



## COMPARATIVE EFFECTS OF WOOD SPECIES, BINDER TYPE, AND BINDER RATIO ON THE PHYSICAL AND COMBUSTION PERFORMANCE OF CHARCOAL BRIQUETTES

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### ABSTRACT

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This study was conducted to investigate the feasibility of using wood of (*Dalbergia sissoo*, *Albizia lebbeck*, *Callistemon viminalis*, *Populus nigra*, *Eucalyptus microtheca*, *Eucllyptus camaldulensis*, *Paulownia tomentosa*, *Pinus brutia*, *Thuja Orientalis*, *Fagus orientalis*, *Populus euphratica* and *Platanus oreinatlis*) in the production of compressed charcoal. two types of locally produced materials were used as binding materials (potato starch and wheat flour) with mixing ratios of (10:90) and (20:80) to the charcoal particles. Compressed density g/cm<sup>3</sup>, horizontal expansion ratio %, durability, mass loss ratio %, Moisture content %, ash%, Volatile matter % and calorific value Cal./g. as a physical and combustion properties were studied. Density values varied for the studied charcoal briquettes type between (0.969 – 1.090)g/cm<sup>3</sup>, The highest value for horizontal expansion of molds was recorded in types manufactured from wood *Fagus orientalis* As it reached 2.772%, Most briquettes type showed good durability and a low loss rate ranging between (1.31 – 1.94)%, Moisture content and ash content values ranged between (5.32-8.22)% and (4.5-7.1)% respectively, The values of volatile matters were within the ranges specified in the standard specifications, except for two types. (*Pinus brutia* and *Thuja Orientalis*) Which amounted to (28.42 and 31.85) % respectively, the highest calorific value was obtained when using wood from both *Dalbergia sissoo* and *Eucllyptus camaldulensis* as it reached to (7075 and 7065) cal./g. Potato starch showed potential for improving the properties of the produced compressed charcoal compared to wheat flour. Increasing the binder ratio from 10% to 20% improved all the studied properties.

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## INTRODUCTION

Concerns about fossil fuels are growing daily as energy demand increases due to a growing global population and rising prices, in addition to their negative impacts, such as high carbon dioxide emissions and their detrimental effect on global warming (Nattapong *et al.*, 2019). Burning biofuels produces pollutants that contribute to more than 1.6 million deaths annually worldwide, including 400,000 in Africa (Njenga *et al.*, 2013). The United Nations Environment Programme (UNEP) reported in 2000 that this problem has worsened over the years in developing countries, where 1.8 million people in rural and urban centers lack access to commercial energy (Onchieku *et al.*, 2012) Poor families resort to unhealthy cooking fuels due to their high cost (Njenga *et al.*, 2013). UNEP reports 2025 emphasize that a rapid transition to

renewable energy is essential to limit global warming, as the energy sector drives 34% of greenhouse gas emissions (UNEP, 2025). Renewable energy alternatives are attracting the attention of many developing countries. Various policies and tools are being implemented to encourage and support research into suitable alternative energy sources, such as biomass, solar, wind, and hydroelectric power (Thanapan *et al.*, 2016).

There are numerous renewable alternative energy sources, including organic waste and biomass. Biomass is a significant energy source capable of meeting future energy demands by utilizing its byproducts in the production of solid fuels. Biomass can be processed and used as an alternative fuel, such as in the form of briquettes, it made from soft and hard materials. They are a solid fuel containing carbon, have a high calorific value, and can burn for extended periods. Briquettes can replace firewood, the consumption of which is on the rise (Mega *et al.*, 2023). Biofuel briquettes are compressed, combustible materials made from biomass, used as fuel for heating or cooking in industry and homes. These briquettes can offer a solution to global and local efforts to find new, renewable, clean, sustainable, and environmentally friendly energy sources. They differ from fossil fuels in that their raw materials are readily available in nature, their cost is low, they are lightweight, and they are easily accessible, in addition to their economic value. Their calorific value is their most important characteristic (Suryaningsih *et al.*, 2012 and Hardiansyah *et al.*, 2023). The quality of these molds depends on the type of material used, the type of adhesive, and the mold compression force. Mold compression, in turn, affects their mechanical properties, such as density, stability, and durability. The carbonization process used also influences the properties of molds made from biochar (Nattapong *et al.*, 2019 and Makgobebele *et al.*, 2021). One of the challenges in using biomass is that it is often loose and has a low energy density. Biomass pelletizing, a technique to increase its density, is one method used to improve its energy efficiency in applications, particularly home heating and power generation. The pelletizing process involves compressing the biomass, with or without a binding agent, under relatively high temperature and pressure to achieve higher energy per unit volume (Aransiola *et al.*, 2019).

Bonding materials play a crucial role in improving the mechanical and thermal properties of pressed molds; therefore, selecting the right bonding material is critical to improving the production process and achieving the desired results (Meena *et al.*, 2024). The authors have suggested using ( paper production waste -sulfate soap, pine needles, animal fat, molasses, bentonite powder, coffee beans, corn, animal manure Sodium humate, red clay, Polyvinyl alcohol, Cassava starch, corn starch, Tapioca flour, gum arabic and gelatin) were considered as binders in different ratios ranging from (1-20)% to enhance binding properties for briquette formation (Makgobebele *et al.*, 2021; Myroslav *et al.*, 2023; Jemseng *et al.*, 2024 and Sotannde *et al.*, 2010) . Starch-based binders are commonly used because of their availability, low cost, biodegradability, and ability to improve briquettes strength and thermal performance (Pamungkas *et al.*, 2025).

In Iraq, wood and charcoal remain a continuous source of energy in urban and rural areas, with a large portion of the wood consumed, estimated at about 11,811m<sup>3</sup> annually, being used in charcoal production. This wood typically comes from

*Populus spp.* & *Salix spp.* trees growing on the banks of the Tigris and Euphrates rivers, as well as *Eucalyptus spp.*, Oak, and other types of trees (Ahmed,2018). With the aim of improving the properties of renewable bioenergy sources, this study was conducted to demonstrate the feasibility of manufacturing compressed charcoal from 12 wood type charcoal, with using potato starch and wheat flour as binders for the briquette components with mixing ratio (10 and 20) %.

