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Drivers and Hindrances to Substituting Wood Fuel with Briquettes Coal in the Minawao Nigerians Refugees' Camp

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Abstract
The objective of this article was to assess the level of substitution of wood fuel with briquettes in Minawao refugees' camp. The chosen methodology combines survey tools for data collection and practice. The results show that the refugees need 18,339 tons of wood fuel that must be substituted by 19,654 tons of biomass briquettes per year. Thus, since the promotion of briquettes coal in Minawao camp, the largest annual production is roughly 75 tons, covering 0.38% of household cooking energy needs. Today, more than 43% of refugees' households have integrated the briquettes use, but they don't have enough tools and biomass to make that much. Within a radius of 12 km around the refugee's camp, the amount of different biomass residue is estimated to 243 ± 1 tons, that produce 111 ± 1 tons of briquettes, which could cover 0.56% of refugees' households needs. All this shows that the refugees will not stop putting pressure on Zamay forest reserve to collect firewood. Thus, it is important to supply refugees with rice husks from SEMRY and scraps wood from sawmill in eastern region of Cameroon and equip them with materials of briquettes making. The implementation of these actions requires financial means.
Keywords: Driver, hindrance, substitution, wood fuel, briquette coal, Minawao refugee Camp
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1. Introduction

During these last decades, the attacks perpetrated by the terrorist Boko Haram, have caused massive displacement of Nigerians populations and returnees to neighboring countries (Cameroon, Chad and Niger) and internally displacement persons (IDPs) (Rabiou et al., 2019; Adam Mahamat, 2021). In Cameroon, they have been received in the Far North region (PNUD, 2018; UNHCR, 2022a), the most vulnerable region of the country (Banque mondiale, 2017) and where the inhabitants depend on the wood fuel supplies at more than 98% (Kodji et al., 2021). The presence of the forced displaced persons has increased the region demand for wood fuel (URD, 2017; Kodji et al., 2021). In addition, youth unemployment and poverty have forced people to increase pressure on the cutting wood, much of which is destined for market (Madi et al., 2003), and likewise in the Minawao refugee camp where it was one of the most income generating activities (URD, 2017; Paul et al., 2021). Pressure on the vegetation cover leads to deforestation, which increases by an average of 0, 06% each year in the region (MINEPDED[1], 2017). Thus, the deforestation and forest degradation lead to several phenomena, including soil impoverishment, erosion, and floods that destroy crops (ONACC, 2018; Boone et al., 2019; Pasiecznik and Reij, 2020). Moreover, the populations have no longer been able to draw from the natural environment the resources they need for their subsistence as in the past (MINEPDED, 2015; Jiagho, 2018; Greening EU cooperation, 2021). The Far North is one of the most affected regions in Cameroon, with roughly 1.2 million people experiencing food insecurity (OCHA, 2021). Thus, to overcome deforestation, poverty, enhance socioeconomic development is to ensure reliable, sustainable and affordable energy for everyone, which is the United Nations goals 7 (Franco et al., 2017). And so, the alternative to wood fuel in this arid area, may lie in biomass briquettes production and adoption (Solannde et al., 2010; Tizé et al., 2020; Kodji et al., 2021), biogas (Tizé et al., 2015) and improved cookstove use (Gebrezgabher et al., 2016; Ndunguru, 2021; Mahoro et al., 2022). Biomass briquettes are an important alternative energy to wood and fossil fuel to be promoted in order to guarantee food, health, economic and social security (Sen et al., 2016; Djomdi et al., 2021). But, before talking about substitution of an unsustainable energy by renewable one, the latter must be available, affordable and reliable (Okwanya et al., 2020). In the Far North region, it has been estimated more than 6.6 million tons of biomass residues that can

