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Valorization of ecological coal as energy source for smoking fish in the locality of Maga, Far North Region of Cameroon

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Abstract

Wood for smoking fish is increasingly rare in the locality of Maga where this activity is practiced intensely. The search for firewood to prepare meals and smoke fish has led to immense deforestation in the area. There is an urgent need to find alternative sources of this fuel. The objective of this work is to construct a fish smoking kiln operating with ecological coal made from rice husk. To achieve this, we have characterized the existing traditional and improved kiln by evaluating the evolution of temperature during smoking and the amount of fuel consumed per kilogram of smoked fish. Then the design of the cupboard kiln and its construction were made taking into account the type of fuel to be used. Its performance was evaluated. It appears from this work that the consumption of wood per unit of smoked fish varies with the type of the kiln. On average and in the locality of Maga, it takes 2.5 kg and 0.36 kg of wood to smoke 1 kg of catfish respectively with drum kiln and double-chamber brick kiln. When using ecological coal, 0.68 kg is sufficient to smoke 1 kg of fish. For the temperature fluctuation, it has been observed that it is most of the time of smoking above 100 °C on drum kiln while the temperature hardly reaches 100 °C with the rest of kiln. In addition, temperature is more stable in cupboard kiln fluctuating around 70 °C. These temperature intervals are quite sufficient for smoking fish. Knowing the potential production of biochar from rice husk in the locality of Maga, around 13,433tons of fish can be smoked just by valuing this type of agricultural residues. The surface area annually protected from deforestation is then estimated to 665 hectares.

Keywords: Cupboard kiln; Ecological coal; Smoking; Fish; Maga

1. Introduction

The locality of Maga is one of the areas where fishing activity is practiced intensively in Cameroon. It has been estimated that fishing in the areas of Maga and Logone produces on average an annual income of more than 2,300,000 CFA francs per fisherman [1]. In that zone, the smoking of fish provides enough employment for the population. Smoking is a technique that combines heat with smoke to produce smoked fish intended for conservation and for direct consumption. According to Ndiaye et al. [2], smoking and drying fish are the only techniques used to conserve fish in countries around the tropics. It has been estimated that 70% of the fish caught during fishing in developing countries is intended for smoking [3]. In some developed countries such as France, it has been estimated that 20% of fish on the markets is smoked [4]. This technique consumes large quantity of wood used as fuel. The production of energy for cooking and fish smoking is the main origin deforestation in the sahelian regions. The intensive cutting of trees, justified by the constantly growing needs for cooking energy, makes firewood inaccessible to poor segments of the urban population. In households, women and children travel long distances on foot to obtain firewood or charcoal. According to Madon [5], the consumption of wood energy is still increasing. He estimated that in 2030, the quantity of wood to be consumed would be 35% larger than the demand in 2012. It has been shown that in Sub Saharan Africa, the number of population

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depending on the wood fuel has increased to more than 29% within 2004 and 2015 and will be around 60% in 2030 while the forest surface is decreasing [6].The scarcity of firewood causes enormous problems on various levels. As far as fishing is concerned, fresh fishes rot in considerable quantities at the outlet of the rivers because of the lack of firewood for smoking. In Benin, these losses have been estimated at 10% [7]. According to the FAO [8], such losses are 20 to 50% in Africa. This is therefore one of the major factors that contributes significantly to the scarcity of fish on the markets. This partly justifies the deficit in fish supply estimated at 180,000 tons in Cameroon [1]. In addition, the deforestation contributes to the intensification of drought in the localities and the exposed soils degrade. The animals have more and more difficulties to find pasture and this pushes herders to transhumance generating multiple conflicts. In short, the more trees disappear, the more life in general is threatened with extinction. However, in the locality of Maga, rice cultivation is strongly practiced. When husking rice, large quantities of husks are formed. These are very little exploited or not valued. It is why huge quantities of rice husks are found around the rice husking factories. They are often dumped into waterways.

In view of this situation, it is worth asking whether the rice husks transformed into ecological charcoal cannot constitute an alternative fuel to firewood for smoking fish. From this fundamental question, the main objective of this work was to construct an appropriate kiln where we test fish smoking with ecological charcoal made from rice husks. Specifically, we first characterize the existing smoking kiln in Maga, then an appropriate kiln using ecological charcoal was designed and constructed. Finally, the performance of the concerned kiln was evaluated.

2. Material and methods

2.1. Characterization of MAGA smoking Kiln

During our investigations, we noted wood consumption and measured temperature variation on the smoking rack using an infrared thermometer. The various smoking tests were carried out by the farmers who do it as their main activity. Three types of kiln encountered in the locality of Maga were the subject of this study. These are the drum kiln, PRESIBAL kiln and double-chamber brick kilns.