## MATERIALS AND METHODS

Wood samples were taken from the branches of three living trees of each of the following species: *Populus euphratica*, *Populus nigra*, *Platanus oreinatlis*, *Dalbergia sissoo*, *Paulownia tomentosa*, *Eucalyptus microtheca* & *Euclyptus camaldulensis* trees growing in the Shanagha Forest, in addition to *Pinus brutia*, *Albizia lebbek*, *Callistemon viminalis*, *Thuja Orientalis* and *Fagus orientalis* trees growing in Kirkuk city north of Iraq (Figure 1). The specimens ranged in diameter from (3-5) cm and 20cm in length. They were taken from the lower branches and from various directions on the tree, ensuring they were free from insect infestations and diseases. bark was removed from the cut branches and left to cure for 14 days at laboratory temperature.



Figure (1). The study sample collection area is in Kirkuk Governorate

### Charcoal preparation

The method described in reference (Ahmed,2018) was followed to prepare the experimental samples. The samples were placed inside a thermally insulated oven and gas-heated to 400°C for 5 hours, then left to cool inside the oven for 24 hours in the absence of air (Figure 2). After that, the samples were removed and transferred to a mill for grinding. The samples were then passed through a 4 mesh sieve to settle onto a 20 mesh sieve. The samples were then stored until use.

### Briquettes charcoal

To bind the components of briquettes prepared from 12 types of wood, potato starch and wheat flour were used as binders, added to the charcoal particle with mixing (10:90 and 20:80). 150 ml of distilled water was added to the binder and allowed to dissolve completely without any lumps. The binder solution was then heated in a water bath at 100°C for 10 minutes, stirring continuously to ensure complete homogeneity, and then manually mixed with the charcoal particles.



Figure (2): Stages of charcoal production from tree branches

Equal amounts of the charcoal mixture and the binder were placed in the molds and then compressed to a pressure of 2 MPa. After molding and depressurization, the molds were dried at room temperature for 20 days. The experiment was conducted using a multi-factor random design. The factors included: type of tree wood (12 types), type of binding material (2 types) and mixing ratio (2 levels) to be 48 experimental unit with replication 15 for each experimental unit (figure 3).



Figure (3). Samples of briquettes charcoal manufactured in this study

### Physical properties

Physical properties evaluated were compressed density, horizontal expansion, durability, and mass loss, following (Borowski *et al.*, 2017). Three samples of compressed charcoal briquettes were randomly selected from the fifteen replicates manufactured for each treatment for testing. For density  $\text{g/cm}^3$  determination, briquettes samples were weighed after drying in an oven at  $100 \pm 2^\circ\text{C}$  for 48 h. and their volume was determined by the distilled water displacement method. Density was determined using Equation (1). To determine the horizontal expansion ratio, the diameter of briquette disc (cm) was measured from two axes immediately after removal from the manufacturing mold, and the readings were repeated after a 20 day drying period. The ratio was found using Equation (2).

$$\text{Compressed Density (g/cm}^3\text{)} = W / V \dots\dots\dots (1)$$

$$\text{Horizontal expansion ratio \%} = (D1-D2 / D1) * 100 \dots\dots\dots (2)$$

Where W: Oven dry weight (g), V: Volume (cm<sup>3</sup>), D1: Diameter rate after briquettes manufacture, D2: Diameter rate after 20 days of manufacturing.

The durability of the compressed charcoal briquettes was determined by dropping experimental replicates of each treatment from a height of 1.5 meters onto a metal base. The integrity and shape of the briquettes were used as indicators of their durability.

Mass loss% was measured according to the methods described in reference (Olufemi et al., 2010). Each briquette was weighed on a precision scale and then placed on a vibrating screen equipped with a 4.75 mm sieve for one minute and a base for collecting the resulting sediment. The samples were reweighed after the vibration period, and the test was repeated sequentially for all formed fuel pieces. The percentage was calculated using equation (3).

$$\text{Mass Loss (\%)} = (W1 - W2 / W1) * 100 \dots\dots\dots (3)$$

Where W1: Sample weight before shaking, W2: Sample weight after shaking.

### **Combustion characteristics**

The combustion characteristics were determined using equations (Olufemi et al., 2010; Ahmed, 2018 and Jemseng et al., 2024), including the percentage of Moisture content, ash content, volatile matter and calorific value.

Moisture content %: briquettes samples were weighed after 20 days of manufacturing. They were then placed in an electric oven at  $100 \pm 2^\circ\text{C}$  for 48 hours. After removal, the samples were removed and put in a desiccator, allowed to cool to room temperature and reweighed, the sample's moisture content was determined using equation: (4)

$$\text{Moisture Content M.C. \%} = (WM1 - WM2 / WM1) * 100 \dots\dots\dots (4)$$

Where WM1 : oven dry weight of briquette, WM2 : weight of briquette after 20 days of manufacture.

Volatile matter% : briquettes samples were weighed, then placed in an oven and heated at  $600^\circ\text{C}$  for 10 minutes. then weighed again, and the percentage of volatile matter was expressed as the percentage of mass loss compared to the mass of the dried sample.

$$\text{Volatile matter \%} = (WV1 - WV2 / WV1) * 100 \dots\dots\dots (5)$$

Where WV1 : weight of briquette after 10m. of heating, WV2 : oven dry weight of briquette.

Ash content%: The dry briquettes samples were weighed and placed inside a weighing vessel (crucible), placed on to a muffle furnace at  $600^\circ\text{C}$  for 2h., the samples were removed and put in a desiccator, allowed to cool to room temperature and reweighed, ash content% was calculated using the following equation:

$$\text{Ash content \%} = (WA1 - WA2 / WA1) * 100 \dots\dots\dots (6)$$

Were WA1 : oven dry weight of briquette samples, WA2 : samples weight after 2h. of burning.