[1] Ministry of Environment, Nature Protection and Sustainable Development

produce 2.65 million tons of briquettes coal per year (Kodji et al., 2021). The non-recovery of waste leads to environmental pollution which subsequently compromises human health (WHO, 2016a; Katutsi et al., 2020; Greening EU cooperation, 2021; Ndecky et al., 2022), and an economic impact resulting in public health costs (PNUE, 2019). Every day, more than 596 million people die worldwide due to environmental unhealthiness (WHO, 2016b). The populations of poor countries are those who suffer the most from this situation and climate change due to insufficient savings and technology to adapt (UNISDR, 2008; OXFAM, 2015; Ndunguru, 2021). According to Alnaser et al. (2022), 12% of people worldwide spend more than 10% of their income on health care; those with very low incomes do not have insurance and experience health stress (WHO, 2016a; Wolkof, 2018). Investment in natural capital would be a driver of the green economy and securing global ecological services (WWF, 2012) and to increase access to clean cooking energy (Ndunguru, 2021). Thus, the objective of this work is to assess the level of the wood fuel substitution with briquettes coal made from biomass residue. The present study is part of an effort to take stock of the adoption of briquettes coal focusing on Minawao Nigerians refugees' camp and its surroundings and professional charcoal consumers.

2. Material and methods

2.1. Description of area of study

The Far North region by projection of the census of 2005 (BUCREP[1], 2005) is densely populated with approximately 4.9 million inhabitants, not including the 128,086 Nigerian refugees who fled the exactions perpetrated by the Boko Haram terrorist (UNHCR, 2022a). The geographic coordinates of Minawao Nigerians refugees' camp are N: 10° 33'38.44''and E: 13° 51'25.83''. It covers an area of more than 632 hectares. The natural environment is characterized by unfavorable climatic conditions with a dry season lasting more than 7 months and high temperatures sometimes reaching over 45°C. The natural vegetation, heavily degraded by human activity, consists of rare patches of shrubs and bushes.

2.2. Methodology for data collection

For this work, data collection was done between 2018 and July 2022. The Knowledge, Attitude and Practice (KAP) was the methodology used with households in Minawao refugee camp and with hosts communities' households trained in briquettes coal manufacturing. The questionnaires were oriented on the time and distance per week devoted for collecting wood fuels up to its consumption, the number of cooking per day, and the availability of raw material and equipment for briquettes coal manufacturing. Thus, a door-to-door surveys with 500 households were conducted. Besides, 3 focus groups were held with women leaders, chiefs of blocs and sectors and young committee on the challenges if any which would encroach the adoption of briquettes coal. Thus, the average of refugees' populations and households were considered in evaluation of their need in cooking energy by using the UNHCR report of June of each year i.e. UNHCR (2014; 2015; 2016; 2017; 2018; 2019; 2020; 2021 and 2022b). In addition, 300 households in host community were surveyed and 30 fish braziers, who previously received each 3 kg of briquettes coal for fish brazing test. The choice of the latter come from the fact that they use charcoal for their daily activities and in order to popularize briquettes. For this purpose, fish brazing, water boiling and cooking test were carried out.

2.2.1. Assessment of the biomass residue

The biomass residue assessment is limited to a 12 km radius of the Minawao refugee's camp. These include cotton stalks, peanut shell, rice husks, corn cob, sorghum husks, sesame stalks, soybean stalks, straws and *Azadirachta indica* leaves, biomass that is not much consumed by pets. Peanut shell, rice husks and corn cobs were evaluated after shelling, and for cotton, sesame and soybean stalks, 5 plots of 10m*10m each were made on one hectare. We did this evaluation on 4 fields located in the four cardinal points at Minawao camp and extrapolated on all the fields of the same speculation. The figure 1 shows the disposition of 5 plots used to evaluate biomass residues *in situ*.

[1] Central Office of Census and Population Studies of Cameroon

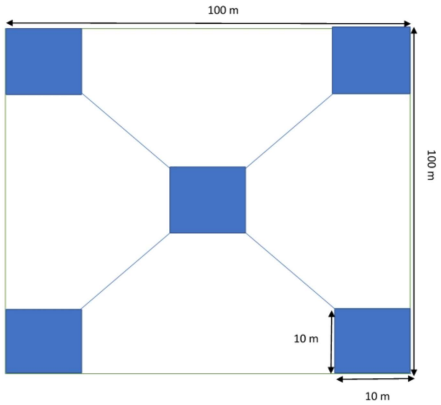

Figure 1. Plots arrangement for biomass harvesting

2.2.2. Cooking and water boiling test (WBT)

In the framework of this study, we accompanied our surveys with practices. This was done in order to better appreciate the respondents' point of view on briquettes coal use. Thus, the Equations 1 to 2 show the water boiling test.

