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RESEARCH ARTICLE OPEN ACCESS

# Assessment of the combustion properties and energy potential of *Ricinodendron heudelotii* (Pax Heckel) husks[☆]

Yves Yatindo Boko-Haya[1,2,*], Christine A.I.N. Ouinsavi[2], Jérémy Valette[3], Gilles Vaitilingom[3] and Clément Agbangla[1]

[1] Laboratoire de Génétique Moléculaire et d'Analyse des Génomes, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, 01BP 526, Cotonou, Bénin
[2] Laboratoire d'Etudes et de Recherches Forestières (LERF), Faculté d'Agronomie, Université de Parakou, BP 123 Parakou/Benin
[3] CIRAD, Unité de Research BioWooEB, 34000, Montpellier, France

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**Abstract** – The use of biomass, such as seed husks, for fuel production through pyrolysis is a key technology aimed at replacing fossil fuels with renewable energy sources, thereby contributing to a cleaner environment. This study assesses the energy potential and chemical composition of the husks of *Ricinodendron heudelotii*, highlighting their suitability for biofuel production. The proximate analysis of the kernel husks revealed ash, volatile matter, fixed carbon, and moisture contents of 18.80%, 59.80%, 21.40%, and 8.60%, respectively. The elemental analysis showed carbon, hydrogen, and nitrogen ratios of 47.0%, 4.52%, and 0.54%, respectively. Additionally, the lower heating value was determined to be 18.29 MJ/kg for the husks (dry basis). This composition, comparable to that of other energy crops cultivated globally for energy production, suggests that *R. heudelotii* could compete with standardized species used as raw materials for biofuels. This study opens up new possibilities for using *Ricinodendron heudelotii* husks as significant woody biomass fuel for domestic or industrial heating.

**Keywords:** Oleaginous seeds / biomass valorization / higher heating value / pyrolysis / renewable fuels

**Résumé – Évaluation des propriétés de combustion et du potentiel énergétique des coques de *Ricinodendron heudelotii* (Pax Heckel).** L'utilisation de biomasse, telle que les coques de graines, pour la production de carburant par pyrolyse, est une technologie clé visant à remplacer les combustibles fossiles par des énergies renouvelables, contribuant ainsi à un environnement plus propre. Cette étude évalue le potentiel énergétique et la composition chimique des coques de *Ricinodendron heudelotii*, mettant en évidence leur aptitude à la production de biocarburant. L'analyse immédiate des coques d'amandes a révélé des proportions de cendres, de matières volatiles, de carbone fixe et d'humidité de 18,8 %, 59,8 %, 21,4 % et 8,6 % respectivement. L'analyse élémentaire a fourni des ratios de carbone, d'hydrogène et d'azote de 47,0 %, 4,52 % et 0,54 % respectivement. En outre, la valeur calorifique inférieure a été déterminée à 18,29 MJ/kg pour les coques (base sèche). Cette composition, comparable à celle d'autres plantes énergétiques cultivées mondialement pour la production de biocombustible, suggère que *R. heudelotii* pourrait rivaliser avec des espèces standardisées utilisées comme matières premières pour les biocarburants. L'étude ouvre de nouvelles perspectives pour l'utilisation des coques de *Ricinodendron heudelotii* comme un combustible biomasse ligneux important pour le chauffage domestique ou industriel.

**Mots-clés :** Graines oléagineuses / valorisation de la biomasse / pouvoir calorifique supérieur / pyrolyse / carburants renouvelables

[☆] Contribution to the Topical Issue: "Non-Food Uses Of Oil- And Protein- Crops / Usages Non Alimentaires des Oléoprotéagineux".
*Corresponding author: tadagbemetin@gmail.com

**Highlights**

- The study evaluates the energy potential and chemical composition of *Ricinodendron heudelotii* husks for biofuel production.
- Proximate analysis reveals 18.8% ash, 59.8% volatile matter, and 21.4% fixed carbon, comparable to standard energy crops.
- The husks have a lower heating value of 18.29 MJ/kg, indicating their bioenergy potential.
- *R. heudelotii* husks could serve as a fossil fuel alternative, promoting cleaner energy.