2.1.1. Traditional drum kiln

It is a kiln formed from a drum. In the smoking test, we weighed 3.2 Kg of fish because this kiln has a small capacity. According to smoking habits with this type of kiln, the fish were covered with the sheet of metal to slow the escape of smoke and thus maximize the amount absorbed by the fish (Figure 1). The experiment was repeated three times.

a b

Figure 1 Smoking process with the traditional barrel oven, a) start of smoking and b) end with smoked fish

During this process, we recorded the temperature variations on the smoking rack every 20 minutes until the end of the process.

2.1.2. Improved PRESIBAL Kiln

It is kiln using several racks placed on top of each other above the combustion site.

The principle of operation is practically the same as that of traditional drum kiln. A mass of 36.12 kg of fish was weighed for smoking and repeated three times. Throughout the process, the evolution of the temperature is recorded at regular time intervals of fifteen minutes. The amount of firewood needed for this operation has been calculated.

a b c

Figure 2 Smoking process with the PRESIBAL kiln, a) PRESIBAL kiln; b and c) fish being smoked

2.1.3. Traditional double chamber brick kiln

The traditional double chamber brick kiln is the most widely used in Maga (figure 3). During the smoking process using 179 kg of fish and 34 kg of firewood, the temperature variation on the rack was recorded every 20 minutes. Data collected allowed us to illustrate the evolution of these temperatures. Firewood used to smoke one kilogram of fish was calculated.

2.1.4. Traditional double chamber brick kiln

The traditional double chamber brick kiln is the most widely used in Maga (figure 3). During the smoking process using 179 kg of fish and 34 kg of firewood, the temperature variation on the rack was recorded every 20 minutes. Data collected allowed us to illustrate the evolution of these temperatures. Firewood used to smoke one kilogram of fish was calculated.

a b

Figure 3 Traditional double chamber brick kiln, a) front view and b) top view

2.2. Design and construction of the cupboard kiln

2.2.1. Cupboard kiln Design and construction

The characteristics of the existing kiln being not adapted to the use of ecological charcoal, we therefore designed a new prototype. To design it, we used Archicad software to highlight its parts and its three-dimensional image. Various materials are used for the construction as it can be seen on figure 4.

a b

Figure 4 Construction of the cupboard kiln, a) cupboard being assembled b) final cupboard kiln

The system is equipped with a small fan to activate combustion at the desired time.

2.3. Cupboard kiln Performance Test

The smoking technique always begins with the post-smoking operations which consist of first scaling (if necessary) and cleaning the fish. The fish is then spread out in the open air. Exposing to the sun, the fish undergoes dehumidification in order to reduce its water content which must not exceed 30% for successful smoking [9]. For the smoking test, we used 11.8 kg of fish. A quantity of 8 kg of ecological coal was used as combustible. Once the combustion was started, the fish were spread out on the smoking racks. The ecological coal used was made from rice husk. From figure 5, that ecological coal and its embers produced during combustion can be seen.

a b

Figure 5 Use of biochar in the kiln, a) biochar and b) kiln showing the embers of the biochar

The actual performance test focused on the analysis of the temperature variation in the kiln. Thus, during the smoking, the temperatures at the level of the four racks were measured every 20 minutes for 4 hours that the smoking lasted. The data collected was used to plot the temperature evolution curves at these different locations in order to assess their effectiveness in ensuring good smoking.