Calorific value cal./g. : by using a calorimeter, 1 g. of charcoal briquette was placed in a sealed, watertight aluminium container, and the sample was burned until it glowed. The sample was burned until it glowed and then placed inside a calorimeter. Distilled water was added to the calorimeter container, and its temperature was measured. The calorimeter was then sealed (avoiding excessive pressure) and left for ten minutes to allow the temperature to stabilize. The

temperature reading was then recorded. The calorific value was calculated using the total energy equation (Equation 7).

$$Q = C * M * \Delta T \dots\dots\dots (7)$$

Where C: specific heat of water = 1cal/g. (C°), C: Water mass (g), ΔT: Water temperature difference before and after adding burning compressed charcoal

### RESULTS AND DISCUSSION

Statistical analysis of the data values related to physical properties and combustion showed that they were significantly affected by the studied factors influencing the properties of charcoal briquettes at the probability level 5%, except for the density values, which were not significantly affected by the type of wood and binder used.

Table 1 shows the averages of some physical properties of charcoal briquettes manufactured from (*Dalbergia sissoo*, *Albizia lebbeck*, *Callistemon viminalis*, *Populus nigra*, *Eucalyptus microtheca*, *Eucllyptus camaldulensis*, *Paulownia tomentosa*, *Pinus brutia*, *Thuja Orientalis*, *Fagus orientalis*, *Populus euphratica* and *Platanus oreinatlis*) tree wood, With Duncan's test results.

Table (1): Average physical properties of charcoal briquettes from several wood type.

Wood types	Compressed density g/cm <sup>3</sup>	Horizontal expansion %	Durability*	Mass Loss %
<i>Dalbergia sissoo</i>	0.976	2.327B	Very good	1.31D
<i>Albizia lebbeck</i>	1.062	2.266BC	Very good	1.48CD
<i>Callistemon viminalis</i>	1.084	1.597F	Medium	1.68ABC
<i>Populus nigra</i>	0.969	1.700F	Very Good	1.56BCD
<i>Eucalyptus microtheca</i>	1.090	1.918E	Medium	1.63BC
<i>Eucllyptus camaldulensis</i>	1.060	1.901E	Medium	1.78AB
<i>Paulownia tomentosa</i>	1.053	2.342B	Medium	1.61BC
<i>Pinus brutia</i>	1.058	1.975E	Good	1.77AB
<i>Thuja Orientalis</i>	1.044	1.911E	Good	1.79AB
<i>Fagus orientalis</i>	1.033	2.772A	Good	1.94A
<i>Populus euphratica</i>	1.055	2.159CD	Good	1.46CD
<i>Platanus oreinatlis</i>	1.059	2.015ED	Very good	1.62BC
Means without the letter are not significantly				
* Relative to the fracture resistance at the bond type levels.				

The density of the charcoal briquettes was not significantly affected by the type of wood or the type of binder. This may be attributed to the use of uniform masses with the same volume, compressive force, and manufacturing conditions. The ratio of the binder to the coal particles significantly affected the density values, with density increasing as this ratio increased. Figure 4 illustrates the interaction of these three factors on this property.

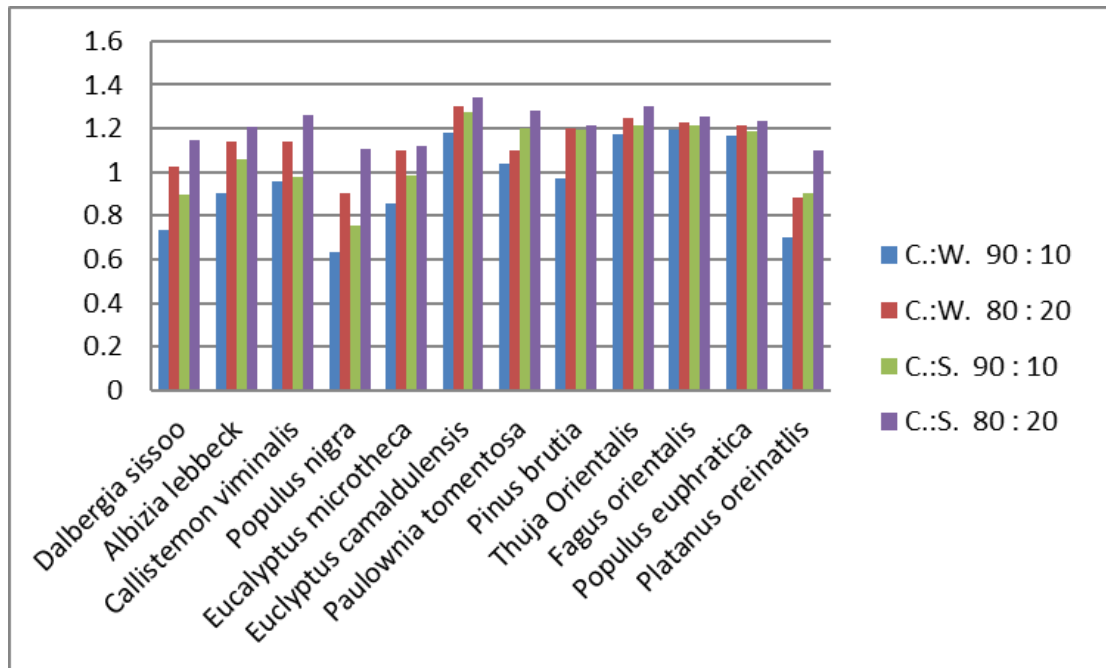


Figure (4): Effect of binder type (potato starch (S) and wheat flour (W)), mixed ratio and wood type on density  $\text{g/cm}^3$  of charcoal Briquettes (C).

Starch and wheat flour also act as pore fillers, increase the mass of compressed coal within the same volume. This approach is consistent with what was mentioned by (Aransiola *et al.*, 2019; Andressa *et al.*, 2021 and Oluwaseyi *et al.*, 2021) regarding the improvement of some physical properties such as density due to the binding materials, Furthermore, increasing the concentration of the binding agent and the compression pressure produces better-quality compressed charcoal briquettes.

Statistical analysis of the horizontal expansion data for the charcoal briquettes showed a significant effect of all the studied factors. Samples made from *Callistemon viminalis* wood showed the lowest expansion rate compared to those made from *Fagus orientalis* wood, The type of binder and mixing ratios affected the expansion rates. Figure 5 shows that increasing the ratio of binder to coal particles reduces the expansion rates when starch is used as a binder compared to wheat flour. In this context, reference (Seboka,2026) indicates that compressed coal briquettes suffer from structural instability and a loss of compressibility.

