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Investigation of Combustion Efficiency of Coconut Shell (Cocos nucifera) in an Improved Stove in Comparison with Neem Wood

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ABSTRACT

The demand for biofuel in the world market is increasing by the day and high cost of it. The problem of environmental degradation as a result of the emission of dangerous gases that has an adverse effect the ozone layer and the need to make good use of our large biomass resources which are thrown away, is becoming too much. Biomass, mainly coconut shells, approximately 90% of coconuts, including empty fruit bunches, fibres, fronds, trunks, and shells, were dumped as waste, either incinerated in open air or allowed to accumulate in waste ponds, were made in this research towards utilization of biomass. This study compares the efficiency of coconut shell biomass and fuel wood (neem wood) using an improved metal stove. The findings reveal that coconut shells have less ash, less charcoal, and uses less fuel but fuel wood uses less time.

Keywords: *Coconut shell; improved stove; water; charcoal; ash; biomass.*

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1. INTRODUCTION

Global interest in biofuel as a renewable energy source for long-term fuel sustainability is driven by the anticipated depletion of fossil fuels [1]. Notably, the lack of a distinct identification method poses a challenge, leading to the consideration that the products obtained through destructive distillation could be either liquid smoke or wood vinegar. This ambiguity highlights the need for a thorough investigation of coconut shell liquid smoke, a valuable resource derived from a potential source of hardwood. Liquid smoke, derived from the pyrolysis of coconut shell charcoal, exemplifies the ingenious repurposing of byproducts traditionally viewed as waste. This substance has carved out a versatile niche for itself, not only as a robust preservative in the food industry but also as a promising candidate for various medicinal applications. As the demand for such versatile compounds increases, it is imperative to intensify research efforts aimed at optimizing their production. Harnessing the potential of this traditional resource, while ensuring sustainable and cost-effective methodologies, will pave the way for not only meeting industrial needs but also mitigating environmental challenges [2].

With potential for Indonesia alone to produce up to 66, 200 tonnes per year, or 12% of all activated carbon raw materials sourced, Coconut shell charcoal (CSC) is a very promising source of raw material for the manufacturing of activated carbon (AC) [3] [4]. Because of its remarkable mechanical qualities, high prosperity, and surface area, activated carbon (AC) made from coconut shell charcoal is in high demand in water purification and water treatment application [5] [6]. Moreover, the generation of AC from CSC is quite straightforward and may be undertaken by small enterprise of domestic companies [4]. Since the CSC comprises natural resources, the procurement of these raw material can be strategically managed and sourced locally [7].

Another possible use for CSC is briquettes, which are solid alternative energy sources made by compacting charcoal [8]. The CSC has good thermal diffusion qualities, making it one of the greatest sources of raw materials for briquet [9]. Turkey, Brazil, as well as a number of European and Latin American countries, highly value Indonesia's briquets due to their outstanding quality [10].

Researchers around are concentrating on methods to utilize industrial or agricultural waste as a source of raw materials for industry [11] [12] One notable result of coconut shell, which is an agricultural waste that is readily available in huge amount, is liquid smoke, which is produced via pyrolysis [13]. All around the world's tropical nations, furthermore, as a new energy source, coconut is becoming as a significant agricultural product for tropical nations worldwide [14].

Coconut shell was formally incinerated as a method of garbage disposal, considerably contributing to carbon monoxide and methane emissions [14]. But in addition to becoming unpredictable, the cost of gasoline, oil, natural gas, and electricity has gone up, and coconut shell is now considered a fuel source rather than trash. In Nigeria, coconut shell is currently utilized as boiler fuel, with leftover coconut shell being used as firewood for traditional fuel, which is obtained either from wood or fallen trees, and responsible for deforestation, desertification, hunger, poverty and biodiversity loss. In this experiment the type of stove involved is an enclosed stove with only one slot for the biofuel. The biofuel in this experiment is coconut in the form of shell and husk biomass. A valuable byproduct of coconut plants, known scientifically as *Cocos nucifera*, is coconut shell. One of the raw materials used to make coconut charcoal is coconut shell, which is made by burning the shells of completely ripe nuts in a small amount of air enough to cause carbonation.

2. MATERIALS AND METHODS

2.1 MATERIALS

Measuring cylinder (500ml)
Beaker 1000ml
Improved force draft stove (locally called Mukubar)
Weighing balance (electronic precision balance).
Matches.
Stopwatch.
Filter paper
Coconut shell.
Fuel wood (Neem wood),
Thermometer

2.2 Methodology

The coconut biomasses were collected from local disposal sites in Maiduguri Metropolis. The biomass (shell and husk) was spread and allowed to dry in the sun. The fuel woods of neem tree were purchased from local fuel sellers in Maiduguri town, Borno State. The fuels were allowed to dry in the sun to reduce their moisture content. The two fuel types (Coconut biomass and fuel wood) were used in an improved metal stove with only one opening as slot and for aeration. This stove was chosen because it was an improvement over the open three stones and partially closed one which have been the traditional domestic stove in circulation and use in Maiduguri. Weight of each fuel type was taken using an electronic precision balance. One liter of water was measured using a measuring cylinder for the water boiling trails, A mercury thermometer was attached to indicate boiling point (100°C) per unit time after boiling, weight of each fuel type residue, charcoal and ash contents were collected. Weighed and recorded. The boiling procedure was replicated three times for each fuel type.