$$\Delta T(°C) = 100\text{-}T_o \qquad (1)$$

With: ΔT : temperature variation, T_o (°C): initial temperature of water

Water boiling test (WBT) by using the briquettes coal and the wood charcoal. Thus, for this test, identical pots (aluminum) with a capacity of 4 liters filled at ¾ were placed on identical cookstove the most used for charcoal in the region. The pot is sealed with plastic and taped well and a small hole is drilled to let the thermocouple dip into the water and await a few minutes for the ambient water temperature to be stabilized. The thermocouple is connected to the digital bomb calorimeter, which allows to display the evolution of the temperature of the boiling water as illustrated by the photo 1.

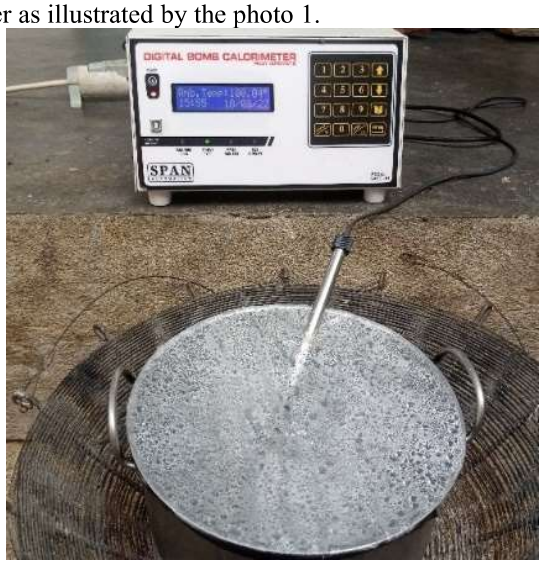

Photo 1. Water boiling test

In addition to boiling test, the cooking tests was conducted. The parameters to be determined are the ignition time, the time to cook and observation of the release of smoke from the different fuels used. The determination of the WBT (min) per kg of water is given by equation 2:

$$WBT = \frac{TB}{(M_o - M_v)} \frac{100}{(100 - T_o)} \qquad (2)$$

M_V: mass of the pot and the thermocouple (kg); M_O: mass of the pot and water (kg); TB: time taken to bring the water to boiling point (min); To: Ambient temperature of water (°C).

2.3. Data analysis

The descriptive analysis of different data collected by surveys and those from the practices was done using SPSS 24 and Excel software. In fact, after the data was processed, it was entered into these programs in order to obtain the appearance of graphs, tables, curves as well as average and standard deviation.

3. Results and discussion

3.1. Situation on wood fuel

The United Nations High Commissioner for Refugees (UNHCR), reported that, since the settlement of the Nigerians refugees' camp at Minawao on July 2, 2013 (UNHCR, 2014), their numbers have continued to increase, and so their need for firewood each year (URD, 2017). In the region, one hectare of forest produces 58.4 tons of wood (MINFOF[1], 2014), and the individual daily consumption of firewood by considering 3 times of cooking, is 0.68 kg (see Table 3). Based on these data, the forest destruction related to the consumption of firewood by the Nigerians' refugees living in the camp is illustrated in Table 1.

Table 1. Evolution of deforestation as function of refugees' firewood consumption

Year	Refugees population	Firewood demand (ton/year)	Estimation of forest destruction (ha)
2013	833	4	0.07
2014	6,068	1,506	26.24
2015	40,858	10,141	176.67
2016	56,916	14,127	246.11
2017	58,819	14,599	254.34
2018	50,342	12,495	217.68
2019	58,561	14,535	253.22
2020	67,502	16,754	291.88
2021	67,702	16,804	292.75
2022	73,887	18,339	319.49
	Total	119,304	2,078.47

