Discovery

To Cite:
Akinwole AO, Fawole OO. Comparative assessment of briquette and charcoal as energy sources for smoking of African catfish (*Clarias gariepinus*). *Discovery* 2025; 61: e6d1513
doi: https://doi.org/10.54905/disssi.v61i337.e6d1513

Author Affiliation:
[1]Department of Aquaculture and Fisheries, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan, Nigeria
[2]Department of Fisheries and Aquaculture, Faculty of Renewable Natural Resources, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

*Corresponding Author
Department of Fisheries and Aquaculture, Faculty of Renewable Natural Resources, Ladoke Akintola University of Technology, Ogbomoso,
Nigeria
Email: oofawole78@lautech.edu.ng

Peer-Review History
Received: 01 October 2024
Reviewed & Revised: 05/October/2024 to 04/January/2025
Accepted: 08 January 2025
Published: 12 January 2025

Peer-Review Model
External peer-review was done through double-blind method.

Discovery
pISSN 2278–5469; eISSN 2278–5450

Comparative assessment of briquette and charcoal as energy sources for smoking of African catfish (*Clarias gariepinus*)

Ayoola O Akinwole[1], **Olaolu O Fawole**[2*]

ABSTRACT

The obvious depletion of wood resources at a rapid rate and the inherent danger posed by the environmental degradation necessitates the need for an improved and eco-friendly alternative source of energy in fish processing. Smoking performance and cost implication of using briquette compared to charcoal in smoking process of eviscerated African catfish (*Clarias gariepinus*) was carried out. Performance evaluation parameters of the two energy sources included fish drying rate, energy consumed, energy efficiency, specific fuel consumption and duration of smoke-drying operation. Data collected were subjected to statistical analysis using descriptive. Charcoal recorded better specific fuel consumption (2.36±0.35kg), smoking time (5.87±1.42h/kg) and fish drying rate (0.13±0.03kg/hr) compared to briquette with 3.61±0.68kg; 8.43±0.84h/kg and 0.09±0.01kg/hr respectively. Energy expended was also higher in briquette (170.55±18.37MJ/kg) than in charcoal (164.08±25.54MJ/kg). Energy efficiency was however better in briquette (99.3%) than charcoal (99.0%). Cost assessment showed no significant difference ($p>0.05$) between the operational cost of the two energy sources. Generally, briquette exhibited a competitive attributes in energy efficiency and cost of production, therefore may serve as a viable alternative to charcoal as energy source for smoking fish.

Keywords: Catfish, charcoal, briquette, energy source, energy efficiency, smoke drying, cost assessment

1. INTRODUCTION

Fish is an extremely nutrient-dense diet. It is beneficial because it offers high-quality nutrients on par with those found in meat, milk, or eggs (Umar et al., 2018). In Nigeria, fish accounts for 50% to 80% of the animal protein consumed by the population with annual per capital consumption estimated at 28kg (FAO, 2018; Sumberg et al., 2016). Fish is extremely perishable and therefore requires a degree of processing to preserve and prolong its shelf life and thus allow for extended distribution and marketing opportunities (FAO, 2016). Among the earliest ways of

preservation, smoking fish is still a common practice (Theobald et al., 2012). At least 80% of the African populations continue to rely upon traditional sources of biomass fuels mainly charcoal and firewood to meet their energy needs (INBAR, 2011).

Charcoal is one of the most important commodities produced by the rural poor across Africa which is largely used in urban areas (Jones, 2015). World wood resources are depleting at a rapid rate and the food and agricultural organization (FAO) during the United Nations conference on new and renewable sources of energy held in Nairobi in 1981, estimated that nearly one billion are living in regions with either acute scarcity or deficit wood supply situation (Ibrahim et al., 2015). Desertification can be reduced by offering an alternative to burning wood for residential and industrial heating and cooking (Agyemang and Opoku, 2018). With increasing pressure on the earth's resources, turning different types of organic waste into clean burning fuel helps safe forests and cut greenhouse gas emissions by replacing wood, charcoal and fossil fuels for fish smoking and other industrial processes.