2.3 Data Analysis

Average values of replicated data were collected from the trial observation, were subjected to a two-way analysis of variance (RCBD) at 5% and 1% probability level and the least significance difference (LSD) were used to compare the significant difference between means [15].

3. RESULTS AND DISCUSSION

3.1 Results

The average weight of coconut biomass after use (residue) was 8193g which represents 36.61% of the initial biomass (500g). About 318.07g of the biomass was utilized to boil 1 liter of water in 5.33 minutes, representing about 63.61% of the biomass. This quantity seems to be more significant.

The large percentage of the residue was due to the nature of the fuel: it is very hard, which made it take time to burn completely. The ash content was1.8g which is equivalent to 0.36% of the whole biomass. It has a very low percentage of ash which is one of the characteristics of good fuel. The average weight of charcoal was found to be 18.57g which is 3.71%.

The result is in concordance with the findings of [16] who found that Coconut shell briquettes had higher compressed density though lower in relaxed form (0.80 g·cm-3 vs 0.78 g·cm-3) when compared to Bambara nutshell briquettes (0.77 g.cm-3 vs0.75 g.cm-3).

According to [17] [18], by closing the carbon loop, using biomass as energy minimize greenhouse gas emissions and lessens reliance on imported petroleum. Additionally, it boosts rural communities' economies and lessens the extensive deforestation caused by the usage of wood trees for domestic uses. According to (Samson, 2002),

In this result, the average weight of fuel wood after use (residue) was 29.53g which represents 5.91% of the initial biofuel (500g). About 470.47g of the whole biofuel was utilized to boil 1 liter of water in 3.7 minutes, representing about 94.04% of the biofuel. This small percentage of residue was about 94.04% of the biofuel. This small percentage of residue was due to the nature of the fuel, it is not hard, and this made it burn easily. The ash content was 11.13g which is equivalent to 2.23% of the whole biofuel. This percentage of ash is higher than that of coconut shell biomass. According to [19] showed that burning 25 kg of coconut shell was optimal, producing a 48% charcoal content. The average weight of charcoal was found to be 15.27g which is 3.05% of the whole biofuel. In contrast [20] found that adding coconut particles enhanced the bio-composites' overall mechanical performance and that CRC-5.0 bio-composites outperform CRS-0.0 bio-composites in terms of surface hardness (23.61%), tensile strength (32.58%), and flexural strength (35.45%). CRC-2.5 bio-composites have greater impact strength, fracture toughness, and fractured energy. [21] also reported that one interesting ingredient for concrete manufacturing is coconut shell, an agricultural by-product that can partially replace coarse aggregates. Their findings suggest that coconut shell can be utilized a s lightweight concrete for non-structural parts, strip footings, and non-loading bearing constructions. Using these leftover coconut shell resources to create sustainable, effective particles can also reduce.

The mean yield in a related study by [22], varied from 33.81% for palmyra shells, to 27.57% for doum palm shells. For palmyra shells, the maximum production of 42.32% was obtain at 280°C, while the lowest yield of 24.42% was recorded.

Table 1. Means attributes of Coconut Shell Biomass, Trails for Boiling Using an Improved Stove

Parameter		Wt. of Biomass before use (g)	Wt. of Biomass after use (g)	Vol of H_2O (Liter)	Time taken to reach 100⁰c (min)	Ash content (g)	Wt. of Charcoal (g)	% different of initial Wt. and residue	% different of initial Wt. and Ash content C	% different of initial Wt. and Charcoal weight
Mean trials		500	181.93	1	5.3.33	1.8	18.57	63.61	99.64	96.29
	% Ash Content			% of Residue				% of Charcoal		
	0.36			36.61				3.71		

Table 2. Means attributes of Fuel wood, Trails for Boiling Using an Improved Stove

Parameter	Wt. of Biomass before use (g)	Wt. of Biomass after use (g)	Vol of H_2O (Liter)	Time taken to reach 100^0c(min)	Ash content (g)	Wt. of Charcoal (g)	% different of initial Wt. and residue	% different of initial Wt. and Ash content C	% different of initial Wt. and Charcoal weight
Mean trials	500	181.93	1	5.3.33	1.8	18.57	63.61	99.64	96.29
% Ash Content			% of Residue				% of Charcoal		
0.36			36.61				3.71		

Table 3. ANOVA for Values of Residue for the two Biofuels

Source of variation	Degree of Freedom (df)	Sum of square (SS)	Mean Sum of Squares (mss)	F. Calculated (Fcal)
Replicate	2	9788.03	3399.02	9.36
Treatment	1	33480.57	33480.57	92.22
Error	2	726.1	363.05	
Total	**5**			