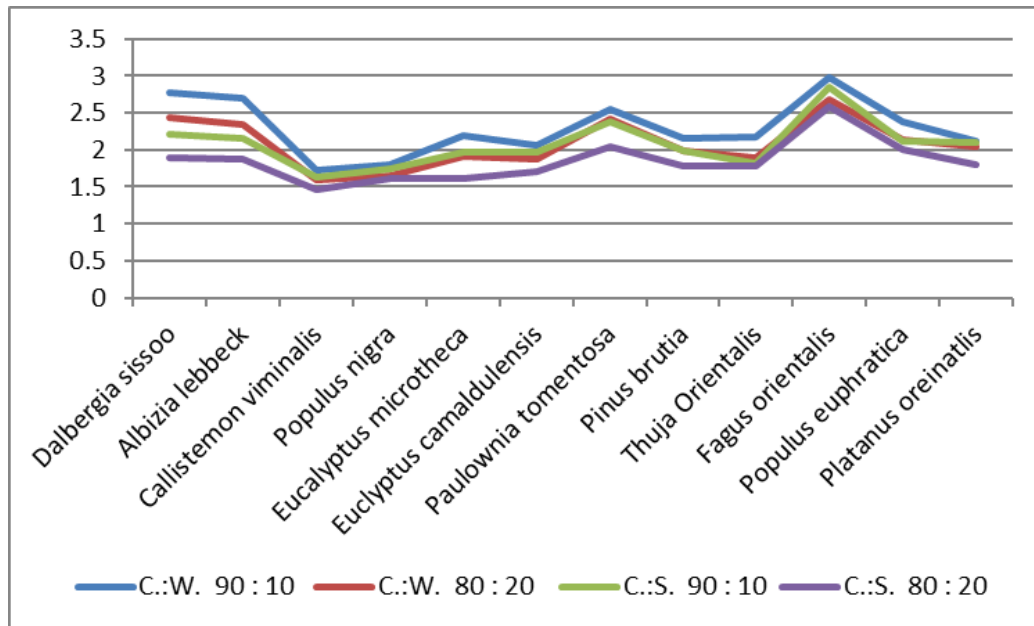


Figure (5): Effect of binder type (potato starch (S) and wheat flour (W)), mixed ratio and wood type on H. expansion % of charcoal Briquettes (C).

Table 2 shows the durability of charcoal briquettes made from different tree wood to crumbling and breakage. We note that some types broke when flour was used as a binder (*Callistemon viminalis*, *Eucalyptus microtheca*, *Eucllyptus camaldulensis*, *Paulownia tomentosa*, *Pinus brutia*, *Thuja Orientalis*, *Fagus orientalis* and *Populus euphratica*), but their resistance improved when the ratio of the binding increase, it improved even more when starch was used. The binder material helps to hold the charcoal particles strongly together in place (Zubariu *et al.*, 2014 and F.A.O., 2014) indicates that starch is the most common and effective binding agent in the production of compressed coal with good qualities.

Regarding the above topic, researchers in (Oluwaseyi *et al.*, 2021) indicated a relationship between moisture content and mold durability, where a decrease in moisture content leads to decreased mold durability and the appearance of cracks and disintegration over time. The moisture content results shown in Figure 7 can be linked to the durability indicators in this study.

Table (2): Effect of binder type, mixed ratio and wood type on durability of charcoal Briquettes.

Wood type	C. : W. 90:10	C. : W. 80:20	C. : S. 90:10	C. : S. 80:20
<i>Dalbergia sissoo</i>	+	+	+	+
<i>Albizia lebbeck</i>	+	+	+	+
<i>Callistemon viminalis</i>	--	-	+	+
<i>Populus nigra</i>	+	+	+	+
<i>Eucalyptus microtheca</i>	-	-	+	++
<i>Eucllyptus camaldulensis</i>	-	-	+	+
<i>Paulownia tomentosa</i>	-	-	+	+
<i>Pinus brutia</i>	-	+	+	+
<i>Thuja Orientalis</i>	-	+	+	+
<i>Fagus orientalis</i>	--	+	+	+
<i>Populus euphratica</i>	-	+	+	+
<i>Platanus oreinatlis</i>	+	+	+	+

(-) : It broke into two parts, (--)It broke into more than two parts  
 (+) : It did not break, with only minor crumbling at the edges.  
 (++) : It was not affected

Mass loss percentage is an important characteristic for determining the extent of loss during transport and storage. Table 1 shows that all the study factors significantly affected this characteristic, noting that the loss percentage was not large among the wood species used.

Figure 6 shows a decrease in loss rates with increasing binder content, especially starch. Comparing the results reveals a correlation between moisture content and this characteristic, with samples exhibiting higher moisture content and lower loss percentages.

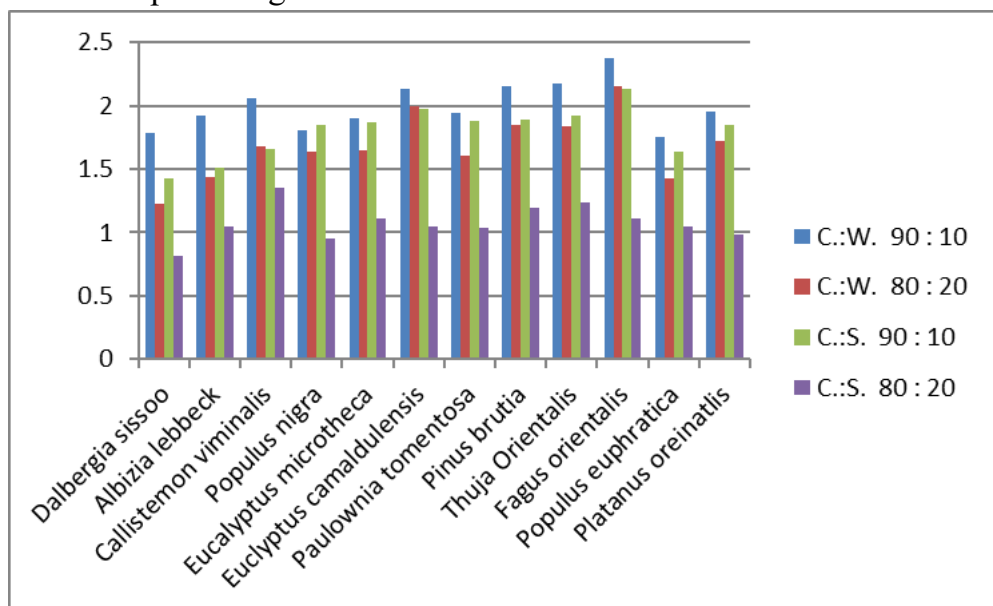


Figure (6): Effect of binder type (potato starch (S) and wheat flour (W)), mixed ratio and wood type on Mass loss ratio% of charcoal Briquettes (C).