3. Results and discussion

3.1. Characterization of existing kilns

3.1.1. Traditional drum kiln

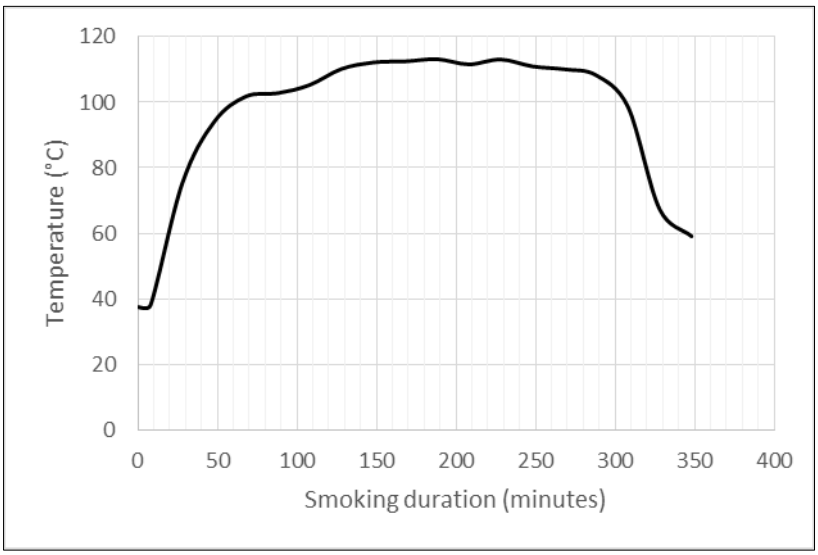

Figure 6 Temperature variation at the racks level of the drum kiln

The smoking of 3.22 kg of fresh fish with the traditional drum kiln consumed 8 kg of firewood costing 700 francs CFA. Thus, 2.5 kg of firewood was needed per kg of fish to be smoked. This quantity of firewood is similar to the one consumed for smoking fish in the coastal zone of Cameroon [10]. The final mass of the fish obtained after smoking is 1.21 kg which

implies a 63% loss of fat and water. This is very high compared to that observed by Costa [11] which was 38.5%. The different temperature values taken at the level of the smoking rack make it possible to appreciate its fluctuation during the process (figure 6).

This figure shows that it takes 15 to 50 minutes for the temperature at the level of the rack loaded with fish to be between 50 and 90 °C which is the temperature range used by Shehata et al. [12] to obtain good smoked fish. From this point, the temperature was fluctuating between 100 and 120 °C for more than 3 hours.

3.1.2. PRESIBAL kiln

We loaded two racks of 18 kg of fish each for this test. The mass of firewood consumed was 20.5 kg at a cost of 2,100 FCFA. This quantity of wood was used to smoke 36 kg of catfish fish indicating a ratio of 0.56 kg of wood per kilogram of fish. It appears that this technology is less energy consuming compared to the traditional drum kiln. Its use can really contribute to slowing down deforestation in fishing localities like Maga. The evolution of the temperature at the level of the first two smoking racks is illustrated in figure 7.

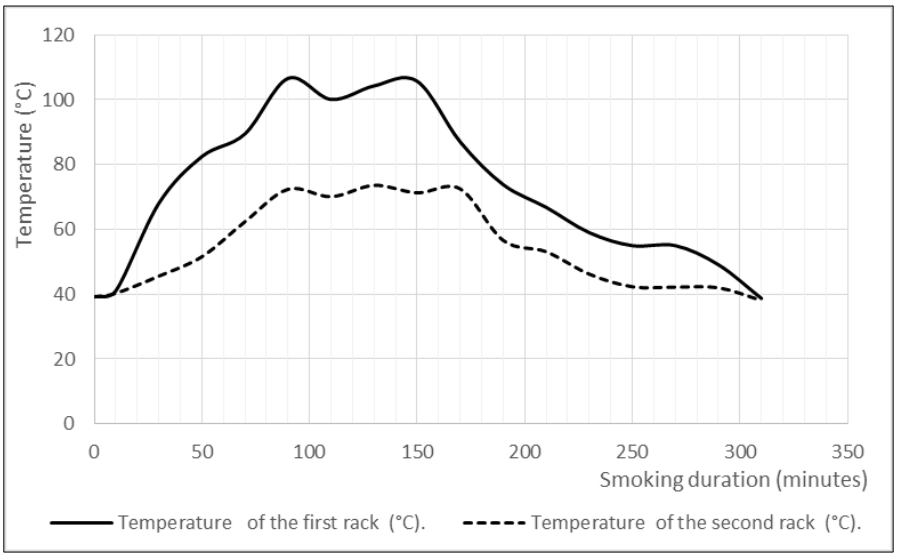

Figure 7 Temperature variation at the racks level of the PRESIBAL kiln

We notice a strong difference between the temperatures of the two smoking racks. Naturally, the first rack located just above the combustion site has the highest temperature, going beyond 100 °C after 1 hour 30 minutes of smoking. On this rack, fish undergoes a temperature varying between 80 °C and 110 °C after a period of between the 40th and 180th minute of smoking, i.e. an average of 2hours 20minutes. On the other hand, the second rack situated above the first one, did not record a temperature reaching 80 °C. These values vary slightly until the 160th minute. These fluctuations are highly similar to what have been described as appropriate temperature variation during fish smoking by Sakyi et al. [13].

