comparison between the weight loss and residues of the biomass. Corn cob had a 2% loss in weight over PKS whereas 76% PKS residual makes its heat value heavier than the 72% weight loss of maize cob.

3.1 SOCIO-ECONOMIC IMPORTANCE OF MAIZE COBS AND PALM KERNEL SHELL PALLETS

3.1.1 MAIZE COBS AND PELLETS

Figure 8 displays the various grain sizes of ground pallets and corn cobs [17].

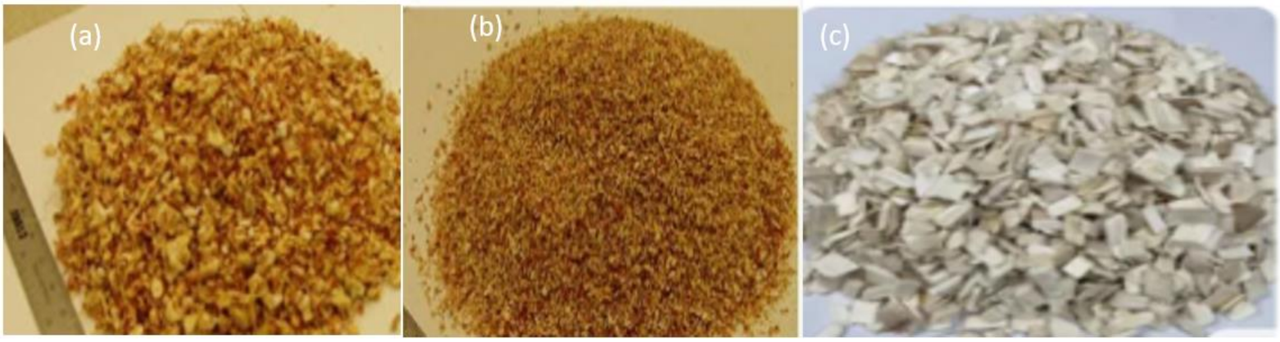

Fig. 6. Grounded Maize cobs and Pallets (a) Corn cob Ground (size 2.81 mm) (b) Corn cob Ground (size 0.85 mm) (c) Corn Cob Pallets

The following application areas for improvement in awareness and novelty technologies were highlighted among the socio-economic relevance [9, 22] which are manufacturing of charcoal and animal bedding, industrial heating to boil water, biofuel for residential appliances like stoves, electricity generation to power equipment, grind and wash to manufacture kitty litter, the corncob pipe raw material is used to make bowls for corncob pipes, if coarsely milled, a moderate abrasive that can be used to clean construction surfaces, in tumbling and vibrating finishing machines, metal pieces are cleaned, dried, and polished.

3.1.2 PALM KERNEL SHELL AND PALLETS

Figure 9 depicts the grounded and palletized palm kernel shell, both of which are employed in household and commercial settings [14].

Ground P K S

P K Pellets

Fig. 7. Ground and Pellets of Palm Kernel Shell

Some of the notable properties and advantages of the PKS are stated below [18]. The Palm kernel shell pellets are of low moisture in nature, PKS pellets are high in heating energy and efficiency, palm kernel shell pellets are easy to handle and store, the PKS pellets are easy to control, and have a broad application, kernel shell pellets are suitable for most boiler grating systems, and the PKS pellets generate low to no smoke during the combustion. The following are practical applications for ground and pelleted palm kernel shells: it added to agricultural soils to improve their properties, the ash is added to animal diets as a mineral supplement, it serves as a substrate for mushroom and crop growth, it is employed as a source of heat to operate machinery and factories, it serves as concrete aggregate, energy source for blacksmithing activities, it is used to purify water in industrial settings, it is utilized to make biochar and activated charcoal, ana an alternate fuel source for biomass-based combined heating is palm kernel pallet.

4 CONCLUSION

The oxidative pyrolysis of two waste products from energy crops—palm kernel shells and maize cobs—was used in the study to determine the thermal degradation rate in different media, extract kinetic parameters, and quantify gas emissions and particle matters. The two selected energy crops' physiochemical characteristics, such as moisture content, carbon percentage, ash value, and volatile matter, were compared and contrasted to ascertain which one had the highest heat value and was the most practically and sustainably produced. The results indicated that PKS contains 9.7% more volatile matter than maize cob and has a proximate analysis combustion value of 15.1% for maize cob and 14.4% for PKS carbon. The final study also revealed that PKS had a greater heat value per kilogram than maize cob, which had a heat value of 16.4 MJ/kg, 47.6% Carbon, 5.3% Hydrogen, and 44.3% Oxygen. The goal of the research was to inform anyone interested in generating biomass energy from energy crops about the precise crop sample that has the highest heating value to improve steam or turbine engines that will be used to produce electricity. The findings of both the theoretical and experimental approaches showed that palm kernel has a comparative advantage of having a larger calorific value and is thought to be the best for producing biomass energy.

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