Table 3 shows the average chemical and thermal properties, including moisture content, ash content, volatile matter content, and calorific value (kcal/g), which were significantly affected by the type of wood used in charcoal production.

Table 3: Average of chemical & thermal properties of charcoal briquettes from several wood type

Wood type	M.C %	Ash %	Volatile matter %	calorific value Cal./g.
<i>Dalbergia sissoo</i>	8.22A	5.2	16.95H	7075A
<i>Albizia lebbeck</i>	6.40C	7.1A	21.52EF	6847.5B
<i>Callistemon viminalis</i>	5.60E	5.4C	20.55F	6372.5C
<i>Populus nigra</i>	7.97A	5.5C	19.10G	6915B
<i>Eucalyptus microtheca</i>	6.72B	5.8BC	21.77EF	6855AB
<i>Eucllyptus camaldulensis</i>	5.87ED	5.3C	17.35H	7065A
<i>Paulownia tomentosa</i>	6.97B	4.5D	23.27CD	5435D
<i>Pinus brutia</i>	5.92D	6.0B	28.42B	5167.5E
<i>Thuja Orientalis</i>	5.65ED	5.4C	31.85A	5355D
<i>Fagus orientalis</i>	5.32F	4.5D	22.80DE	6420C
<i>Populus euphratica</i>	6.92B	5.7BC	21.37EF	6501.25C
<i>Platanus oreinatlis</i>	6.45C	4.6D	24.60C	4900F

Means without the letter are not significantly

Regarding the moisture content values, their rates ranged between (4.82 - 7.77) % for compressed charcoal manufactured from several types of trees using binding materials with different mixing ratios. The types did not show a strong effect on the variation in moisture content, and this may be due to the similarity of the density values of the manufactured briquettes.

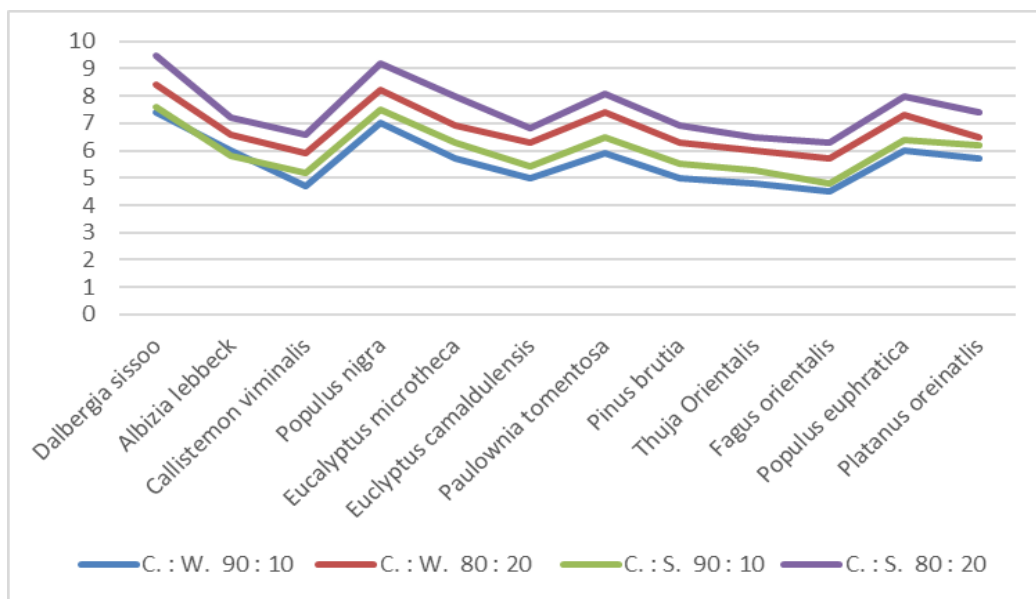


Figure (7): Effect of binder (potato starch (S) and wheat flour (W)), mixed ratio and wood type on Moisture content % of charcoal Briquettes (C).

Binding materials and mixing ratios had a significant effect; the use of starch in a 20:80 ratio with charcoal particles improved the moisture content of the manufactured molds. Overall, the moisture content achieved in the molds falls within the ranges recommended in references (Nurek *et al.*, 2019, and Akowuah *et al.*, 2012), which is good for ensuring the long-term durability of the molds. Figure 7 shows the combined effect of factors on moisture content %.

The ash content showed variation in the average values of its ratios according to the different tree woods used in the preparation of compressed charcoal briquettes (table 3). The variation is associated with the nature of the tree species and their ash content, with an increase in their ratios when comparing the tested results for the same species present in the study area (Ahmed, 2018 and Ahmed *et al.*, 2025) as a result of the difference in density and volatilization of materials during the preparation of charcoal, Regarding the effect of the binding agent and its proportions, it had a significant impact, as ash decreased with increasing proportions of the binding agent, especially starch.

(Nattapong *et al.*, 2019) noted that the Volatile matter % in charcoal briquettes consist of combustible gases such as hydrogen, carbon monoxide (CO), and methane (CH<sub>4</sub>), and non-combustible gases such as carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O). These affect the efficiency of combustion and the intensity of the fire. Charcoal with high volatilization produces more smoke and has a good combustion rate.