## 1 Introduction

The Sustainable Development Goal (SDG) addressing the use of energy for cooking is SDG 7, specifically target 7.1, which aims to "ensure universal access to affordable, reliable, and modern energy services by 2030." This includes access to clean, safe, and sustainable cooking solutions, replacing traditional methods such as wood or charcoal use, which are often inefficient and polluting. The latest report from the International Energy Agency shows that among the 2.3 billion people worldwide who still lack access to clean cooking facilities, Asia and sub-Saharan Africa are the main areas of concern, with more than 1.2 billion and 990 million respectively in 2022. The rate of access to clean cooking facilities in sub-Saharan Africa is below 20%, with an increasing number of people without access to clean cooking (https://www.iea.org/reports/sdg7-data-and-projections/access-to-clean-cooking, consulted on May 18, 2024). The traditional use of wood and charcoal for cooking is responsible for indoor air pollution from cooking smoke, which causes approximately 3.7 million premature deaths per year. Furthermore, the use of wood and charcoal for cooking negatively impacts the environment through deforestation and climate change (Vihi *et al.*, 2022; Bockarie *et al.*, 2020).

The use of biogas, improved cookstoves, or less polluting cooking fuels are some recommended solutions (Negash *et al.*, 2021). Among the less polluting cooking fuels, pyrolyzed seed husks represent a viable and less polluting solution, particularly suited to rural populations (Azeta *et al.*, 2021). These fuels, produced from biological resources like plants, animal waste, and organic waste, are known as "biofuels."

The pyrolysis process of biological resources (biomass), such as wood, cereals, or seed husks, involves heating organic matter in the absence of oxygen to produce bio-oil, charcoal, and flammable gas (Yang *et al.*, 2014; Dhyani and Bhaskar, 2018; Husain *et al.*, 2020; Azeta *et al.*, 2021). This method has great potential for long-term waste management as it reduces the amount of unused plant products while reducing greenhouse gas emissions, contributing to addressing climate change concerns. Numerous studies on lignocellulosic biomass have demonstrated various conversion technologies that can transform lignocellulosic biomass into biofuels (Abdullah *et al.*, 2022; Ramesh *et al.*, 2021; Anwar *et al.*, 2014). The pyrolysis of raw biomass is considered a promising technology for producing renewable fuels and reducing greenhouse gas emissions (Aboelela *et al.*, 2023; Fan *et al.*, 2011).

Oleaginous seeds are an important source of renewable energy as they contain a large amount of oil that can be used directly as fuel in diesel engines (Torres-García *et al.*, 2020). In a context of increasingly accentuated climate change, the diversification of energy sources has become very urgent. According to the International Energy Agency's report (2022), diversifying energy sources in Africa is essential to reduce dependence on imported fossil fuels. Biofuels produced from oleaginous plants can play a key role in this transition by offering a renewable and local energy option, especially in rural areas where access to energy is limited.

Sub-Saharan Africa is characterized by the presence of numerous untapped oleaginous trees with the greatest potential for biofuels (Hounsou-Dindin *et al.*, 2022; Ambali *et al.*, 2011). The sustainable management of oleaginous plants in bioenergy can help reduce dependence on fossil fuels, combat climate change, and promote sustainable agriculture (Zhang *et al.*, 2018). However, potential biomass resources have not been studied, particularly the waste from oleaginous plants integrated into agro-systems and widely distributed geographically.

*Ricinodendron heudelotii*, a Euphorbiaceae forest tree, is widely distributed throughout West, Central, and East Africa (Tchoundjeu and Atangana, 2006; Leonard, 1961). *R. heudelotii* is an important species in agroforestry as it is often associated with economically valuable species such as cocoa (*Theobroma cacao* L.), oil palm (*Elaeis guineensis*), and coffee (*Coffea arabica* L.), as highlighted by the work of Franzel *et al.* (2007), Mollet *et al.* (1995) and Djeugap *et al.* (2013) in Cameroon and Nigeria. Many traditional uses and numerous anti-inflammatory and antioxidant activities have been recognized by various studies (Nguyen *et al.*, 2022; Kinge *et al.*, 2019; Yakubu *et al.*, 2019; Ene-Obong *et al.*, 2018; Boko-haya *et al.*, 2017). The fruit of this tree is a yellow-green indehiscent capsule, generally spherical, measuring 2 to 5 cm in length and 2.5 to 4 cm in width; it typically contains 1, 2, or 3 seed lobes and can weigh between 19 and 47 g (Ngo Mpeck *et al.*, 2003). The single seed is spherical, rough on the surface, weighs 2 g, is reddish-black in color, and contains a yellow kernel inside. The production and marketing of the kernels are growing, allowing local farmers to make profits (Ndumbe *et al.*, 2018; Cosyns *et al.*, 2011; Tabuna, 1999). Previous studies have highlighted a significant variation in kernel size with high levels of carbohydrates (6.11–8.83%), proteins (49.9–65.2%), and lipids (43.1–67%) [(Boko-haya *et al.*, 2022; Manga *et al.*, 2000; Yirankinyuki *et al.*, 2018; Coulibaly *et al.*, 2018)]. Several parts of the fruit, such as the mesocarp, the endocarp constituting more than 20% of the fresh fruit, and the seed husks are often considered waste. However, their valorization as a potential raw material for biofuel production could offer additional sources of income to fight poverty (Ejigu, 2008; Adeoye *et al.*, 2022).