Aside from being cleaner and easier to handle, briquettes are also helping to reduce the pollution that comes from wood processing (David and Anne, 2014). The use of charcoal as a source of thermal energy requires the felling of trees for the purpose of fuel wood, which is not environmentally beneficial. Briquette is a compressed block of wide range of materials which among other things may include rice husk, jute, coal dust, alfalfa, nutshells, leaf straw, sawdust, sunflower husks, leather waste, wood chips, peat and paper which contributes to environmental management by saving forest degradation and reuse of waste (Musa, 2006; Nasrin et al., 2011). This study therefore seeks to assess the attributes of briquette and charcoal as energy sources for fish smoking.

2. MATERIALS AND METHODS

The experiment was carried out on the fish farm of the Department of Aquaculture and Fisheries, University of Ibadan, Nigeria located at Latitude 7.45851290 N, Longitude 3.87530650E. Ten kilogramme (10kg) each of charcoal and briquette were purchased from the local markets in Ibadan metropolis. Twenty kilogramme (20kg) of African Catfish (*Clarias gariepinus*) was also procured from a reputable fish farm in Ibadan. The fish was weighed before and after gutting; then folded and arranged on trays ready for the smoke-drying process. The smoking kiln used is the UI-CORAF kiln constructed instrument which functions without any electrical or sophisticated mechanical appliances to generate heat, but with the help of natural air convention through air vent (Ikenweiwe and Bolaji, 2010).

Component parts of a smoking kiln include fish trays, tray roller, smoking chamber, chimney, reflector, combustion chamber, overhead cover, fan, heating elements (heaters), charcoal chamber, charcoal tray, fluid collector and temperature regulator (Ajewole et al., 2021). The experimental design used for this project is 1x2x2. One type of fish African catfish (*C. gariepinus*) was smoked with 2 replicates and 2 sources of heat. The performance of the two heat sources was done by calculating and comparing the following parameters: energy efficiency, specific fuel consumption, smoking (drying) time, moisture content, drying rate and energy consumed.

Experimental procedure

The smoking kiln was fired by burning 5-7kg of charcoal and briquettes in the charcoal chamber respectively. Eviscerated fresh African catfish was weighed and loaded on the trays of the smoking kiln and the weight of the smoked fish was later weighed to give the initial and final weight of the fish. The temperature during smoking was noted both within the kiln and outside the kiln. Inlet air temperature in the combustion chamber is the temperature within the kiln and outlet air coming out of the chimney is the outlet air temperature. Smoking was done thrice to serve as replicates for two treatments. Smoking schedule was as follow: Morning started by 6:00am; Afternoon started by 12 noon; Evening started by 6:00pm. The quantity of the energy sources remaining after smoking was measured in order to obtain the amount of the solid fuel sources consumed.

Performance evaluation Parameters

The performance of the two fuel materials (charcoal and briquettes) was based on selected performance parameters. Data was collected on moisture content of smoked fish, duration of smoke-drying operation, specific fuel consumption, drying rate, energy consumed and energy efficiency of smoke-drying kiln.

Moisture content was calculated using the expression given by (Issa et al., 2020).

$$\text{Moisture Removed (\%)} = \frac{\text{Weight of fresh catfish(g)}}{\text{Weight of smoked-dried catfish}} \times \frac{100}{1}$$

Drying rate of the fish was calculated using the following relationship as provided by (Ajewole et al., 2021):

$$Dr = \frac{Mi - Mf}{T}$$

Where Dr =Drying Rate (Kg/hr) Mi = initial Mass of fish (kg)
Mf = final mass of fish (kg) T = Total Drying Time (t)
Energy consumed was calculated with regards to the energy source used in drying the fish (Ajewole et al., 2021)
(a) Charcoal heat source is given as: Ed = Ec x Mc
Where Ed = Energy expended in drying. Ec = Energy present in 1kg of charcoal = 29.3MJ/kg (Hulscher, 2016)
Mc = Total weight of charcoal used.
(b) Energy consumed using briquette source Ed = Eb x Mb
Where Ed = Energy used in drying. Eb = Energy present in 1kg of briquettes = 24.9MJ/kg (Ajimotokan et al., 2019).
Mc = Total weight of briquette used.
Smoking (Drying) time was calculated by adopting equation by (18) as follows:

$$\text{Time spent (hrkg-1)} = \frac{\text{Total time spent in smoking (h)}}{\text{Total weight of smoked fish (kg)}} \text{ hr/kg}$$