The Table 1 shows the longer the refugees remain in the camp, the more the pressure is on wood resources. After the refugees finished with the destruction of the shrubs around the camp, they started cutting firewood in the Zamay Forest Reserve (ZFR) since the year 2016. Given the ever-increasing number of refugees and the fact that it is a regular occurrence in the ZFR, logging seems to be becoming a favorite and even major activity. Refugees no longer go to the forest reserve only to collect dead trees (this is not forbidden) but also to cut the legally forbidden fresh ones. Children, young people, adults, go daily in massive groups sometimes reaching the number of 500 people, equipped with axes, machetes, and any other useful tool for cutting trees. They do not fail to mark the trees as a sign of private property to be able to return to fish them to the root the next day when it has not been cut down the same day. Moreover, they do not choose which trees species to cut, whether they are sacred, poisonous or not. Sometime, when forest agents or members of the vigilance committee grab their firewood, they return in the night to cut trees. Therefore, they could be exposed to the dangerous wild animals or reptiles such as snakes, looking for prey. In addition, the inhabitants of the surrounding villages of the reserve, often complain of disturbance of their sleep by the blows of axes whose echoes go far the night. Even if discontent is sometimes not expressed between refugees and host community populations because they are brothers and sisters, it is nevertheless clear that these problems could be sources of tension. As Oucho (2007) said, refugee is seen as a "person with problem". In view of this negative footprint of refugees, effective and efficient alternatives to firewood must be found as soon as possible for them (Okwanya et al., 2020). The figure 2 illustrates the ZFR in process of disappearing.

Figure 2. Image of the Zamay Forest Reserve

[1] Ministry of Forest and Wildlife

These images in figure 2 provide ample evidence of the level of destruction of ZFR.

3.2. Briquettes production and adoption

Briquettes coal is a renewable energy introduced to the Minawao Nigerians refugees' camp to address a cooking energy crisis and to curb the negative footprint of refugees on wood resources (URD, 2017). Thus, two briquettes manufacture units are set up at Minawao and more than 12,000 households trained on briquettes making at home. The most briquettes made at home are hand-molded into round and cubic shapes, but those manufactured with mechanic press are cylinder shape. The manufacturing process of the briquettes adopted by the households is illustrated by the photos 2 and the availability of raw materials and briquettes (from peanut shells), resulting and cooking and boiling water test by Tables 2, 3 and 4 respectively.