The objective of this study was to evaluate the potential of *R. heudelotii* seed shells fuel energy sources by determining the energy content of the husks and comparing them with other

**Fig. 1.** Husks of ***Ricinodendron heudelotii***.

common fuels. The results will help clarify the viability of *R. heudelotii* husks as a renewable energy source.

## 2 Materials and methods

### 2.1 Description of the collection site

The seeds used originated from the southern phytogeographic zone of Benin (6°25'E to 7°30'N), characterized by a Guineo-Congolese climate with annual rainfall ranging from 900 to 1300 mm. This region includes the Plateau phytodistrict, which is dominated by semi-deciduous dense forests on hydromorphic soils, with annual rainfall between 1100 and 1300 mm (Adomou *et al.*, 2006).

### 2.2 Sampling

Mature fruits that had fallen to the ground were collected, and the seeds were extracted. In Akassato (6°30'25.207"N, 2°20'58.382"E), with an average temperature of 27 °C, these seeds were alternately dried in the shade and under sunlight. This process promoted the natural detachment of the kernels from the shell walls, facilitating the extraction of intact kernels after a light cracking of the extremely hard husks (Fig. 1).

### 2.3 Evaluation of fuel characteristics

The moisture content (MC) of the solid fuel was determined according to the standard NF EN ISO 18134-3. One gram of the sample was heated in an oven at 105 °C until a constant mass was obtained. The samples were then cooled in a desiccator and their mass was measured and compared to their initial mass before heating to determine the MC.

For ash content, 1 gram of the biomass sample ($M_{\text{biomass}}$) was calcined in a muffle furnace (NF EN ISO 18122) maintained at 550 °C until a constant mass was obtained. The samples were then cooled in a desiccator and their mass was measured ($M_{\text{Ash}}$). The ash content was calculated on a dry mass basis according to equation (1).

$$\text{Ash}(\%) = \left[100 \times \frac{\text{MAsh}}{\text{Mbiomass}}\right] \times \frac{100}{100 - \text{MC}}. \quad (1)$$

For volatile matter, it was calculated according to the standard NF EN ISO 18123. Approximately 1 g of the biomass sample ($M_{\text{biomass}}$) was heated in a muffle furnace for 7 min at 900 °C without oxygen. The samples were then cooled in a desiccator and their mass was measured ($M_{\text{residue}}$). The volatile matter was calculated on a dry mass basis according to equation (2).

$$\text{MV}(\%) = \left[100 \times \frac{\text{Mbiomass} - \text{Mresidue}}{\text{Mbiomass}} - \text{MC}\right] \times \frac{100}{100 - \text{MC}}. \quad (2)$$

The fixed carbon is the remaining carbon after the removal of volatile matter and ash. The fixed carbon content (CF) is deduced by difference on a dry basis and is given by the formula: $CF(\%) = 100 - (MV\ (\%) + \text{Ash content}\ (\%))$

Elemental analyses were performed using an Elementar Vario Macro Cube CHN analyzer according to the standard EN ISO 16948 for raw biomass (and adapted for vegetable oil) of *R. heudelotii*. Before analysis, samples were wrapped in tin foil and three tests were performed for the sample. The carbon, hydrogen, and nitrogen contents were determined respectively from the quantification of $CO_2$, $H_2O$, and $N_2$ (after reduction of $NO_x$) produced by the combustion of the samples. All results from triple repetition (MC and ash) and double repetition (MV, C, H, and N) are reported with a precision of 0.20%.