Table 4. ANOVA for Values of Content for the two Biofuels

Source of variation	Degree of Freedom (df)	The sum of square (SS)	Mean Sum of Squares (mss)	F. Calculated (Fcal)
Replicate	2	10.58	5.29	1.35
Treatment	1	130.66	130.66	33.37
Error	2	7.83	3.915	
Total	**5**			

Table 5. ANOVA for Values of Charcoal Weight for the two Biofuels

Source of variation	Degree of Freedom (df)	The sum of square (SS)	Mean Sum of Squares (mss)	F. Calculated (Fcal)
Replicate	2	83.21	41.61	3.78
Treatment	1	16.34	16.34	1.48
Error	2	22.02	11.01	
Total	**5**			

Analysis of variance (ANOVA) is a statistical technique used to determine whether there are significant differences between group means in an experiment [23]. The results in Tables 3, 4, and 5 illustrate the ANOVA findings for residue, content, and charcoal weight for two biofuels: coconut shell biomass and fuelwood.

The ANOVA results for residue values show that treatment effects were highly significant (F_cal = 92.22) at a 5% probability level but non-significant at a 1% level. This suggests that the type of biofuel had a strong influence on residue production, aligning with previous studies that highlight differences in combustion efficiency between biomass fuels [24]. However, replicates were not significant (F_cal = 9.36), indicating consistency in experimental observations across replications.

For ash content, the treatment factor was significant (F_cal = 33.37) at a 5% probability level, demonstrating that the type of biofuel significantly influenced ash content, a key factor in fuel quality assessment [25]. Meanwhile, replicates were non-significant (F_cal = 1.35), reinforcing the reliability of the measurements. The low error variance further supports the robustness of the findings. In contrast to residue and ash content, the ANOVA for charcoal weight showed no significant differences between treatments (F_cal = 1.48) at a 5% probability level. This implies that the biofuel type did not significantly impact the charcoal yield, which may be attributed to similar carbonization processes and material properties [26]. The replicates also exhibited non-significant variation (F_cal = 3.78), suggesting experimental consistency. The ANOVA results suggest that while biofuel type significantly influenced residue and ash content, it had no significant impact on charcoal yield. These findings align with prior research on biomass fuel properties and combustion behavior [27].

Future studies should incorporate a larger sample size and additional biofuel types to enhance statistical power and generalizability.

4. SUMMARY, CONCLUSION AND RECOMMENDATION

4.1 Summary

The study investigated the efficiency of coconut shells as a biofuel compared to that of fuel wood (neem wood). The research was conducted to investigate some efficient parameters such as boiling time, ash content, weight of residue, and charcoal weight. The study was divided into five chapters to be handled especially in each phase of the study: this was to give room for easy organization and flow of ideas as the researcher works through the project as well as giving the reader the opportunity to go through the research work very easily.

The introductory part of the project highlighted the important aspect of the study which stated the aim and objectives of the study. Related literatures such as textbooks, written documents, Google and journals were consulted and reviewed on the research topic to back up the study. The research breaks into various sub-headings. The method and procedures the researcher used in carrying out the research was through practical using an improved stove and comparing the efficiency of coconut shell biomass with that of fuel wood (neem wood). Major findings of the research work were highlighted and a discussion of each was made.

4.2 Conclusion

Nowadays the use of fuelwood as an alternative fuel for energy generation is increasing day by day which leads to high deforestation and global warming. Therefore, we can introduce some fuel as an alternative like coconut shell. After analyzing the cost, heat value, and availability of coconut shells by this project, it is expected to make good use of coconut shell biomass as an alternative fuel because of its environmentally friendly, environmental degradation as a result of the emission of dangerous gases that has adverse effects on the ozone layer will be managed, and the need to make good use of our large biomass which are regarded as waste rather than fuel which will save our forest from deforestation. The shell biomasses contain less ash, about 0.36% of 500g compared to that of wood which was 2.23%, furthermore, only 318.07g of shell biomass was utilized to boil 1 liter of water in 5.33mins while that of fuel wood was 470.47g was used in 3.7mins. From the above observations of the two biofuels, it clearly shows that coconut shell biomasses are more efficient, healthy, and safe for use as an alternative biofuel.

4.3 Recommendation

After examining the efficiency of coconut shell biomass as an alternative biofuel compared to fuel wood, the researcher has therefore recommended the following which will assist in the encouragement of using an alternative fuel rather than relying only on fuel wood.

1. The use of coconut shell biomass as an alternative fuel.
2. There should be public enlightenment on the importance of using alternative fuels and the effects of using fuel wood which lead to global warming, deforestation, and others.
3. Further research should be carried out on other different biofuels such as rice husk (hull) and sawdust using a suitable improved stove for the research to compare their efficiency.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

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