The specific fuel consumption (SFC) was also determined using the equation adopted by (Davies et al., 2012):

$$SFC = \frac{\text{Total mass of fuel consumed (kg)}}{\text{Total mass of smoked fish (kg)}} \times \frac{100}{1}$$

The energy efficiency of fuel materials was calculated using the expression of (Mujumdar, 1995)

$$\text{Energy efficiency} = \frac{Tcc - Tout}{Tcc - Tamb} \times \frac{100}{1}$$

Where Tamb: Mean ambient temperature (outside); Tcc: Mean inlet air temperature (combustion chamber); Tout: Mean outlet air temperature (chimney)

Economic Assessment

The cost of smoke-drying with the kiln for each heat source material was calculated using the method by (Mondo et al., 2021). Profit gained from sales of 20kg of fish smoked using charcoal and briquette were established using the basic formulae for determining profit (Profit = Selling price – Buying price).

Data Analysis

The data collected was subjected to statistical analysis using Descriptive statistics of mean, standard deviation and frequency count. The statistical analysis was conducted by using IBM SPSS version 20 software.

3. RESULTS

Smoking performance of heat sources

The measurement for both charcoal and briquette heat sources were presented over a 20-hour period on input temperature (Tin), output temperature (Tout) and relative humidity (RH). Highest outlet air temperature (33.10C) was recorded in 13th hour for charcoal, while briquette was highest (31.80C) in the 4th hour (Table 1). The measurement of operational variables helps to identify the optimal condition for smoking fish. Briquette consumed more energy (170.55±18.37MJ/kg) than charcoal (164.08±25.54MJ/kg) as shown in (Table 2). A faster drying rate of 0.13±0.03kg/h of fish was recorded in charcoal against 0.09±0.01kg/h for briquette.

Charcoal also performed better in the area of percentage moisture content removed from smoke fish samples with value of 75.65±5.81 over briquette with 73.03±5.34. A lower specific fuel consumption rate of 2.36±0.35kg was also recorded in charcoal fuel source than briquette with higher fuel consumption of 3.61±0.68kg. However, duration of smoking for briquette was 20 hour and 12 hours for charcoal. The highest performance percentage in energy efficiency was 99.3% in briquette while charcoal recorded highest of 99.0% as shown in (Figure 1).

Table 1 Average operational and environmental variables during the smoking of African Catfish with charcoal and Briquette

Heat source						
	Charcoal			Briquette		
Time (hr)	Tin (0C)	Tout (0C)	RH (%)	Tin (0C)	Tout (0C)	RH (%)
1	77	30.1	67.7	75.3	29.8	67
2	69.7	30.2	63.3	66.3	29.9	65
3	67.7	30.4	62.3	66.7	30.8	61
4	69.3	31.4	59.7	58.3	31.8	58
5	55.3	31.2	58.3	58	30.9	59
6	62.3	31.6	61	54	31.5	59.7
7	51.7	31.7	64	48.3	30.7	63.3
8	67.3	30.7	66.3	62.7	30.8	65
9	68.3	30.6	65.7	61	30.4	65.3
10	61	30.2	65	59.3	29.6	66.7
11	66.7	29.9	66.3	64.7	29.9	67.3
12	64	30.1	68	59.7	29.6	60
13	30	33.1	59	53	29.4	70.7
14	70	31.8	61	60	28.2	70.7
15	65	30.8	65	55	28.8	71.3
16	75	31.7	61	57.5	29.7	67
17	60	31.3	60	66	30.7	58
18	70	29.6	70	64	29.2	72
19	-	-	-	65	28.6	75
20	-	-	-	55	26	72

Table 2 The mean value of performance evaluation of the heat sources parameters in smoking African catfish (*Clarias gariepinus*)