**Table 1.** Proximate, ultimate, and calorific values of raw husks of *R. heudelotii* compared to other species considered as standard solid fuels.

| Parameters | *R. heudelotii* | [1]Sunflower | [2]Peanut | [3]Argan | [4]Palm | [5]Coconut |
|---|---|---|---|---|---|---|
| % Fixed Carbon (db) | 21.40 ± 1.12 | 16.10 | 13.40 | 28 | 26.14 ± 0.15 | 12.04 ± 0.04 |
| % Humidity (db) | 8.60 ± 0.15 | 9.61 | 9.72 | 9.50 | 8.92 ± 0.17 | 7.82 ± 0.02 |
| % Volatile matter (db) | 59.80 ± 0.46 | 82.70 | 80.24 | 61 | 72.02 ± 0.21 | 79.91 ± 0.05 |
| % Ash (db) | 18.80 ± 0.69 | 1.20 | 3.25* | 1.50 | 1.35 ± 0.53 | 0.23 ± 0.003 |
| % Carbon (db) | 47.0 ± 1.98 | 46.21 | 46.42 | 51.33 | 53.29 ± 0.09 | 39.22 ± 0.71 |
| % Hydrogen (db) | 4.52 ± 0.15 | 6.06 | 6.84 | 6.32 | 6.15 ± 0.11 | 4.46 ± 0.08 |
| % Nitrogen (db) | 0.54 ± 0 | 0.88 | 1.03 | 0.005 | 0.30 ± 0.01 | 0.22 ± 0.02 |
| HHV (MJ/kg) | 19.25 ± 0.08 | 18.11 | 18.54* | 18.3 | 18.72 | 9.62 ± 0.50 |
| LHV (MJ/kg) | 18.29 ± 0.11 | – | 17.11* | 17 | 17.27** | – |

Note: results of *R. heudelotii* are given as the mean ± standard error of three analyses. [1](Turzyński *et al.*, 2021); [2](*Perea-Moreno *et al.*, 2018; Varma *et al.*, 2022); [3](Rahib *et al.*, 2021); [4](Shrivastava *et al.*, 2021); **(Pawlak-Kruczek *et al.*, 2020); [5](Sarkar and Wang, 2020); db = dry basis.

### 2.4 Calorific values

The calorific value was determined according to EN ISO 18125 standard, using an Isoperibol Fixed Bomb Parr 6200 automatic bomb calorimeter, under an O2 atmosphere to ensure complete combustion of the sample. The calorimetric equivalent ($E_{\mathrm{cal}}$) was determined before starting the experiments using benzoic acid. Approximately 0.5 g of biomass mass was required to perform the calorific tests. Three repetitions were analyzed for the biomass material. The higher heating value (HHV) is defined as the amount of heat released per unit mass of fuel (initially at 25 °C) when burned and brought back to a temperature of 25 °C (Basu, 2013). The calorimeter automatically calculates the highest calorific value of the received sample HHV, taking into account the correction of the fuse combustion according to equation (3).

$$\mathrm{PCS}\left(\mathrm{MJKg}^{-1}\right)=\frac{\mathrm{K1}\ \times\ \mathrm{Ecal}(\mathrm{Tm}-\mathrm{ti})-\mathrm{K1}\ \times\ \mathrm{L}\ \times\ \mathrm{Ept}}{\mathrm{M}}. \tag{3}$$

where $K_1$ is a conversion factor ($4.18 \times 10^{-6}$ MJ cal$^{-1}$); $E_{\mathrm{cal}}$ is the calorimetric equivalent of the calorimeter device in Cal.°C$^{-1}$; $T_m$ and $T_i$ are the maximum and initial temperatures in °C; $L$ is the length of the burned fuse in cm; $E_{pt}$ is the higher heating value of the constant volume fuse wire in cal cm$^{-1}$ (= 2.3 cal cm$^{-1}$); and $M$ is the mass of the sample in kg. The higher heating value on a dry basis (HHV db) and the corresponding lower heating values at constant pressure for a dry sample (LHV db) were calculated in accordance with the CEN/TS 14918 standard (Biofuels, 2005) using equations (4) and (5).

$$\mathrm{HHV_{db}}\left(\mathrm{MJkg}^{-1}\right)=\mathrm{HHV}\ \times\ \frac{100}{100-\mathrm{MC}}. \tag{4}$$

$$\mathrm{LHV_{db}}=\mathrm{HHV_{db}}-(212.2\ \times\ \mathrm{X}). \tag{5}$$

with $X$: Hydrogen content of the sample in % dry basis. Calorific analyses were duplicated for each sampling modality, and all results are given with a precision of ±1%.