3.1.3. Traditional double-chamber brick kiln

The traditional double-chamber brick kiln is the most used in the Maga area. On average, their dimensions are: length 350 cm, width 150 cm and height 100 cm. It is indeed a combination of two ovens. For the test carried out on this kiln, 179.69 kg of catfish were used to fill the two smoking racks. At the end of smoking, the mass of smoked fish is 116.12 Kg indicating a loss of 35.98 Kg. This smoking operation required 64.93 Kg of firewood at a cost of 4950 francs CFA. On average, 0.36 kg of wood was consumed per kilogram of fish to be smoked. This quantity of wood is very insignificant compared to that required for smoking fish in the coastal zone of Cameroon, estimated at 2.5 kg [10]. Several factors may account for this discrepancy. Indeed, traditional smoking in the coastal area often lasts 24 to 72 hours [10] while fish in the locality of Maga is smoked for less than 5 hours. The scarcity of wood in the Sahelian zone (Maga) explains the time reduction of smoking process. At the current rate of deforestation, it is obvious that the use of wood energy resources will not be sustainable. According to some research works on the coastal zone of Cameroon, it has been noted that the smoking of fish is the main cause of the disappearance of the mangrove [10]. Temperature variations at the smoking rack are shown in figure 8.

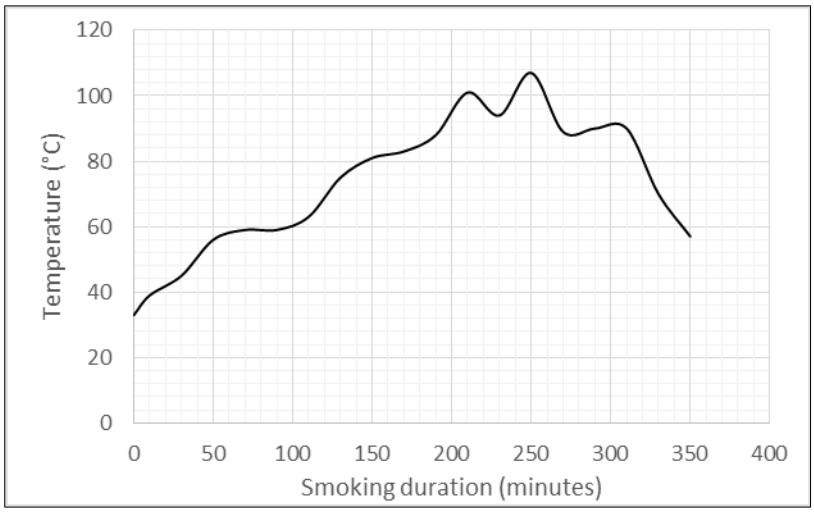

Figure 8 Temperature fluctuation at the level of rack during smoking

Unlike previous kiln, the temperature of the rack reaches 80 °C after more than 2 hours 30 minutes of smoking. It oscillated in the interval of 80 and 100 °C for about 3 hours. This figure presents the three stages of a good smoking described by Sakyi et al. [13]. At first, the temperature rises and stabilizes around 60 °C for almost an hour which is similar to the one of 63 °C indicated for the cooking stage. After this one, we have drying stage which requires enough heat to dry fish. At the final stage, smokes are built from firewood and the temperature drops to 60 °C or less.

3.2. Constructed cupboard kiln

The designed and constructed cupboard kiln is shown on figure 9.

Figure 9 Cupboard kiln constructed

This cupboard kiln has a height of 135 cm, a depth of 50 cm and a width of 70 m. The interior has four drawers. They constitute the smoking racks spaced 20 cm apart. Below the lower rack is the combustion chamber equipped with a ventilation system. This unit ensures a renewal of air in the combustion chamber.

3.3. Cupboard kiln Performance

During the two tests carried out, we used 11.8 kg of fresh fish to obtain 7.7 kg of smoked fish. The quantity of ecological charcoal used during this test is 8 kg. That is an average of 1.20 kg of briquette per kilogram of smoked fish (or 0.68 kg of ecological coal for 1 kg of fish to be smoked). Knowing that ecological charcoal is made of 20% clay used as a binder and 80% of rice husk, the consumption is 0.54Kg of rice husk for 1Kg of fish to be smoked. This consumption is quite similar to that of charcoal which was 0.4 kg/kg of fish for smoking using the FAO-Thiaroye transformation technique

(FTT-Thiaroye) developed by Ndiaye et al. [2]. According to the National Institute of Statistics of Cameroon and Delot [14, 15], the localities of Maga (SEMRY) produce annually around 30 000 tons of rice husk. Converted into bio-charcoal for smoking fish using the cupboard kiln, this fuel alone would smoke approximately 13,433 tons fish. Consequently, 4,434 tons of firewood will be saved which corresponds to 665 hectares of areas for firewood collection protected. In fact, according to Ntsama et al. [16], the consumption of a ton of wood is equivalent to the destruction of 0.15 ha of the forest in the Sahel region.