Parameters					
Heat source	**Specific fuel consumption (kg)**	**Smoking time (h/kg)**	**Moisture removed (%)**	**Drying rate (kg/h)**	**Energy consumed (MJ/kg)**
Charcoal	2.36±0.35	5.87±1.42	75.65±5.81	0.13±0.03	164.08±25.54
Briquette	3.61±0.68	8.43±0.84	73.03±5.34	0.09±0.01	170.55±18.37

Economic assessment

The total cost of production for charcoal heat source amounts to N16,100.00, while the total cost for briquette heat source was N16,600.00. The cost of charcoal was lower than that of briquette as shown in (Table 3). The weight of the smoked fish recorded after smoking 10kg each fish samples with charcoal and briquette was 3.4kg. At N10,000.00 per kilogramme market price of smoked fish during the smoking period, the fish was sold for N34,00.00 each. The profit margin was N17,900.00 for charcoal and N17,400 for briquette respectively. The cost effectiveness of charcoal can be attributed to its lower cost per kilogram (N200/kg) compared to the cost of briquette per kilogram (N250/kg). Other factors such as transportation costs and labour were however similar in both cases.

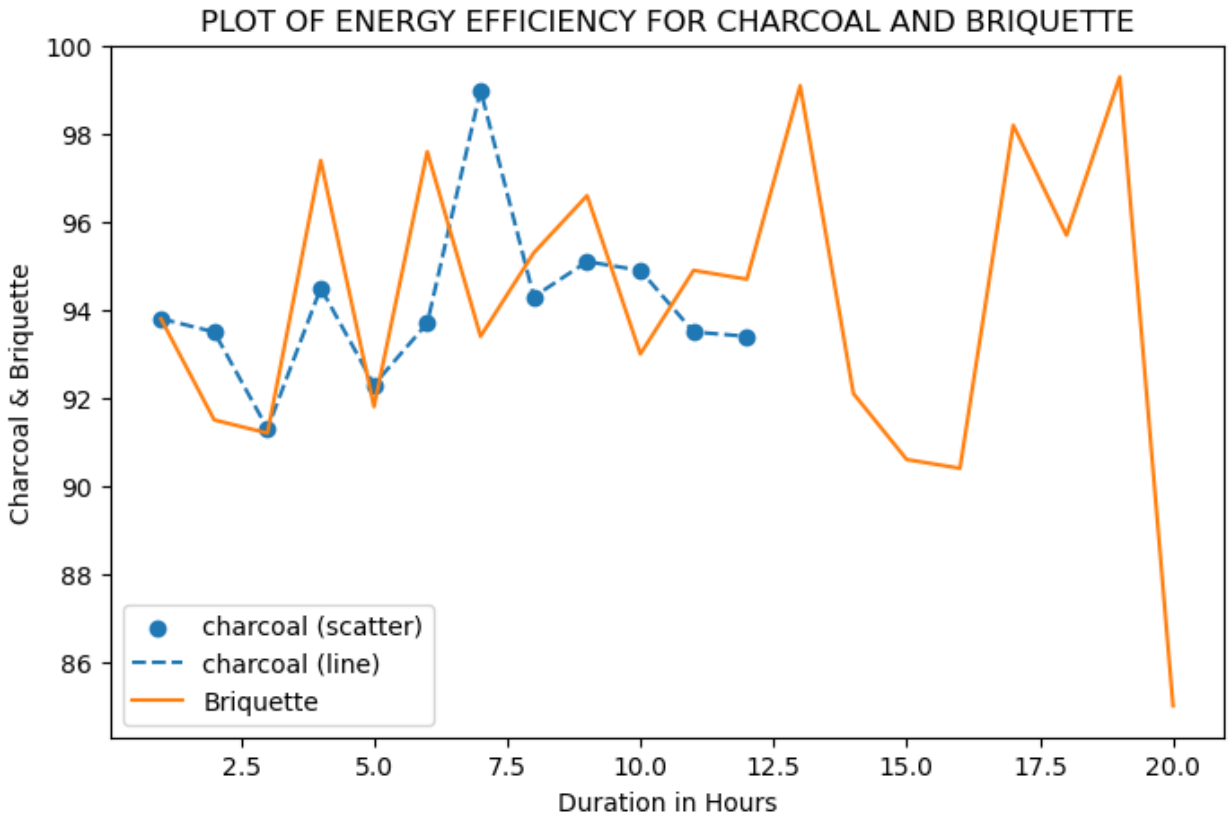

Figure 1 Energy efficiency of charcoal and briquette in smoking African Catfish (*Clarias gariepinus*)