## 3 Results and discussion

Proximate, ultimate, and calorific value analyses of the raw husks of *Ricinodendron heudelotii* is reported for the first time in this study. Table 1 presents the results of proximate, ultimate, and calorific value analyses of the raw husks of *Ricinodendron heudelotii*, compared to other species whose shell characteristics are considered standard solid fuels. The concentration of essential chemical elements for evaluating the energy potential of the raw husks of *R. heudelotii* indicates that the average ash content is 18.80 ± 0.69%, which is higher than other standardized biomasses such as peanut husks, argan husks, palm husks, and sunflower husks, which have ash contents of 3.25%, 1.50%, 1.35%, and 1.20%, respectively. However, despite this high value, it is similar to the current ash content (18.30%) of rice husks used in boilers (Kaniapan *et al.*, 2021; Nazar *et al.*, 2021).

The moisture content of *R. heudelotii* seed husks is 8.60 ± 0.15%, which is lower than all other referenced species except for coconut husks, which have a moisture content of 7.82%. Moisture content influences the lower calorific value, combustion efficiency, and mechanical durability of solid biofuels (Shojaeiarani *et al.*, 2019). Low moisture content in biofuels increases their energy efficiency as less energy is required to evaporate the water from the fuel before it can be burned. Additionally, the observed moisture content remains low compared to the limit value (usually below 10%) required for the optimal operation of boilers. The average volatile matter content of *R. heudelotii* husks is 59.80± 0.46%, lower than that of sunflower husks (82.70%) (Turzyński *et al.*, 2021) and peanut husks (80.24%) (Perea-Moreno *et al.*, 2018). Generally, biofuels with low volatile matter tend to burn more efficiently and produce fewer emissions.

On average, the fixed carbon content of *R. heudelotii* husks is 21.40 ± 1.12%, which is lower than that of palm and argan husks (26.14% and 28%, respectively), but higher than that of peanut and sunflower husks (13.40% and 16.10%, respectively) already used as energy sources. The proximate analysis of *R. heudelotii* husks compared to various plants already utilized shows great potential for energy production or biochar.

The elemental chemical analysis of the raw husks of *Ricinodendron heudelotii* revealed a higher concentration of carbon (47.0%) and a lower nitrogen content (0.54%) on a dry basis. These results are consistent with those of referenced species considered standard solid fuels, where the carbon content of raw biomass ranged from 39.22% (coconut husks) to 53.29% (oil palm husks) and the nitrogen content ranged from 0.005% (argan husks) to 1.03% (peanut husks).

These findings confirm that raw biomasses are predominantly composed of the element carbon (Biaye, 2022). The high carbon content suggests a high energy density. Indeed, there is a linear relationship between the carbon content (C) and the higher heating value (Demirbas et Demirbas, 2004; Sedai *et al.*, 2016).

The higher heating values (HHV) of 19.25 MJ/kg and lower heating values (LHV) of 18.29 MJ/kg obtained for *R. heudelotii* husks are among the highest when compared to standardized species. These values are notably similar to those reported for peanut husks (18.54 MJ/kg and 17.11 MJ/kg, respectively) according to a previous study (Perea-Moreno *et al.*, 2018). Furthermore, they are comparable to those measured for the trunk of *Acacia holosericea* (18.13 MJ/kg), recognized as a decent biomass for biofuel production (Reza *et al.*, 2019). These findings highlight the substantial energy potential of *R. heudelotii* husks in comparison to the husks of other standardized species used as reference solid fuels. These energy-rich husks can be used as fuel in household stoves. This high energy potential is likely due to the elevated fixed carbon content (21.40%).

## 4 Conclusion

This study highlights the potential of *Ricinodendron heudelotii* (Pax Heckel) husks as a biofuel source. The elemental and proximate compositions, along with the calorific values, are comparable to those of established biofuel species. *R. heudelotii* husks demonstrate suitability for use in household or improved cookstoves, offering a sustainable alternative that could help reduce deforestation and air pollution from smoke. However, further research is necessary to evaluate the socio-economic and environmental implications of adopting *R. heudelotii* husks as a fuel source. Establishing a framework for integrating such renewable resources into the country's energy strategies is essential to support future sustainable development initiatives.

### Conflicts of interest

The authors declare no conflicts of interest in regards to this article.

### Author contribution statement

Conceptualization: B.Y., G.V., O.C,; Supervision : OC, AG, GV.; Validation : G.V., O.C., Survey, Original draft preparation : B.Y., Writing, Mehods and analysis : J.V., G.V., Review & Editing : G.V., O.C.; J.V. Resources : G.V.