In Table 3, the volatile matter values varied according to the type of wood used in charcoal briquette production. Dalbergia sissoo wood recorded the lowest percentage, 16.95%, while Thuja orientalis wood recorded the highest, 31.85%. The effects of the binder and the percentage of added material also varied, with all three factors having a significant impact. Figure 8 shows that the percentage of volatile matter increases with increasing binder percentage, with starch having the strongest effect, which is consistent with what was stated in reference (Ige, 2020).

The average of calorific value ranged between (4900 - 7075) cal./g. depending on the variation of wood type used in charcoal briquettes manufacture. (Sukarta *et al.*, 2023) indicates that the calorific value of compressed briquettes depends on their composition. The calorific value is affected by several factors, most importantly the raw material, the carbonization temperature, as well as the content of water, ash, volatile matter and fixed carbon. The binding agent and increased mixing ratios significantly increased the calorific value. Figure 9 illustrates the combined effect of the studied factors on the calorific values.

In general, when comparing the obtained values with the international standard ranges mentioned in (Mencarelli *et al.*, 2022) in his study, which set the volatile matter content between (15.0 and 35.0) % in raw coal and between (10.0 and 20.0) % in briquettes, and the calorific value between (6660 and 7950) kcal/g,

the manufactured briquettes are practically acceptable.

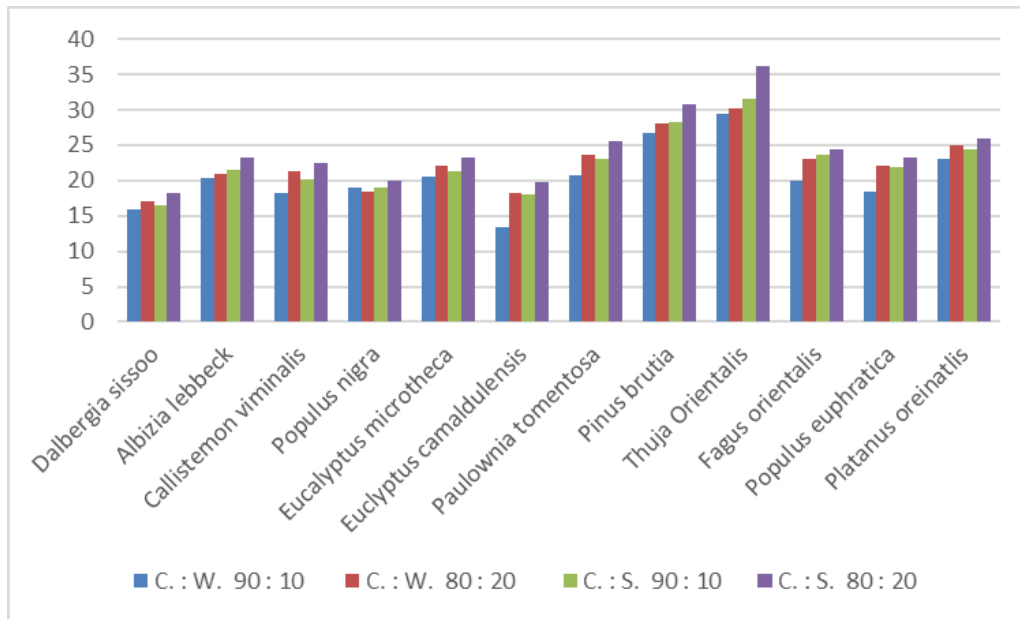


Figure (8): Effect of binder (potato starch (S) and wheat flour (W)), mixed ratio and wood type on Volatile matter % of charcoal Briquettes (C).

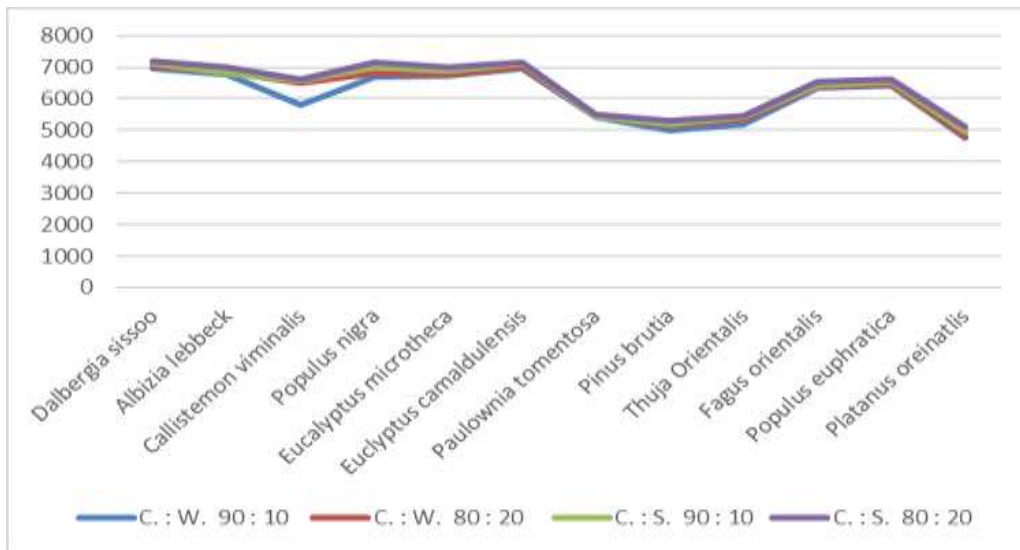


Figure (9): Effect of binder (potato starch (S) and wheat flour (W)), mixed ratio and wood type on of calorific value % of charcoal Briquettes (C).

### CONCLUSIONS

It is possible to manufacture compressed charcoal from various types of tree wood growing in the study area. Potato starch and wheat flour can be used as binders for compressed charcoal briquettes. The physical properties and combustion characteristics of compressed charcoal improve with increasing the binder content. Coniferous wood species, such as pine and thuja, should be avoided in this study due to their high volatile matter content, which may negatively affect health and efficiency.

## CONFLICT OF INTEREST

The authors state that there are no conflicts of interest with the publication of this work.