Table 3 Cost Assessment of Charcoal and Briquette heat sources in smoking African catfish (*Clarias gariepinus*)

Fuel source	Cost of fuel (10kg) (N)	Transportation (N)	Labour (N)	Cost of fresh catfish (10kg) (N)	Total cost (N)	Price of fish (N)
Charcoal	2,000	2,000	2,000	10,100	16,100	34,000
Briquette	2,500	2,000	2,000	10,100	16,600	34,000

4. DISCUSSION

Charcoal exhibited better specific fuel consumption than briquette. The implication is that lesser amount of charcoal was required to obtain 1kg of smoked fish than briquette amount required to obtain 1kg smoked fish. This is in agreement with similar work by Amposah et al., (2022) who recorded 2.57kg and 4.20kg in fuel consumption for charcoal and briquette respectively. One of the elements that adversely affect briquettes' particular fuel consumption is their percentage ash concentration (Onuegbu et al., 2012). The smoking time of 5.87±1.42h/kg for charcoal is faster than 8.43±0.84h/kg for briquette. This implies that using briquette as fuel material requires additional 2.56hours to smoke 1kg of fish.

This is in agreement with Erikkson, (2006) who stated that the calorific value of briquette is an important factor in determining the competitiveness of the fuel. Briquette however showed advantages in fuel efficiency which is due to its relatively lower burning temperature and ability to keep most of its heat energy in the smoking chamber as postulated by (Amposah et al., 2022). The use of briquette as an alternative fuel source to charcoal cannot be over emphasized as it helps to prevent 'other energy crisis of wood fuel' Akinbami, (2001) and also help to contribute to waste management and reduce the strain on biomass resources (Asamoah et al., 2016).

5. CONCLUSION

Overall, briquette compares favourably with charcoal in smoking catfish and could be considered as an alternative heat source and this helps to reduce the pressure of deforestation due to charcoal production.

Acknowledgement

The authors would like to thank Miss Oyediran Faith Similolu and the entire management and staff of the Department of Aquaculture and Fisheries, University of Ibadan, Nigeria for all the facilities provided throughout this research process.

Authors contribution

Professor AO Akinwole designed the experiment. Data collection, statistical analysis and writing of the manuscripts were carried out by Dr OO Fawole.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Ethical approval

In this article, the animal regulations followed as per the ethical committee guidelines of Department of Fisheries and Aquaculture, Faculty of Renewable Natural Resources, Ladoke Akintola University of Technology, Nigeria; the authors observed the briquette and charcoal as energy sources for smoking of African catfish (*Clarias gariepinus*). The Animal ethical guidelines are followed in the study for species observation, identification & experimentation.

Funding

The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES

1. Agyemang S, Opoku R. Turning sawdust into cooking fuel: An operational framework for a briquette plant at Sokoban wood village, Kumasi. J Ind Pollut Control 2018; 34:1888-1899.
2. Ajewole P, Oluwatobi OB, Oni IO. Development of a Dual Powered Fish Smoking Kiln. Int J Res Inno Appl Sci 2021; 6:90 -95.
3. Ajimotokan HA, Ehindero AO, Ajao KS, Adeleke AA, Ikubanni PP, Shuaib-Bababta YL. Combustion Characteristics of fuelbriquettes made from charcoal particles and sawdust agglomerate. Sci Afr 2019; 6:e00202. doi:_10.1016/j.sciaf.2019.e 00202
4. Akinbami JFK. Renewable energy resources and technologies in Nigeria: present situation, future prospects and policy framework. Mitig Adapt Strateg Glob Change 2001; 6:155-181.
5. Amposah SK, Asare H, Okyere H, Owusu-Asante JO, Minkah E, Ketemepi HK. Performance Characterization of a locally developed fish smoke-drying kiln for charcoal and briquette. J Agric Sci 2022; 14(11):43-53.
6. Asamoah B, Nikiema J, Gebrezgabher S, Oonkor E, Njenga M. A review on production, marketing and use of fuel briquette. Resource, recovery and reuse 2016; 7:51.
7. David F, Anne W. Biomass briquettes and pellet. Ashden Award on sustainable developed kiln. Int J Fish Aqua 2014; 3: 96-98.
8. Davies OA, Davies RM, Abolude DS. Organoleptic and Economic Appraisal of Fish Smoked with Water Hyacinth Briquettes and Traditional Energy Sources. FS J Res Basic App Sci 2012; 1(2):4-7. doi: 10.12983/ijsres-2013-p144-151