### References


Abdullah I, Ahmad N, Hussain M, Ahmed A, Ahmed U, Park Y-K. 2022. Conversion of biomass blends (walnut shell and pearl millet) for the production of solid biofuel via torrefaction under different conditions. *Chemosphere* **295**: 133894.

Aboelela D, Saleh H, Attia AM, Elhenawy Y, Majozi T, Bassyouni M. 2023. Recent advances in biomass pyrolysis processes for bioenergy production: optimization of operating conditions. *Sustainability* **15**: 11238.

Adeoye AO, Quadri RO, Lawal OS. 2022. Assessment of biofuel potential of tenera palm kernel shell via fixed bed pyrolysis and thermal characterization. *Res Surf Interfaces* **9**: 100091.

Adomou AC, Sinsin B, Van der Maesen LJG. 2006. Phytosociological and chorological approaches to phytogeography: a meso-scale study in Benin. *System Geogr Plants* **76**: 155–178.

Agence internationale de l'énergie (AIE). 2022. *Africa Energy Outlook 2022*.

Ambali A, Chirwa PW, Chamdimba O, Van Zyl WH. 2011. *Review of sustainable development of bioenergy in Africa: an outlook for the future bioenergy industry.*

Anwar Z, Gulfraz M, Irshad M. 2014. Agro-industrial lignocellulosic biomass a key to unlock the future bio-energy: a brief review. *J Radiat Res Appl Sci* **7**: 163–173.

Azeta O, Ayeni AO, Agboola O, Elehinafe FB. 2021. A review on the sustainable energy generation from the pyrolysis of coconut biomass. *Sci Afr* **13**: e00909.

Basu P. 2013. Gasification theory. *Biomass gasification, pyrolysis and torrefaction*: 199–248.

Biaye T. 2022. *Mesures en laboratoire des émissions et des performances des foyers de cuisson utilisant des briquettes de charbon de biomasse*.

Biofuels S. 2005. Method for the Determination of Calorific Value. *CEN/TS* **14918**: 2005.

Bockarie AS, Marais EA, MacKenzie AR. 2020. Air pollution and climate forcing of the charcoal industry in Africa. *Environ Sci Technol* **54**: 13429–13438.

Boko-haya YY, Ouinsavi AIN, Houngbeme GA, Gbaguidi F, Agbangla C. 2017. Traditional uses, phytochemistry and in vitro evaluation of toxicity of Ricinodendron heudelotii (Baill Pierre Ex Heckel) leaves in Benin. *Int J Rec Sci Res* **8**: 21227–21236.

Boko-haya YY, Ouinsavi CAIN, Akin YY, Agbangla C. 2022. Influence of geographic provenance on phenotypic variation in seed and kernel traits of the African oil tree from southern Benin and implications for species breeding. *Nova Geodesia* **2**: 76–76.

Cosyns H, Degrande, A., De Wulf, R., Van Damme, P., Tchoundjeu, Z. 2011. Ricinodendron heudelotii kernel group commercialization and its impact on farmers' livelihoods in Cameroon. *J Agric Rural Dev Trop Subtrop* **112**: 45–56.

Coulibaly M, N'dri DY, Abouo V, Kouamé CA, Kouassi NK, Amani GN. 2018. The impact of post −harvest traditional technologies on nutritional value and antioxidant activity of seeds Kernels "akpi" of Côte d'Ivoire (West Africa). *Int J Food Sci Nutr Eng* **8**: 15–26.

Demirbas A, Demirbas AH. 2004. Estimating the calorific values of lignocellulosic fuels. *Energy Explor Exploit* **22**: 135–143.

Dhyani V, Bhaskar T. 2018. A comprehensive review on the pyrolysis of lignocellulosic biomass. *Renew Energy* **129**: 695–716.

Djeugap FJ, Bernier L, Dostaler D, Khasa D, Fontem DA, Nwaga D. 2013. Opportunités et contraintes agroforestières de Ricinodendron heudelotii au Cameroun. *Int J Biolog Chem Sci* **7**: 344–355.

Ejigu M. 2008. Toward energy and livelihoods security in Africa: smallholder production and processing of bioenergy as a strategy. *Nat Resour Forum* **32**: 152–162.

Ene-Obong H, Onuoha N, Aburime L, Mbah O. 2018. Chemical composition and antioxidant activities of some indigenous spices consumed in Nigeria. *Food Chem* **238**: 58–64.