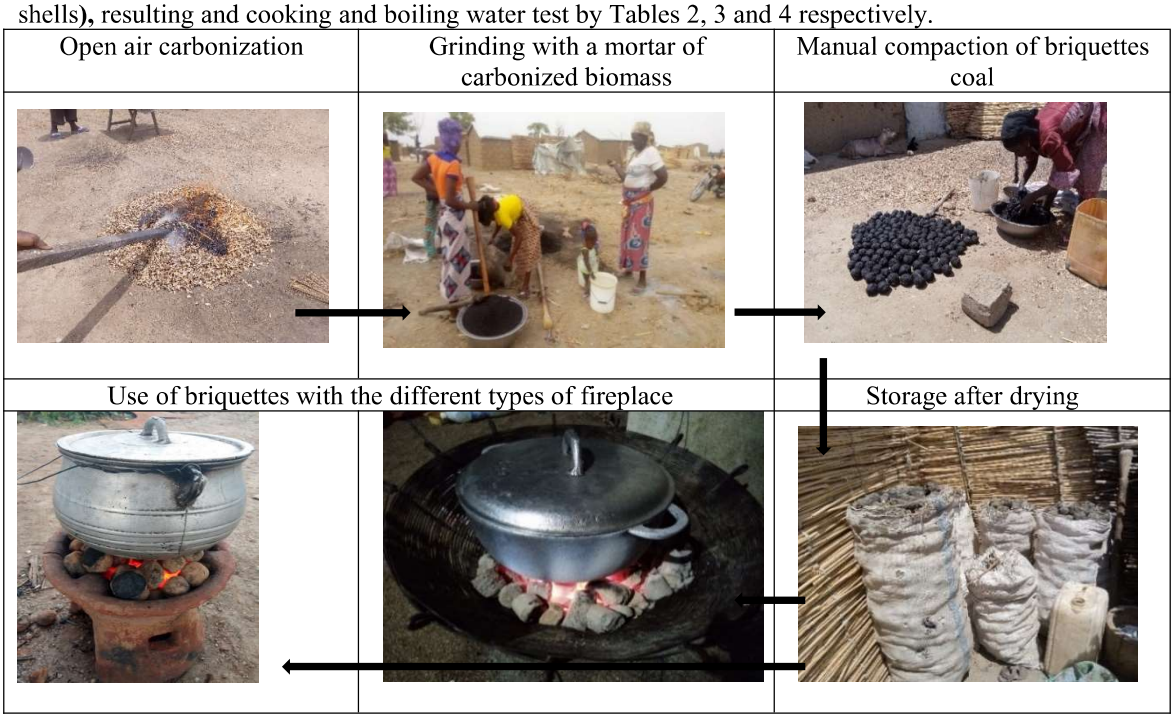

Photo 2. Briquettes process making and use

Table 2. Raw materials availability with potential briquettes resulting

Types of raw materials	Estimation of raw materials per year (tons)	Quantity of briquettes coal resulting (ton)
Sorghum husks	65 ± 3	27 ± 1.28
Rice husks	9 ± 2	3 ± 0.64
Peanut shell	27 ± 2	13 ± 0.73
Corn cob	28 ± 2	12 ± 0.87
Sesame stalks	13 ± 3	5 ± 1.21
Soybean stalks	7 ± 1	3 ± 0.39
Cotton stalks	79 ± 4	41 ± 2.27
A. indica leaves	5 ± 1	2 ± 0.37
Straws	12 ± 1	6 ± 0.47
Total (tons)	243 ± 1	111 ± 1

Table 3. Cooking test

Type of fuel	Type of food cooked for 4 persons	Cooking time per test (hours)	Fuels consumed per test (kg)
Wood fuel	Couscous + okra sauce	2.70^{a} ± 0.28	0.90^{a} ± 0.10
Briquettes	Couscous + okra sauce	2.95^{b} ± 0.25	1^{b}± 0.01

Table 4. Results on the WBT (3 L)

Types of fuels	Ignition time (minutes)	Boiling time from 27,41°C to 100°C (minutes)	Fuel consumed (kg)
Wood charcoal	$8.25^{a} \pm 1.5$	$19.75^{a} \pm 1.7$	$0.38^{a} \pm 0.01$
Briquettes	$10.25^{a} \pm 1.7$	$28^{b} \pm 0.8$	$0.41^{b} \pm 0.02$

As regards the ANOVA (test of Fisher, $P<0.05$), the results having the same letters in exponent on the same column are not significantly different.

The figure 4 illustrates the evolution of the boiling temperature of water as a function of time.