9. Erikkson SMP. The briquetting of Agricultural waste for fuel. FAO Environmental and Energy paper 11, 2006; 78-80.
10. FAO. Fishery and Aquaculture Country Profiles. The United Nations Food and Agricultural Organization, Fisheries and Aquaculture Department. Rome, 2016.
11. FAO. The State of World Fisheries and Aquaculture. Food and Agriculture Organization of the United Nations FAO, 2018.
12. Hulscher WS. Basic energy concepts. University of Twente, The Netherlands, 2016.
13. Ibrahim A, Olayimika SO, Oyero JO, Yisa TA, Ibrahim SU, Yakubu UP. A study of optimal utilization of wood resource through alternative use of wood waste in fish smoking. Int J Fish Aquat 2015; 7(8):127-131. doi: 10.5897/ijfa14.0466
14. Ikenweiwe B, Bolaji B. Fabrication and performance assessment of a locally developed fish smoking kiln. Ocean J Appl Sci 2010; 3(4):363-369.
15. INBAR. New bamboo Charcoal technologies promise to jump start African Bioenergy sector, slow deforestation and fight climatic change. INBAR newsletter e-Newsletter, 2011.
16. Issa WA, Abdulmumuni B, Okpara OB. Design and Fabrication of a Charcoal Fish Smoking Kiln. Int J Recent Technol Eng ISSN: 2277-3878, 2020; 9.
17. Jones B. Social and environmental impacts of charcoal production in Liberia. (Doctoral dissertation), University of Michigan, 2015.
18. Mondo B C, Akoll P, Masette M. Cost benefit analysis and efficacy of smoking technologies in removing moisture content of *Mormyrus caschive* and *Oreochromis niloticus* in Terekeka-South Sudan. Global J Fish Sci 2021; 3:51-59.
19. Mujumdar AS. Drying fundamentals. In: CGJ Baker (Ed.), Industrial drying of Foods. Blackie Academics and Professional, London, 1995; 112-149.
20. Musa NA. Fuel characteristics of some selected biomass briquettes. Int J Sci Tech Res 2006; 6:24-28.
21. Nasrin AB, Choo YM. Lim WS, Joseph L, Michael S, Rohaya MH, Astimar AA, Loh SK. Briquetting of empty fruit bunch, fibre and palm shell as a renewable energy fuel. J Eng Appl Sci 2011; 6:446-451.
22. Onuegbu TU, Ekpunobi UE, Ogbu IM, Ekeoma MO, Obumselu FO. Comparative studies of ignition time and water boiling test of coal and biomass briquettes blend. IJRRAS 2012; 7(2):153–159.
23. Sumberg J, Jatoe J, Kleih U, Flynn J. Ghana's evolving protein economy. Food Secur 2016; 8:909-920. doi: 10.1007/s12571-016-0606-6
24. Theobald A, Arcella D, Carere A, Croeraa C, Engelc KH, Gott D, Walker R. Safety assessment of smoke flavouring primary products by the European Food Safety Authority. Trends Food Sci Tech 2012; 27:97-108. doi: 10.1016/j.tifs.2012.06.002
25. Umar F, Oyero JO, Ibrahim SU, Maradun HF, Ahmad M. Sensory evaluation of African catfish (*Clarias gariepinus*) smoked with melon shell briquettes and firewood. Int J Fish Aquat Stud 2018; 6(3):281-286.