Fan J, Kalnes TN, Alward M, Klinger J, Sadehvandi A, Shonnard DR. 2011. Life cycle assessment of electricity generation using fast pyrolysis bio-oil. *Renew Energy* **36**: 632–641.

FAO. 1968. *Food composition table for Use in Africa*. Retrieved December 8, 2022, from https://www.fao.org/3/x6877e/x6877e00.htm.

Franzel S, Akinnifesi FK, Ham C. 2007. Setting priorities among indigenous fruit tree species in africa: examples from Southern, Eastern and Western Africa regions. *Indigenous Fruit Trees Trop: Domest Utilliz Commercial* 1–69.

Hounsou-Dindin G, Idohou R, Akakpo ADM, Adome N, Adomou AC, Assogbadjo AE, Glèlè Kakaï R. 2022. Assessment of wild oil plants diversity and prioritization for valorization in Benin (West Africa): a multivariate approach. *Trees Forests People* **7**: 100210.

Husain Z, Ansari KB, Chatake VS, Urunkar Y, Pandit AB, Joshi JB. 2020. Valorisation of biomass pellets to renewable fuel and chemicals using pyrolysis: characterisation of pyrolysis products and its application. *Indian Chem Eng* **62**: 78–91.

ICRAF. 1999. *Ricinodendron heudelotii*.

Kaniapan S, Suhaimi H, Hamdan Y, Pasupuleti J. 2021. Experiment analysis on the characteristic of empty fruit bunch, palm kernel shell, coconut shell, and rice husk for biomass boiler fuel. *J Mech Eng Sci* **15**: 8300–8309.

Kinge EE, Djikeng FT, Karuna MSL, Ngoufack FZ, Womeni HM. 2019. Effect of boiling and roasting on the physicochemical properties of Djansang seeds (*Ricinodendron heudelotii*). *Food Sci Nutr* **7**: 3425.

Leonard J. 1961. Notulae systematicae XXXII: Observations sur des especes africaines de Clutia, Ricinodendron et Sapium (Euphorbiacees). *Bulletin du Jardin botanique de l'État a Bruxelles* **31**: undefined-undefined.

Manga TT, Fondoun JM, Kengue J, Thiengang C. 2000. Chemical composition of *Ricinodendron heudelotii*: an indigenous fruit tree in southern Cameroon. *Afr Crop Sci J* **8**: 195–201.

Mollet M, Tiki-Manga T, Kengue, J, Tchoundjeu Z. 1995. The "top 10" species in Cameroon: a survey of farmers' views on trees. Agroforestry Today 7(3–4): 14–16.

Momeni J, Djialeu Ntchatchoua WP, Fadimatou MT, Akam MT, Ngassoum MB. 2010. Antioxidant activities of some cameroonian plants extracts used in the treatment of intestinal and infectious diseases. *Indian J Pharm Sci* **72**: 140–144.

Nazar M, Yasar A, Raza SA, Ahmad A, Rasheed R, Shahbaz M, Tabinda AB. 2021. Techno-economic and environmental assessment of rice husk in comparison to coal and furnace oil as a boiler fuel. *Biomass Convers Biorefinery*. https://doi.org/10.1007/s13399-020-01238-3

Ndumbe LN, Ingram V, Tchamba M, Nya S. 2018. From trees to money: the contribution of njansang (*Ricinodendron heudelotii*) products to value chain stakeholders' financial assets in the South West Region of Cameroon. *Forests Trees Livelihoods*. https://doi.org/10.1080/14728028.2018.1559107

Negash D, Abegaz A, Smith JU. 2021. Environmental and financial benefits of improved cookstove technologies in the central highlands of Ethiopia. *Biomass Bioenergy* **150**: 106089.

Ngo Mpeck ML, Asaah E, Tchoundjeu Z, Atangana AR. 2003. Strategies for the domestication of *Ricinodendron heudelotii*: evaluation of variability in natural populations from Cameroon. *Food Agric Environ* **1**: 257–262.

Nguyen ATL, Akanbi TO, Tawiah NA, Aryee ANA. 2022. Valorization of seed and kernel marcs and evaluation of their antioxidant potential. *Food Chem* **390**: 133168.

Pawlak-Kruczek H, Arora A, Mos cicki K, Krochmalny K, Sharma S, Niedzwiecki L. 2020. A transition of a domestic boiler from coal to biomass – emissions from combustion of raw and torrefied Palm Kernel shells (PKS). *Fuel* **263**: 116718.