The temperature variation curves of the four smoking racks are shown in Figure 10.

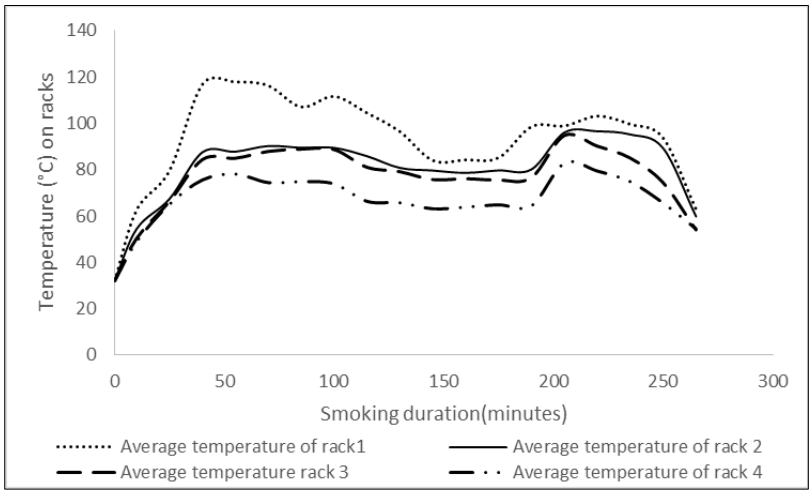

Figure 10 Temperature variation curve on cupboard kiln racks

Overall, it appears from these curves that the temperatures at the level of the racks depend intimately to the distance from the combustion site. The highest temperature recorded on rack 1 which is the lowest rack located just above the combustion chamber, reached 117 °C while those of the others were most of the time below 80 °C. The sudden rise in temperature noted just after 200 minutes is due to the switching on of the ventilation system which activated the embers. For 2 hours 30 minutes, the temperature was slightly varying on racks 1, 2 and 3 oscillating between 60 and 80 °C. These temperature intervals are quite sufficient for smoking fish [12]. According to Sathish and Priya [17], the above smoking process presents a very good time of drying stage which temperature is recommended to be around 80 °C. Indeed, a study conducted by Adepoju et al. [3] revealed a strong consumer appreciation for fish smoked at 70 °C. In addition, Cunguara and Sakyi et al. [18, 13], indicate that such temperature and its duration are sufficient to destroy most of the potential bacteria that have infested fish. The appreciation of consumers could be justified by the fact that fish smoked at less than 80 °C abounds in the partially degraded protein while it is highly degraded beyond this threshold [17] [4]. However, the duration of smoking practiced by these authors depends on the type of fish and varied from 1 hour 30 minutes to 2 hours, which is shorter than what we did in this study. However, a long smoking time commonly results in the highest concentration of polycyclic aromatic hydrocarbons which can make the fish unfit for consumption [3].

The gradual rise in this temperature observed at the level of the racks is important for smoking and allows a gradual elimination of fat. A rapid rise makes the product very crumbly after smoking. The ecological coal used with cupboard kiln shows more positive results compared to the traditional and improved kilns that we have characterized. In addition to the average temperature at the level of the smoking racks which remains in the correct smoking interval, a significant saving in time of 30 minutes has been recorded compared to the usual smoking time. As for the point of view collected during the survey on the organoleptic test of some smokers and dealers in the central market of Maroua, about 95% indicated that the fish smoked with biochar is clean and of good quality.

4. Conclusion

At the end of this study, it appears that various types of kiln are used to smoke fish in the locality of Maga. The double-chamber brick kiln is however the most widespread. This kiln has greater energy efficiency. It consumes an average of 0.36 kg of wood to smoke 1 kg of fish, while the drum kiln uses 2.5 kg. With the cupboard kiln using biochar as the source of energy for fish smoking, we observed that 0.68kg of biochar is sufficient to smoke 1kg of fish. Valuing potential rice husk in the locality of Maga into biochar for fish smoking, around 13,433tons of smoked fish will be produced without

using firewood. This will save annually 4,434 tons of firewood and 665 hectares from destruction. As regards the variation in temperature at the level of the smoking racks, it is more stable, oscillating around 80 °C in the cupboard kiln. This corresponds to the interesting temperature range for obtaining a good smoked fish as it was appreciated by smokers and smoked fish traders in Maroua. The implementation of this technology on field should be urgent as a strategy to fight against deforestation and ensure sustainable development.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that no conflict of interest exists.

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