التأثير المقارن لنوع ونسبة إضافة المادة الرابطة على الصفات الفيزيائية والاحتراق لقوالب الفحم المضغوط المصنع من عدة أنواع من خشب الأشجار

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قسم علوم الحياة / كلية التربية / جامعة تكريت / صلاح الدين / العراق<sup>2</sup>

## الخلاصة

أجريت هذه الدراسة لبيان مدى إمكانية استخدام خشب أشجار *Albizia*، *Dalbergia sissoo*، *Eucalyptus microtheca*، *Populus nigra*، *Callistemon viminalis*، *lebbeck*، *Fagus*، *Thuja Orientalis*، *Pinus brutia*، *Paulownia tomentosa*، *camaldulensis* و *Populus euphratica*، و *Platanus oreinatlis* في إنتاج الفحم المضغوط، استخدم نوعان من المواد المنتجة محلياً كمواد رابطة (نشا البطاطس ودقيق القمح) وبنسب خلط (10:90) و(20:80) مع جزيئات الفحم المطحون. دُرست الخصائص الفيزيائية والإحتراق لعينات الفحم المصنعة وشملت: الكثافة المضغوطة (غم/سم<sup>3</sup>)، ونسبة التمدد الأفقي (%)، والمتانة، ونسبة فقدان الكتلة (%)، ومحتوى الرطوبة (%)، ونسبة الرماد (%)، ونسبة المواد المتطايرة (%)، والقيمة الحرارية (سعة حرارية/غم). تراوحت قيم الكثافة لأنواع قوالب الفحم المدروسة بين (0.969 - 1.090) غم/سم<sup>3</sup>، وسُجلت أعلى قيمة للتمدد الأفقي للقوالب في الأنواع المصنعة من خشب الزان الشرقي *Fagus orientalis* إذ بلغت 2.772%. أظهرت معظم أنواع القوالب متانة جيدة ومعدل فقد منخفض يتراوح بين (1.31 - 1.94)%. تراوحت قيم محتوى الرطوبة ومحتوى الرماد بين (5.32-8.22) % و(4.5-7.1) % على التوالي. كانت قيم المواد المتطايرة ضمن النطاقات المحددة في المواصفات القياسية، باستثناء نوعين *Thuja Orientalis* و *Pinus brutia* بنسبة (28.42 و 31.85) % على التوالي. وقد تم الحصول على أعلى قيمة حرارية عند استخدام خشب كل من *Dalbergia sissoo* و *Eucalyptus camaldulensis*، حيث بلغت (7075 و 7065) سعة حرارية/غرام على التوالي. أظهر نشأ البطاطس إمكانية تحسين خصائص الفحم المضغوط المُنتج مقارنةً بدقيق القمح. وقد أدى رفع نسبة المادة الرابطة من 10% إلى 20% إلى تحسين جميع الخصائص المدروسة.

**الكلمات المفتاحية:** قوالب الفحم المضغوط، خشب الأشجار، نشأ البطاطا، الدقيق، نسبة المادة الرابطة.

## REFERENCES

- Ahmed, Osamah Ibrahim (2018). Some Physical and Chemical Characteristics of Charcoal Produced From Forest Trees in North Of Iraq. *Kirkuk University Journal for Agricultural Sciences (KUJAS)*. (9)1: 96-104. <https://doi.org/10.58928/ku18.09112>
- Ahmed, Osamah Ibrahim; Mohammed M. Ibrahim; Iman Hussain Zainulabdeen and Rusul Muhammad Ahmed (2025). The Anatomical and Chemical Characteristics of *Poloena Tomontosa* Wood and the Extent of its Suitability in the Production of Pulp and Paper. *NE Sciences*, 10(1): 374-384. <https://doi.org/10.28978/nesciences.1651141>
- Akowuah, J. O., Kemausuor, F., & Mitchual, S. J. (2012). Physico-chemical characteristics and market potential of sawdust charcoal

- briquette. *International Journal of Energy and Environmental Engineering*, 3(1), 20. <https://doi.org/10.1186/2251-6832-3-20>
- Andressa, S. Sena; Bacus Nahime; Elton C. Lima; Fausto A. Lobo; Jorge L. Akasaki<sup>5</sup> & Igor S. dos Santos (2021). Characterization of briquettes produced from eucalyptus wood waste generated in agro-industries. *Brazilian Journal of Agricultural and Environmental Engineering*. 25(11): 794-798, 2021. <https://doi.org/10.1590/1807-1929/agriambi.v25n11p794-798>
- Aransiola, E.F.; T.F. Oyewusi, J.A.; Osunbitan and L.A.O. Ogunjimi (2019). Effect of binder type, binder concentration and compacting pressure on some physical properties of carbonized corncob briquette. *Energy Reports* 5: 909–918. <https://doi.org/10.1016/j.egy.2019.07.011>
- Borowski, G., W. Stępniewski, and K. Wójcik-Oliveira. (2017). Effect of starch binder on charcoal briquette properties. *Int. Agrophys.* 31: 571-574. <https://doi.org/10.1515/intag-2016-0077>
- F.A.O. (2014). Forestry Department, Briquetting of Charcoal- chapter 11, FAO Corporate Repository. [www.fao.org/docrep](http://www.fao.org/docrep).
- Hardiansyah Tambunan; Jajang Sutiawan and Arif Nuryawan (2023). Wood briquettes as a renewable energy resource: A mini-review. The 4th Talenta Conference On Engineering, Science And Technology (Cest)-2021: Sustainable Infrastructure and Industry in the New Normal Era, *AIP Conference Proceedings*, 2741(1). <https://doi.org/10.1063/5.0129161>
- Ige, A. R., Ogala, H., Elinge, C. M., & Habeeb, A. (2020). The effect of binder ratio on the physical and combustion characteristics of carbonized rice stalk briquettes. *Int. J. Adv. Acad. Res.(Sciences Technol. Engineering)*, 6(10). <https://doi.org/10.46654/ij.24889849.e6101>
- Abineno, J. C., Dethan, J. J., Bunga, F. J. H., & Bunga, E. Z. H. (2025). Characterization and performance analysis of Kesambi branch biomass briquettes: A study on particle size effects. *Journal of Ecological Engineering*, 26(1). <https://doi.org/10.12911/22998993/195643> .
- Makgobebele, N. W., Mbaya, R. K. K., Bunt, J. R., Leokaoke, N. T., & Neomagus, H. W. J. P. (2021). Evaluation of the mechanical properties of wood-derived charcoal briquettes for use as a reductant. *Journal of the Southern African Institute of Mining and Metallurgy*, 121(5), 187-192. <https://doi.org/10.17159/2411-9717/903/2021>
- Mani, S., Tabil, L. G., & Sokhansanj, S. (2006). Specific energy requirement for compacting corn stover. *Bioresource Technology*, 97(12), 1420-1426. <https://doi.org/10.1016/j.biortech.2005.06.019> .
- Meena, L. K., R. Singh, P. K.V.Kalyan, D. Meena and N. Sharma. (2024). Impact of Binder Materials on the Mechanical and Thermal Properties of Biofuel