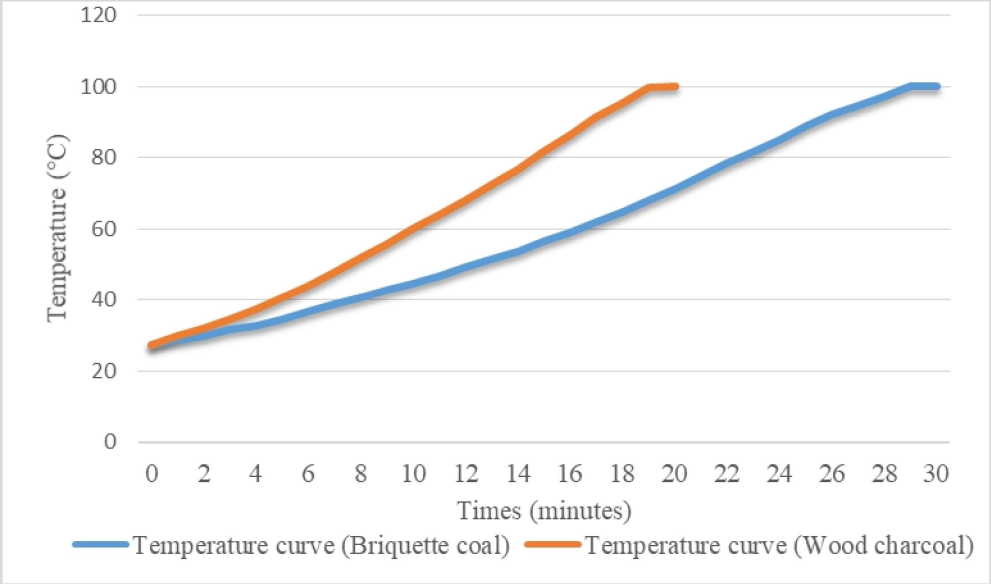

Figure 3. Evolution of water boiling test temperature curve

It appears from the figure 3 that the charcoal brought the water whose ambient temperature was 27.41°C to 100°C the boiling point in 20 minutes, while the briquettes coal did it in 29 minutes. Thus, there is a difference of 9 minutes, which is significantly great according to ANOVA ($P<0.05$). The Table 3 shows that on average, one person needs 0.75 kg of ecological charcoal per day to cook. Thus, a household of 4 persons needs 3 kg per day (i.e. 1.1 ton per year). Based on this calculation, the availability of the residue biomass estimated at 243 ± 1 tons per year, presented in Table 2, can produce an average of 111 ± 1 tons of briquettes, which could only cover the needs of about 101 households per year. We noticed that there is slight difference between firewood and briquettes consumption, rapidity for cooking and boiling. Firewood wood or charcoal cook rapidly than briquettes. This could be in line with briquettes quality. Thus, since the introduction of briquettes coal production in Minawao Nigerians refugees' camp, the coverage rate of the households' need of briquettes coal is illustrated in Table 5.

Table 5. Evolution of briquettes production and coverage rate of cooking energy

Year	Average number of households	Estimated needs in briquettes per year (ton)	Quantity of briquettes coal produced per year (ton)	Rate of coverage of households with briquettes (%)
2017	16,162	17,778	6	0.03
2018	13,462	14,808	12	0.08
2019	15,560	17,116	24	0.14
2020	17,788	19,567	67	0.34
2021	17,867	19,654	75	0.38

The results in Table 5 shows that the households coverage rate for briquettes remains very low, hence the dependence on the region's wood resources. The investigation carried out with refugees living in Minawao camp on cooking energy resources is illustrated in Figure 4.