Perea-Moreno M-A., Manzano-Agugliaro F, Hernandez-Escobedo Q, Perea-Moreno A-J. 2018. Peanut shell for energy: properties and its potential to respect the environment. *Sustainability* **10**: 3254.

Rahib Y, Boushaki T, Sarh B, Chaoufi J. 2021. Combustion and pollutant emission characteristics of argan nut shell (ANS) biomass. *Fuel Process Technol* **213**: 106665.

Ramesh M, Adithya K, Kumar CMJ, Mohan CG, Nalawade J, Prakash R. 2021. 9 – Thermochemical conversion methods of bio-derived lignocellulosic waste molecules into renewable fuels. In Khan A, Jawaid M, Pizzi A, Azum N, Asiri A, Isa I (eds.) Advanced Technology for the Conversion of Waste into Fuels and Chemicals. Woodhead Publishing, 197–215.

Reza MS, Ahmed A, Caesarendra W, Abu Bakar MS, Shams S, Saidur R, Aslfattahi N, Azad AK. 2019. Acacia Holosericea: an invasive species for bio-char, bio-oil, and biogas production. *Bioengineering* **6**: 33.

Sarkar JK, Wang Q. 2020. Different pyrolysis process conditions of south Asian waste coconut shell and characterization of gas, bio-char, and bio-oil. *Energies* **13**: 1970.

Sedai P, Kalita D, Deka D. 2016. Assessment of the fuel wood of India: A case study based on fuel characteristics of some indigenous species of Arunachal Pradesh. *Energy Sources, Part A* **38**: 891–897.

Sharapov N. 1959. Maslichnye rasteniya i masloobrazovatel'nyi protsess (Oil Plants and Oil Production Process), Moscow-Leningrad: Akad. *Nauk SSSR*.

Shojaeiarani J, Bajwa DS, Bajwa SG. 2019. Properties of densified solid biofuels in relation to chemical composition, moisture content, and bulk density of the biomass. *BioResources* **14**: 4996–5015.

Shrivastava P, Khongphakdi P, Palamanit A, Kumar A, Tekasakul P. 2021. Investigation of physicochemical properties of oil palm biomass for evaluating potential of biofuels production via pyrolysis processes. *Biomass Convers Biorefinery* **11**: 1987–2001.

Tabuna H. 1999. Le marché des produits forestiers non ligneux de l'Afrique centrale en France et en Belgique. *Occasional paper*, (19).

Tchoundjeu Z, Atangana AR. 2006. *Ricinodendron heudelotii. Southampton Centre for Underutilised Crops, University of Southampton, Southampton, UK*.

Torres-García M, García-Martín JF, Jiménez-Espadafor Aguilar FJ, Barbin DF, Álvarez-Mateos P. 2020. Vegetable oils as renewable fuels for power plants based on low and medium speed diesel engines. *J Energy Inst* **93**: 953–961.

Turzyński T, Kluska J, Ochnio M, Kardas D. 2021. Comparative analysis of pelletized and unpelletized sunflower husks combustion process in a batch-type reactor. *Materials* **14**: 2484.

Varma AK, Singh S, Rathore AK, Thakur LS, Shankar R, Mondal P. 2022. Investigation of kinetic and thermodynamic parameters for pyrolysis of peanut shell using thermogravimetric analysis. *Biomass Convers Biorefinery* **12**: 4877–4888.

Vihi S, Onaivi MY, Malel MF, Akunna CE, Godfrey O, Selzing PM, Blessing O. 2022. Analysis of household fuelwood consumption as cooking energy and the implications on the environment: a case of Vandeikya Local Government Area of Benue State, Nigeria. *UMYU Scientifica* **1**: 241–253.

Yakubu O, Adebayo AH, Dokunmu TM, Zhang Y-J., Iweala EEJ. 2019. Cytotoxic effects of compounds isolated from *Ricinodendron heudelotii*. *Molecules* **24**: 145.

Yang Y, Brammer JG, Mahmood ASN, Hornung A. 2014. Intermediate pyrolysis of biomass energy pellets for producing sustainable liquid, gaseous and solid fuels. *Bioresour Technol* **169**: 794–799.

Yirankinyuki FF, Lamayi DW, Muhammad UA, Musa B. 2018. Assessing the suitability of *Ricinodendron heudelotii* seed oil for paint formulation. *IOSR J Appl Chem* **11**: 37–42.

Zhang J, Cong R-G., Hasler B. 2018. Sustainable management of Oleaginous trees as a source for renewable energy supply and climate change mitigation: a case study in China. *Energies* **11**: 1123

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