- Briquettes. *Biological Forum – An International Journal* 16(9): 178-184(2024). <https://www.researchtrend.net/Impact-of-Binder.pdf>
- Yusuf, M. A., Witdarko, Y., & Pamungkas, W. A. (2023). Characteristics of charcoal briquettes from rice husk waste with compaction pressure variations as an alternative fuel. *Journal of Ecological Engineering*, 24(4). <https://doi.org/10.12911/22998993/159966>
- Mencarelli, A., Cavalli, R., & Greco, R. (2022). Variability on the energy properties of charcoal and charcoal briquettes for barbecue. *Heliyon*, 8(8). <https://doi.org/10.1016/j.heliyon.2022.e10052>
- Myroslav, Malovanyy; Nataliya Vronska; Ivan Tymchuk; Volodymyr Zhuk; Oleksandr Moroz and Nataliya Chornomaz (2023). The Use of Binders of Natural Origin to Improve the Technology of Creating Fuel Briquettes from Wood Waste. *Journal of Ecological Engineering*. 24(11), 314–320. <https://doi.org/10.12911/22998993/171901>.
- Kongprasert, N., Wangphanich, P., & Jutilarptavorn, A. (2019). Charcoal briquettes from Madan wood waste as an alternative energy in Thailand. *Procedia Manufacturing*, 30, 128-135. <https://doi.org/10.1016/j.promfg.2019.02.019>
- Njenga, M.; A. Yonemitsu; N. Karanja; M. Iiyama; J. Kithinji; M. Dubbeling; C. Sundberge and R. Jamnadass. (2013). Implications of Charcoal Briquette Produced by Local Communities on Livelihoods and Environment in Nairobi- Kenya. *Int. Journal of Renewable Energy Development*. 2(1): 19-29. <https://doi.org/10.14710/ijred.2.1.19-29>.
- Nurek, T., Gendek, A., Roman, K., & Dąbrowska, M. (2019). The effect of temperature and moisture on the chosen parameters of briquettes made of shredded logging residues. *Biomass and Bioenergy*, 130, 105368. <https://doi.org/10.1016/j.biombioe.2019.105368>
- Sotannde, O. A., Oluyege, A. B., & Abah, G. A. (2010). Physical and combustion properties of charcoal briquettes from neem wood residues. *International Agrophysics*, 24(2), 189-194. <https://www.international.org/Physical-and-combustion-p.pdf>
- Fadele, O. K., Amusan, T. O., Afolabi, A. O., & Ogunlade, C. A. (2021). Characterisation of briquettes from forest wastes: Optimisation approach. *Research in Agricultural Engineering*, 67(3). <https://doi.org/10.17221/6/2021-RAE>
- Onchieku, J. M., Chikamai, B. N., & Rao, M. S. (2012). Optimum parameters for the formulation of charcoal briquettes using bagasse and clay as binder. *European Journal of Sustainable Development*, 1(3), 477-477. <https://doi.org/10.14207/ejsd.2012.v1i3p477>
- Pamungkas, W. A., Yusuf, M. A., & Teraka, M. (2025). Wood Waste Charcoal

- Briquettes: Physical and Thermal Characteristics Based on Particle Size and Wood Type. *Journal of Agricultural Engineering/Jurnal Keteknik Pertanian*, 13(4), 613. <http://journal.ipb.ac.id/index.php/jtep>
- Seboka, A. D., Morken, J., Adaramola, M. S., Ewunie, G. A., & Feng, L. (2025). Optimization of briquetting parameters and their effects on thermochemical fuel properties of biowaste briquettes. *Bioresource Technology*, 133277. <https://doi.org/10.1016/j.biortech.2025.133277>
- Sotannde, O. A.; A.O. Oluyeye and G.B. Abah (2010). Physical and combustion properties of charcoal briquettes from neem wood residues. *Int. Agrophysics*, 2010, 24, 189-194. <https://www.researchgate.net/publication/285581531>
- Sukarta, I. N., Sastrawidana, I., & Suyasa, I. (2023). Proximate analysis and calorific value of fuel briquettes from wood and coffee skins biomass as a renewable energy source. *Ecological Engineering & Environmental Technology*, 24. <https://doi.org/10.12912/27197050/172506>
- Suryaningsih, S., Nurhilal, O., Yuliah, Y., & Mulyana, C. (2017, May). Combustion quality analysis of briquettes from variety of agricultural waste as source of alternative fuels. In *IOP Conference Series: Earth and Environmental Science* (Vol. 65, No. 1, p. 012012). IOP Publishing. <https://doi.org/10.1088/1755-1315/65/1/012012>
- Tantiwatthanaphanich, T., & Zou, X. (2016). Empowering the local community via biomass utilization: a case study in Thailand. *International review for spatial planning and sustainable development*, 4(2), 30-45. [http://dx.doi.org/10.14246/irspsd.4.2\\_30](http://dx.doi.org/10.14246/irspsd.4.2_30)
- UNEP (2025). Emission Gap report 2025. UNEP-UN Environment programme. <https://www.unep.org/resources/emissions-gap-report-2025>
- Zubairu, A., & Gana, S. A. (2014). Production and characterization of briquette charcoal by carbonization of agro-waste. *Energy power*, 4(2), 41-47. <https://doi.org/10.5923/j.ep.20140402.03>