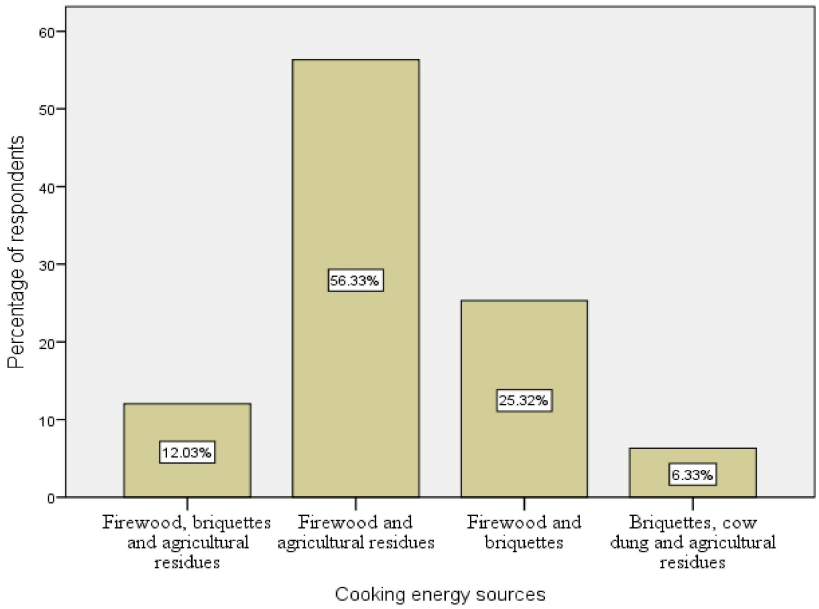

Figure 4. Different types of cooking energy sources used by the refugees

This figure 4 shows that about 12.03% of households use firewood, briquettes and agricultural residues, 25.32% households use briquettes coal and firewood and 6.33% use briquettes, cow dung and agricultural residues as a cooking energy source. This would mean that 43.68 % of refugees' households (i.e. 7,800 households) have integrated the use of briquettes coal in their cooking energy sources. Today, some households make a quantity of briquettes during the dry season, when the little available biomass residue is around the camp and others brought from surrounding villages. A household manages to make between 0.1 and 0.5 ton of briquettes during this period. However, the coverage rate of cooking energy of these households still remains less than 0.87%. Nevertheless, this sufficiently shows that households are ready for briquettes coal adoption. Most of households store these briquettes for use in the rainy season; while they make more use of firewood and agricultural residue such cotton stalks, cow dung and sorghum stalks in the dry season. Certainly, during the rainy season, family members of households could devote their time to field work instead of collecting wood fuel. It appears from these investigations and cooking tests that refugee households appreciate ecological coal, despite the fact that the briquettes cooking time is long compared to firewood. In fact, refugees do not rely on the time factor for cooking because they do not have strenuous work that would lead them to rely on it. However, the problems faced by households in adoption briquettes coal include: insufficient biomass residues to fully substitute for wood fuel; appropriate equipment (manual or mechanic press, pyrolizer), good binders, to make enough briquettes coal. In fact, most of households make open air carbonization due to insufficient of pyrolizers and the binder used is only the black clay due to it availability. In fact, the addition of binder can enhance certain physical properties of briquettes coal (Solannde et al., 2010). The lack of an appropriate cookstove for briquettes coal use hinders it adoption too. Peša (2017) reported that in Zambia, the combination of briquettes coal with appropriate improved cookstove was successfully adopted.

3.2. Adoption of the briquettes in host community

According to the survey we conducted, some households in the host population (Gadala and Gawar) have been trained in briquettes making since 2019. Thus, the figure 5 presents the status of the cooking energy sources used in these localities.

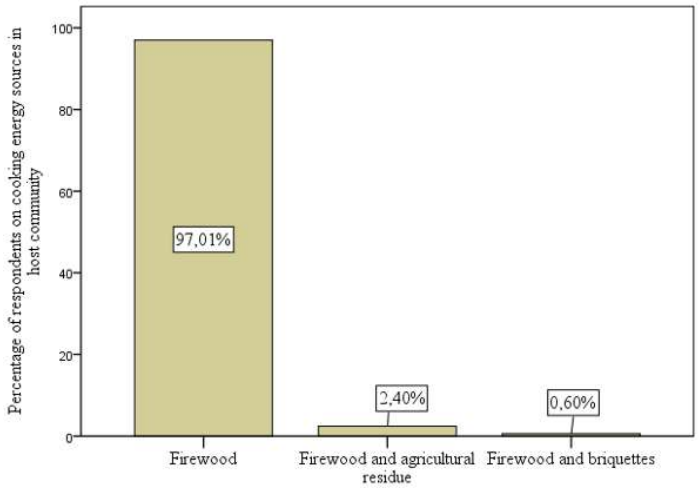

Figure 5. Cooking energy sources in host community

The figure 5 shows that more than 97.01% of respondents use firewood and only 0.60% of households have integrated the use of briquettes among the cooking energy sources. The first observation made by the women of the hosts communities is that the briquettes cooking time is long compared to that of the firewood. However, for the first time, they wondered how briquettes coal do not emit flames but succeed in cooking food well. For them, it is the flame emitted by the wood fire that cooks and that the cooking time depends on the flame magnitude. According to them, the charcoal cannot cook the meal quickly. This conception is in line with what Madi et al. (2003) reported that wood charcoal is not used in rural areas of the Far North region of Cameroon, even though they are the producers. In fact, three-stone fireplaces are used by the majority of households in the region (MINFOF, 2014; URD, 2017). In their mind, the flame resulting from the quantity of wood suggests a rapid cooking process. As the flame decreases, more firewood is added to create a large flame. In rural areas, the women who are responsible for cooking, are focusing on cooking time and, the self-supply of firewood at no monetary cost, hinders the adoption of briquettes. Moreover, the three-stone fireplaces are not suitable for the use of briquettes coal. However, these women appreciated the fact that briquettes do not blacken the utensils like wood fire does. This advantage would not only reduce dishwashing time, but also reduce the expense of buying detergent and a metal sponge for washing dishes. It should be highlighted that if both refugees and host communities are effectively involved in the manufacture of briquettes, there would be great pressure on the limited biomass residue available. In fact, the host populations that have these raw materials, will no longer allow refugees to collect them. However, Djomdi et al. (2021) reported that more than 20,000 tons of rice husks are available at SEMRY[1] industry in the Mayo Danay Division, not recovered. Based on the carbonization yield of 38% of the of rice husks (Kodji et al., 2021), these raw materials from SEMRY could produce 7,600 tons of briquettes, representing a coverage rate of 39 % in cooking energy, considering the average households in the year 2022 of the Minawao refugee's camp. Since SEMRY's rice husks cannot meet the refugees' cooking energy needs, it is important to use scrap wood from sawmill in eastern region of Cameroon, where 422,702 m^3 of carbonizable waste are produced GIZ (2020). Certainly, the transportation and processing of these biomasses require financial and logistic means. If the refugees are supplied with the raw material, they will be able to produce a large quantity of briquettes and sell the surplus. This could therefore be an income-generating activity for the populations (Mwampamba et al., 2013), as was the good business in Bangladesh (Ahiduzzaman et al., 2008).

3.3. Adoption of briquettes coal by professional charcoal users

The results of the survey conducted with the 30 fish braziers who had previously received this fuel gave their points of views illustrated in Table 6.

Table 6. Fish braziers' perceptions on the adoption of green charcoal

Types of tests	Number of tests	Consumption of briquettes (kg) per kg of fish	Braziers willing to continue using briquettes
Braising fish	25	0.6 ± 0.02	18

Table 6 shows that out of the 30 women surveyed, 25 women tried briquettes use for braising fish, and the 5 others refused to try it. Thus, these fish braziers raised the fact that they could not sprinkle the briquettes with water for sustainable reuse as they do with wood charcoal. Indeed, these fish braziers usually sprinkle water on the charcoal embers in order to mitigate the combustion and reduce the consumption of charcoal. In addition,

[1] Yagoua Rice Expension and Modernization Company

briquettes coal produces a lot of ashes that fill the hearth on which the fish are braising. Sometimes, binder used for briquettes making, increases ashes content (Olugbade et al., 2019). This situation limits the good appreciation of the briquettes that could give these large consumers of wood charcoal. With regard to the permanent use of briquettes, out of the 25 women surveyed, 18 fish braziers, are ready to use briquettes. However, they highlighted that the briquettes will be mixed with charcoal when brazing fish, and suggested that the price of briquettes should be lower than that of wood charcoal, i.e. if the price of 35 kg of wood charcoal bag costs US$ 11.89 that the price of briquettes must be US$ 7.92. This was also suggested by charcoal users in Gambia, either to reduce the price of briquettes (Mike, 2019). In contrast, the other 5 women responded that they prefer to continue with the use of charcoal because it produces little ash and it can be sprinkled with water and reused immediately. Although, the ecological charcoal has these shortcomings, it can nevertheless be reused but after drying. Mokaya et al. (2020) reported that in Kenya, the low level of education and the lack of awareness hinder the adoption of the briquettes coal.

4. Conclusion

It was in this article to evaluate the level of substitution of wood fuel with briquettes coal in order to curb the pressure of the populations on forest reserve around Minawao Nigerians refugees' camp, located in the far north region of Cameroon. From this work, the barriers to the adoption and substitution of wood fuel by briquettes lie in the lack of biomass residues, appropriate materials, the quality of binder used and lot of ashes. However, roughly 43% of refugees' households have made between 0.1 and 0.5 ton of briquettes per year. They are increasingly involved in briquettes coal making at home, but they face a shortage of biomass residues shortage and production tools. So far, around Minawao, there are 243 ± 1 tons of biomass residues available of which 111 tons of briquettes can be made and will cover the need of less than 1% of the camp households. Thus, there are need to supply refugees' households with materials of briquettes making.

Author contributions: Conceived and designed the experiments: E.K. performed the experiments. E.K. and J.T.K.; Analyzed and interpreted the data. E.K., J.T.K., A.A. and R.D.D.; Contributed reagents, materials, analysis tools or data; E.K., J.T.K., A.A. and R.D.D.; wrote the paper E.K., J.T.K., A.A. and R.D.D.

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